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DRONE BASED PESTICIDE SPRAYING TECHNOLOGY FOR MANAGING JASSIDS IN BRINJAL

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ABSTRACT

Jassids (*Amrasca biguttula biguttula*) represent a considerable risk to brinjal (*Solanum melongena* L.) leading to significant reductions in yield attributable to their sap-extraction behavior and the facilitation of plant virus transmission. Conventional manual pesticide application techniques are characterized by their labor-intensive and time-consuming nature, frequently resulting in uneven distribution, excessive chemical application, and potential health hazards for agricultural workers. This investigation examines the effectiveness of drone-assisted pesticide application technology as a precise intervention for the management of jassid infestations in brinjal cultivation. A drone equipped with a 10-liter capacity tank, GPS-guided navigational capabilities, and a variable-rate spraying mechanism was employed and assessed in field trials. The findings revealed that among the evaluated drone and traditional spraying methodologies against jassids infesting brinjal, T_1 (100% recommended dose administered via drone) emerged as the most efficacious treatment, achieving the lowest average populations of jassids, specifically (2.34 jassids/3 leaves/plant for azadirachtin, 1.02 jassids/3 leaves/plant for imidacloprid, 2.01 jassids/3 leaves/plant for lambda cyhalothrin, and 1.45 jassids/3 leaves/plant for thiamethoxam). Insecticides applied through drones at 75% of the recommended dose (T_2) effectively diminished mean jassid populations, yielding values of 2.69 for azadirachtin, 1.22 for imidacloprid, 2.15 for lambda cyhalothrin, and 1.58 for thiamethoxam, thereby ranking second in overall efficacy. T_3 (50% recommended dose via drone) exhibited lower effectiveness in comparison to T_4 (100% recommended dose via knapsack), while T_5 (untreated) recorded the highest pest populations. The implementation of drone-based spraying techniques resulted in a reduction of pesticide usage by as much as 25% relative to manual methods, while simultaneously ensuring uniform application.
***Keywords*: Brinjal, jassids, drone, knapsack spraying**

Introduction

Brinjal (*Solanum melongena*), commonly known as eggplant or aubergine, is one of the most important vegetable crops in India, valued for its nutritional content and culinary versatility. As a fiber-rich, low-calorie food, it plays a critical role in food security and dietary diversity, particularly in rural and urban households. In India, brinjal is a cornerstone of the agricultural economy, supporting millions of small and marginal farmers who rely on its cultivation for their livelihoods.

India is the second-largest producer of brinjal globally, after China, with an annual production of approximately 12.8 million metric tonnes, cultivated over about 0.73 million hectares. This accounts for about 25-27% of the world's brinjal production, which totals around 55-60 MMT (China contributes ~65%). The crop covers roughly 8-9% of India's total vegetable area and contributes 9% to vegetable production, making it a key horticultural crop.

Andhra Pradesh cultivates brinjal over approximately 0.04-0.05 million hectares, which translates to 40,000-50,000 hectares. This accounts for about 5-7% of India's total brinjal area, aligning with the national figure of 0.73 million hectares. The state's annual brinjal production is estimated at 0.8-1.5 MMT, contributing approximately 5-7% to India's total output of 12.8 MMT. The average yield is approximately 20-25 tonnes per hectare, slightly above the national average of 17.5 tonnes per hectare (Indian Horticulture Database, NHB). This higher productivity is attributed to fertile soils, irrigation facilities, and the adoption of hybrid varieties in key districts.

The production of Brinjal is often threatened by pests, with jassids (Amrasca biguttula biguttula) being one of the most destructive and causing up to 30% loss in severe cases, necessitating innovations like drone-based spraying and biopesticides (Bhusan *et al*., 2023). Jassids, scientifically classified under the family Cicadellidae, are small, sap-sucking insects, typically green or yellowish-green, measuring 2 to 3 mm in length. They cause severe damage by feeding on the plant's sap, leading to leaf curling, yellowing, and reduced photosynthetic efficiency. Additionally, jassids act as vectors for diseases such as little leaf and mosaic virus, which can drastically reduce crop yields and affect fruit setting, posing a significant threat to farmers' livelihoods.

Traditional pest management strategies for jassids in brinjal primarily rely on chemical pesticides, while these methods can be effective, they present several challenges. Environmental contamination is a major concern, as pesticide runoff can poison aquatic life and reduce biodiversity. There is also the risk of pesticide resistance developing in pest populations, diminishing long-term efficacy. Furthermore, manual spraying is labor-intensive, often resulting in uneven distribution and increased costs, while exposing farmers to health risks, including skin irritation and various respiratory issues.

This research paper aims to investigate the application of drone-based pesticide spraying for managing jassids in brinjal crops. The study evaluated the efficacy of drone spraying in controlling jassid populations and analyzes its economic feasibility for farmers. By integrating drone technology into pest management strategies, the research seeks to develop a more sustainable, efficient, and effective approach that addresses the limitations of traditional methods. Expected outcomes include improved pest control, reduced pesticide use, and enhanced farmer safety, contributing to the advancement of precision horticulture and providing practical solutions for brinjal production.

Materials and Methods

The present research on drone-based pesticide sprayer for application of CIB and RC recommended chemicals against jassids in brinjal crop was conducted during rabi season in the year 2022-23 and 2023-24 at College of Horticulture, Venkataramannagudem, DR. Y.S.R. Horticultural University, Tadepalligudem, Andhra Pradesh. The experimental field was divided into equal size plots for each treatment conducting the feasibility of drone based pesticide sprayer studies in brinjal. A minimum of 15-20 m length plots without having the electrical wires and trees were selected. A minimum plot size of 200 m² (20 m x 10 m) per treatment was maintained. The plots were well separated by maintaining buffer zone of ten meters between the treatments.

Table 1 : Technical specification of the drone sprayer used in this experiment

	Particulars	Parameters
Key features	Structure	Quadracopter structure
	Flight modes	Manual/Semi-Autonomous/Fully Autonomous
	Capacity	Upto 10 acres/hour.
	Range	Files upto 1 km (LOS) using Ground Control System
	Return to launch	Empty tank, Battery drained, Mission complete
Aircraft	Maximum takeoff weight	23.2 kg
	Diagonal wheelbase of frame	1200 mm
	Folded size (L×B×H)	625mm × 570 mm × 625 mm
	Maximum speed	8 m/s
	Maximum height	10 meters
	Maximum flight time	15-20 minutes
	Maximum hovering time	25 minutes
	Operating temperature range	0˚C to 50˚C
	Maximum flight distance	Up to 1 km

Battery	Capacity	1600 MAH
	Voltage	44.4 V
	Connector	AS150U / XT (for heavy duty applications)
	Type	Lithium polymer (dry)
	Charging time	50 ˜ 120 minutes
	Life	Upto 200 cycles
Spray system	Tank volume	10 L
	Standard operating payload	10 Kg
	Material of tank	HDPE, safe for using chemicals
	Material of tubes	PVC, safe for using chemicals
	Nozzle (model)	High pressure flat spray
	Quantity	4 pcs / 2 pcs
	Material of Nozzles	Polypropylene housing with metal/ plastic/ ceramic tips
	Maximum spray speed for nozzle	0.85 / L
	Spray width	3.0 meter (4 nozzles, 1.5m ˜ 2.5m above the crops)
	Spray Height	2.5 to 3 m depending on crop stage
	Number of pumps	1
	Material of nozzle mounting boom	Carbon fiber

Fig. 1: Drone used for spraying against jassids in brinjal.

Treatment details

The experiment was conducted in t- test statistical model and comprised off five plots of 200 m^2 each with five treatments *i.e.* T_1: 100% RDP with drone, T_2: 75% RDP with drone, T_3: 50% RDP with drone, T_4: 100% RDP with knapsack sprayer and T_5: Untreated control (Water spray). Various insecticides which were evaluated in present experiment were sprayed sequentially at 15 days interval. The main objective of this trial was to test efficacy of insecticide at recommended dose and also to assess whether there is any scope for reducing insecticide dose while using drone. The active ingredient dose g a.i./ ha was same in case of drone as well as conventional spray system and considered as 100% RDP (dose approved by CIB & RC). Accordingly, 75% RDP and 50% RDP dose for drone spraying was calculated (Table 2-6). The drone sprayer used for this treatment is described in table 1 and figure 1.

Fig. 2 : Drone spraying of insecticides against jassids on brinjal crop

Table 2 : Particulars of the insecticides used in the experiment.

S.No.	Common name	Trade name	Source of supply
1.	Azadirachtin 1% (10000ppm)	Neemol	Greemnpeace Agro Industries
2.	Imidacloprid 17.8% SL	Confidor	Bayer Crop Science Ltd.
3.	Lambda-cyhalothrin 5% EC	Karate	Syngenta India Pvt Ltd
4.	Thiamethoxam 25% WG	Actara	Syngenta India Pvt Ltd.

Table 3 : Treatment details of insecticide spray Azadirachtin 1% (10000ppm).

Treatment details		Formulation (ml)	Chemical per litre of water	Water volume (l/ha)	Spray equipment
T_1	Azadirachtin 1% (10000ppm)	100% RDP (1500 ml)	60 ml	25	Drone
T_2	Azadirachtin 1% (10000ppm)	75% RDP (1125 ml)	45 ml	25	Drone
T_3	Azadirachtin 1% (10000ppm)	50% RDP (750 ml)	30 ml	25	Drone
T_4	Azadirachtin 1% (10000ppm)	100% RDP (1500 ml)	3 ml	500	Knapsack sprayer
T_5	Untreated control	Water spray	-	-	-
Note: Azadirachtin 1% (10000ppm) @ 1500 ml per ha					

Table 4 : Treatment details of insecticide spray Imidacloprid 17.8% SL.

Treatment details		Formulation (ml)	Chemical per litre of water	Water volume (l/ha)	Spray equipment
T_1	Imidacloprid 17.8% SL	100% RDP (125 ml)	5 ml	25	Drone
T_2	Imidacloprid 17.8% SL	75% RDP (93.75 ml)	3.75 ml	25	Drone
T_3	Imidacloprid 17.8% SL	50% RDP (62.5 ml)	2.5 ml	25	Drone
T_4	Imidacloprid 17.8% SL	100% RDP (125 ml)	0.25 ml	500	Knapsack sprayer
T_5	Untreated control	Water spray	-	-	-
Note: Imidacloprid 17.8% SL @ 125 ml per ha					

Table 5 : Treatment details of insecticide spray Lambda-cyhalothrin 5% EC.

Treatment details		Formulation (ml)	Chemical per litre of water	Water volume (l/ha)	Spray equipment
T_1	Lambda-cyhalothrin 5% EC	100% RDP (300 ml)	12 ml	25	Drone
T_2	Lambda-cyhalothrin 5% EC	75% RDP (225 ml)	9 ml	25	Drone
T_3	Lambda-cyhalothrin 5% EC	50% RDP (150 ml)	6ml	25	Drone
T_4	Lambda-cyhalothrin 5% EC	100% RDP (300 ml)	0.6 ml	500	Knapsack sprayer
T_5	Untreated control	Water spray	-	-	-
Note: Lambda-cyhalothrin 5% EC @ 300 ml per ha					

Table 6 : Treatment details of insecticide spray Thiamethoxam 25% WG.

Treatment details		Formulation (ml)	Chemical per litre of water	Water volume (l/ha)	Spray equipment
T_1	Thiamethoxam 25% WG	100% RDP (200 g)	8.0 g	25	Drone
T_2	Thiamethoxam 25% WG	75% RDP (150 g)	6.0 g	25	Drone
T_3	Thiamethoxam 25% WG	50% RDP (100 g)	4.0 g	25	Drone
T_4	Thiamethoxam 25% WG	100% RDP (200 g)	0.4 g	500	Knapsack sprayer
T_5	Untreated control	Water spray	-	-	-
Note: Thiamethoxam 25% WG @ 200 ml gms per ha					

Knapsack sprayer

Drone aerial spraying was compared with the locally popular manual spraying equipment, knapsack electro battery sprayer with a fluid tank capacity of 16 liters. The nozzle type was flat fan nozzle. The spraying height of the knapsack sprayer is 0.1 m above the crop canopy, operated at spray pressure of 3.45 bar (50 psi) and flow rate of 3.0 L/ min. Under these application conditions, the spray volume was close to 500 L/ha with a field coverage capacity of 2.0 ha/day

All working parameters and spray volumes for each sprayer were established taking into account of scientific specifications and local farmers practices before initiating the experiments. Before experimentation, a preliminary test was performed to calibrate the spraying equipment to ascertain the flow rate of the nozzles, based on which the travelling speed was calculated to obtain the stated application rate and velocity. Each spraying treatment was administered by a well-trained applicator.

Spray schedule

Application of chemicals was carried out on sequential basis as per the schedule given below through Drone and conventional sprayers.

1. Spraying of Azadirachtin 10000 ppm at 30 days after transplanting.
2. Spraying of Imidachloprid 17.8 SL at 45 days after transplanting.
3. Spraying of Lambda cyhalothrin 5 EC at 60 days

after transplanting.

4. Spraying of Thiamethoxam 25WG at 75 days after transplanting.

Nymphs and adults of jassids were recorded 24 hours before spraying and 3, 7 and 10 days after each spraying by visual observation on both surfaces of the leaf on three randomly selected leaves from top, middle and bottom canopy of the plant from 10 per cent of sampled plants in drone, conventional and control plots of brinjal.

Results and Discussion

The findings from the experiment aimed at controlling jassids using drone and knapsack sprayer with recommended chemicals are outlined in detail below.

Efficacy of azadirachtin sprays against jassids of brinjal

During *rabi* 2022-23, the initial population of jassids before any treatment exhibited a consistent distribution, showing no significance difference ranging from 5.23 to 5.58 jassids per 3 leaves per plant. The data on mean population of jassid (*Amrasca bigutulla bigutulla*)at third day after exposure to biopesticide azadirachtin 10000 ppm spray indicated that the treatment T_1- 100% RDP with drone sprayer recorded lowest jassid population (2.47 jassids/ 3 leaves/ plant) followed by T_2- 75% RDP with drone sprayer (2.87 jassids/ 3 leaves/ plant). However, T_4- 100% RDP with knapsack sprayer (2.97 jassids/ 3 leaves/ plant) is better than T_3- 50% RDP with drone sprayer (3.83 jassids/ 3 leaves/ plant). Whereas in T_5 - untreated control plot, maximum jassid population of 5.47 jassids/ 3 leaves/ plant was recorded.

The average population of jassids on seven days after spraying with azadirachtin 10000 ppm spray was found to be least in treatment T_1- 100% RDP with drone sprayer (3.00 jassids/ 3 leaves/ plant), surpassing T_4- 100% RDP with knapsack sprayer(3.83jassids/ 3 leaves/ plant) and T_5 -untreated control (5.40 jassids/ 3 leaves/ plant). While, T_2- 75% RDP with drone sprayer (3.23jassids/ 3 leaves/ plant), is superior over T_4, T_5 and T_3- 50% RDP with drone sprayer (4.57jassids/ 3 leaves/ plant)in suppressing the jassids.

The jassid population ranged from 3.10 to 5.43 jassids / 3 leaves/ plant in all the treatments tested at ten days after spraying with azadirachtin 10000 ppm. The mean number of jassids were 1.75 times higher than in T_5 (untreated control – 5.43 Jassids / 3 leaves/ plant) over T_1 (100% RDP with drone sprayer- 3.10 jassids/ 3 leaves/ plant). However, the jassid population declined to 3.30 jassids/ 3 leaves/ plant in T_2 (75% RDP with drone sprayer). The jassid population in T_3- 50% RDP with drone sprayer (4.83 jassids/ 3 leaves/ plant) was higher than in T_4- 100% RDP with knapsack sprayer (4.23 jassids/ 3 leaves/ plant).

The mean jassid population during *rabi* 2022-23 after spray of azadirachtin 10000 ppm was 2.86 jassids/ 3 leaves/ plant and 3.13 jassids/ 3 leaves/ plant in T_1- 100% RDP with drone sprayer and T_2- 75% RDP with drone sprayer respectively which were on par with each other. However, T_3 - 50% RDP with drone sprayer (4.41 jassids/ 3 leaves/ plant) was inferior to T_4- 100% RDP with knapsack sprayer (3.68 jassids/ 3 leaves/ plant) in suppressing the jassids. While maximum jassids (5.43 jassids/ 3 leaves/ plant) were recorded in T_5- untreated control.

During *rabi* 2023-24, the pre-treatment population of jassids was uniform among the treatments with their highest peak of 4.70 to 4.97 jassids per 3 leaves per plant as depicted in Table 7and figure 2. Jassid population at third day after exposure to azadirachtin 10000 ppm spray recorded lowest jassid population of 0.93 jassids/ 3 leaves/ plant in T1- 100% RDP with drone sprayer followed by T2- 75% RDP with drone sprayer (1.40 jassids/ 3 leaves/ plant). However, T4- 100% RDP with knapsack sprayer showed 2.17 jassids/ 3 leaves/ plant which was better than T3- 50% RDP with drone sprayer 3.17 jassids/ 3 leaves/ plant. Whereas in T5 - untreated control plot, maximum jassid population of 4.73 jassids/ 3 leaves/ plant was recorded.

At seven days after spraying with azadirachtin 10000 ppm spray the mean number of jassid population was found to be least in treatment T1- 100% RDP with drone sprayer (1.47 jassids/ 3 leaves/ plant) followed by T2- 75% RDP with drone sprayer (1.90 jassids/ 3 leaves/ plant). On the other hand T3- 50% RDP with drone sprayer (3.70 jassids/ 3 leaves/ plant) was inferior in suppressing jassid population over T4- 100% RDP with knapsack sprayer (2.80 jassids/ 3 leaves/ plant). However T5 - untreated control (4.80 jassids/ 3 leaves/ plant) accounted for the highest count of jassids.

The jassid population ranged from 3.10 to 4.83 Jassids / 3 leaves/ plant in all the treatments tested at ten days after spraying with azadirachtin 10000 ppm. The mean number of jassids were 3.10 jassids/ 3 leaves/ plant in (T1- 100% RDP with drone sprayer) and 3.47 jassids/ 3 leaves/ plant in (T2 -75% RDP with drone sprayer) respectively. T4- 100% RDP with knapsack sprayer recorded an average of 3.30 jassids/ 3 leaves/ plant which was effective than T3- 50% RDP with drone sprayer (4.10 jassids/ 3 leaves/ plant). T5 (untreated control) had the maximum count of jassids *i.e,* 4.83 Jassids / 3 leaves/ plant.

The mean of jassids during *rabi* 2023 differed among treatments after spray of azadirachtin 10000 ppm with respect to number of jassids per three leaves. Jassid population was recorded lowest in T1- 100% RDP with drone sprayer (1.83 jassids/ 3 leaves/ plant) followed by T2- 75% RDP with drone sprayer (2.26 jassids/ 3 leaves/ plant). However, T3 - 50% RDP with drone sprayer (3.66 jassids/ 3 leaves/ plant) was inferior to T4- 100% RDP with knapsack sprayer (2.76 jassids/ 3 leaves/ plant) in suppressing the jassids. While maximum jassids were recorded in T5- untreated control recorded the highest count of jassid (4.79 jassids/ 3 leaves/ plant).

An examination of the overall mean across both seasons (r*abi* 2022-23 and 2023-2024) indicated that following the application of azadirachtin 10000 ppm, the lowest population of jassids was observed in T1- 100% RDP utilizing a drone sprayer (2.34 jassids/ 3 leaves/ plant), succeeded by T2- 75% RDP with drone sprayer (2.69 jassids / 3 leaves/ plant). Conversely, T3- 50% RDP with drone sprayer (4.03 jassids /3 leaves/ plant) demonstrated inferior performance in jassid suppression compared to T4-100% RDP with knapsack sprayer (3.22 jassids / 3 leaves/ plant). The highest population of jassids was recorded in T5- untreated control (5.11 jassids / 3 leaves/ plant).

Comparative efficacy of azadirachtin sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons

Comparitive efficacy of drone over conventional sprayings against jassid populations are depicted in table 8 and figure 3. 100% RDP with drone sprayer (T_1) could reduce the pest population by 27.33 % over conventional sprayer (T4- 100% RDP with knapsack sprayer) as per the t statistic t cal. (5.26) and $p<0.05$ proving that the 100% RDP with drone sprayer (T_1) is best treatment than the conventional sprayers. Similarly, when 75% RDP of azadirachtin is sprayed through drone (T_2) recorded 16.46 % reduction in jassid population ($p < 0.00$, t cal. 3.34) over T4- 100% RDP with knapsack sprayer which is the next best treatment after T_1. On the other hand T_3 - 50% RDP with drone sprayer resulted in 25.16 % increase in jassid population *i.e,* $p < 0.01$, t cal. 3.51 over T4- 100% RDP with knapsack sprayer, affirming that 50% RDP of azadirachtin through drone sprayer is ineffective than 100% RDP with knapsack sprayer. However all the treatments T_1 (54.21%), T_2 (47.36%), T_3 (21.24%) and T_4 (36.99%) were significantly superior in reducing jassid populations over untreated control (T_5).

Table 7 : Efficacy of azadirachtin sprays against jassids in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Treatments	Mean number of jassids/3 leaves/plant										Overall mean
	Season 1 (2022-23)					Season 2 (2023-24)					
	1DBS	3 DAS	7 DAS	10 DAS	Mean	1 DBS	3 DAS	7 DAS	10 DAS	Mean	
T1	5.30	2.47	3.00	3.10	2.86	4.70	0.93	1.47	3.10	1.83	2.34
T2	5.27	2.87	3.23	3.30	3.13	4.83	1.40	1.90	3.47	2.26	2.69
T3	5.40	3.83	4.57	4.83	4.41	4.90	3.17	3.70	4.10	3.66	4.03
T4	5.23	2.97	3.83	4.23	3.68	4.97	2.17	2.80	3.30	2.76	3.22
T5	5.58	5.47	5.40	5.43	5.43	4.93	4.73	4.80	4.83	4.79	5.11

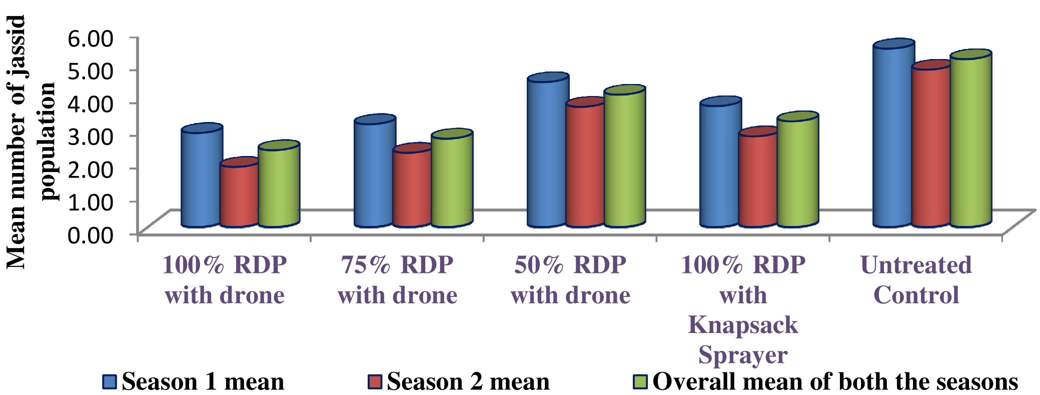

Fig. 2 : Efficacy of azadirachtin sprays against jassids in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Table 8 : Comparative efficacy of azadirachtin sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons.

Spray Type 1	Spray Type 2	Mean ± SD of treatments		t cal.	p value (<0.05)	percent difference spray type 1 over 2
		Spray Type 1	Spray Type 2			
T1	T2	1.82 ± 0.36	2.05 ± 0.29	1.56	0.14	11.22 %
T1	T3	1.82 ± 0.36	2.98 ± 0.28	8.06	0.00	38.93 %
T1	T4	1.82 ± 0.36	2.51 ± 0.36	4.24	0.00	27.49 %
T1	T5	1.82 ± 0.36	4.23 ± 0.34	15.53	0.00	56.97 %
T2	T3	2.05 ± 0.29	2.98 ± 0.28	7.22	0.00	31.21 %
T2	T4	2.05 ± 0.29	2.51 ± 0.36	3.08	0.01	18.33 %
T2	T5	2.05 ± 0.29	4.23 ± 0.34	15.42	0.00	51.54%
T3	T4	2.98 ± 0.28	2.51 ± 0.36	3.27	0.00	-18.73 %
T3	T5	2.98 ± 0.28	4.23 ± 0.34	3.27	0.00	29.55%
T4	T5	2.51 ± 0.36	4.23 ± 0.34	10.99	0.00	40.66%

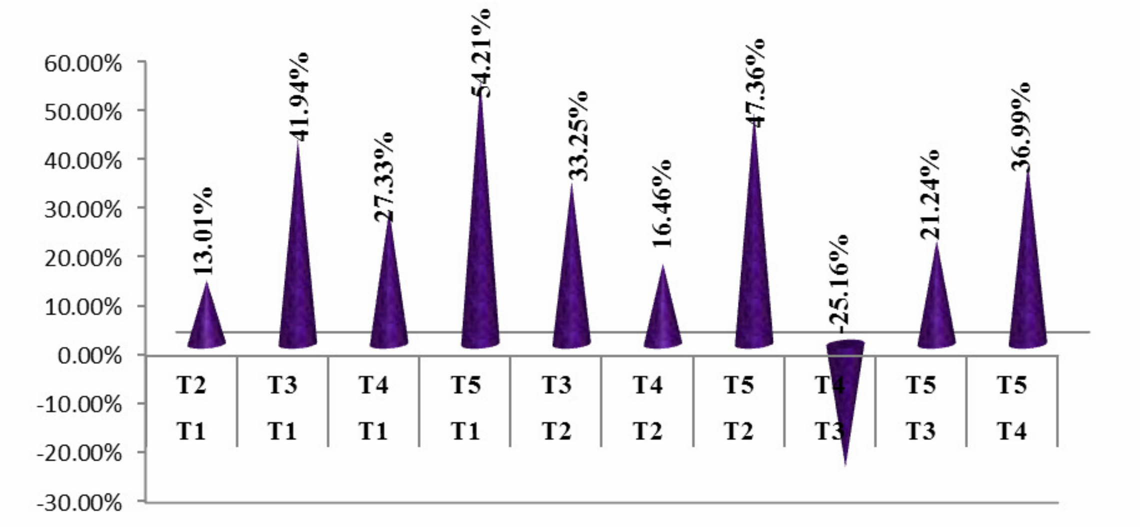

Fig. 3 : Comparative efficacy of azadirachtin sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons

Efficacy of imidacloprid sprays against jassids of brinjal

During *rabi* 2022-23, the pre-treatment population of jassids was uniform among the treatments ranging from 3.50 to 3.63 per 3 leaves per plant as depicted in table 9 and figure 4.

The jassid population ranged from 0.50 to 3.03 jassids per 3 leaves per plant across all treatments on the third day after exposure to imidacloprid 17.8% SL spray. T_1 with 100% RDP using a drone sprayer had an average of 0.50 jassids per 3 leaves per plant, while T_2 with 75% RDP using a drone sprayer had an average of 0.87 jassids per 3 leaves per plant. T_4 using 100% RDP with a knapsack sprayer showed 0.60 jassids per 3 leaves per plant, proving more effective than T_3 with 50% RDP using a drone sprayer with 1.57 jassids per 3 leaves per plant. The untreated control plot, T_5 had the highest jassid population of 3.03 jassids per 3 leaves per plant.

Population of jassid was monitored seven days after exposure to imidacloprid 17.8% SL spray and the lowest jassid population of 1.20 jassids/ 3 leaves/ plant was observed in T_1- 100% RDP with drone sprayer, followed by T_2- 75% RDP with drone sprayer (1.13 jassids/ 3 leaves/ plant). T_4- 100% RDP with knapsack sprayer had a population of 1.30 jassids/ 3 leaves/ plant, better than T_3- 50% RDP with drone sprayer (1.93 jassids/ 3 leaves/ plant), while the untreated plot (T_5) had maximum population of 2.93 jassids/3 leaves/plant compared to rest of the treatments.

A similar trend was observed ten days after spraying with imidacloprid 17.8% SL, showing that treatment T_1 with 100% RDP using a drone sprayer had the lowest jassid population (1.30 jassids/ 3 leaves/plant). T_2 with 75% RDP (1.53 jassids/ 3 leaves/ plant) followed closely behind. T_3 with 50% RDP using a drone sprayer (3.07 jassids/ 3 leaves/plant) was less effective at controlling jassids compared to T_4 with 100% RDP using a knapsack sprayer (2.40 jassids/ 3 leaves/plant). The untreated control (T_5) had the highest jassid count at 3.50 jassids/ 3 leaves /plant.

The mean jassid population in the *rabi* season of 2022-23 showed variability after imidacloprid 17.8% SL application. Treatments varied in the number of jassids observed per three leaves. The lowest population was in treatment T_1 with 100% RDP using a drone sprayer (1.00 jassids/ 3 leaves/ plant), followed by treatment T_2 with 75% RDP using a drone sprayer (1.18 jassids/ 3 leaves/ plant). Treatment T_3 with 50% RDP using a drone sprayer (2.19 jassids/ 3 leaves/ plant) was less effective than treatment T_4 with 100% RDP using a knapsack sprayer (1.43 jassids/ 3 leaves/ plant). The untreated control in treatment T_5 had the highest jassid population (3.16 jassids/ 3 leaves/ plant).

During *rabi* 2023-2024, Initial jassids population before pesticide treatment was evenly distributed and ranged from 3.90 to 4.17 per 3 leaves per plant as indicated in table 9 and figure 4. Mean population of jassids on the third day after exposure to imidacloprid 17.8% SL spray varied among treatments. The treatment T_1 with 100% RDP using a drone sprayer had the lowest population (0.47 jassids /3 leaves/plant), followed by T_2 (0.60 jassids /3 leaves/plant). T_4 with 100% RDP using a knapsack sprayer (1.03 jassids /3 leaves/plant) was better than T_3 (1.97 jassids /3 leaves/plant) and the untreated control plot (T_5) had the highest jassid population (3.93 jassids /3 leaves/plant).

Observations on jassids seven days post-imidacloprid 17.8% SL spraying revealed differences among treatments. T_1 had the fewest jassids (1.13 jassids/3 leaves/plant) with drone spray, followed by T_2 (1.17 jassids /3 leaves/plant). T_4 with knapsack sprayer (1.07 jassids /3 leaves /plant) performed better than T3 (2.87 jassids /3 leaves /plant). Untreated control plot (T_5) had the highest whiteflies population (3.93 jassids /3 leaves /plant).

The jassid population ranged from 1.50 to 4.10 jassids per 3 leaves per plant across all tested treatments after ten days of spraying with imidacloprid 17.8% SL. The mean number of jassids was 2.73 times higher in the untreated control (4.10 jassids per 3 leaves per plant) compared to the treatment with 100% RDP using a drone sprayer (1.50 jassids per 3 leaves per plant). In T_2 with 75% RDP using a drone sprayer, the jassid population increased to 2.00 jassids per 3 leaves per plant. On the other hand, in T_3 with 50% RDP using a drone sprayer, the jassid population was higher at 3.20 jassids per 3 leaves per plant compared to T_4 with 100% RDP using a knapsack sprayer (2.40 jassids per 3 leaves per plant).

During season 2 (2023-24), the mean number of jassids in T_5- untreated control reached 3.99 jassids/ 3 leaves/ plant, significantly higher than in T1- 100% RDP with drone sprayer (1.03 jassids/ 3 leaves/ plant). T_2 (75% RDP with drone sprayer) had 1.26 jassids/ 3 leaves/ plant. Conversely, T_3 (50% RDP with drone sprayer) showed higher jassid population at 2.68 jassids/ 3 leaves/ plant compared to T_4- 100% RDP with knapsack sprayer (1.50 jassids/ 3 leaves/ plant).

Overall mean data for the seasons of 2022-23 and 2023-24 revealed that the lowest jassid population in T_1 (1.02 jassids/ 3 leaves/ plant) with 100% RDP and a drone sprayer using imidacloprid 17.8% SL. The next best options were T_2 (1.22 jassids/ 3 leaves/ plant) with 75% RDP and a drone sprayer and T_4 (1.47 jassids/ 3 leaves/ plant) with 100% RDP and a knapsack sprayer. The least effective treatment was T_3 (2.43 jassids/ 3 leaves/ plant) with 50% RDP and a drone sprayer. The highest whitefly population was observed in T5, the untreated control (3.57 jassids/ 3 leaves/ plant).

Comparative efficacy of imidacloprid sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons

In the present study (table 10 and figure 5), drones effectiveness in controlling jassid populations in brinjal was compared to traditional spraying for two seasons (2022-23 and 2023-24). Results showed that using a drone sprayer with 100% RDP (T_1) led to a 30.61% reduction in pests compared to a knapsack sprayer (T_4). The statistical analysis (t cal. 5.51, $p<0.05$) confirmed the superiority of the drone sprayer. Additionally, spraying 75% RDP of imidacloprid via drone (T_2) resulted in a 17.01% decrease in jassid population, outperforming the knapsack sprayer (T_4). T_3 with 50% RDP using a drone sprayer led to a 65.31% increase in the jassid population compared to T_4 with 100% RDP using a knapsack sprayer ($p < 0.00$, t cal. 9.23). This suggests that the 50% RDP of imidacloprid through a drone sprayer is less effective than the 100% RDP with a knapsack sprayer. However, all treatments (T_1: 71.43%, T_2: 65.83%, T_3: 31.93%, T_4: 58.82%) were significantly better at reducing jassid populations than the untreated control T_5.

Table 9 : Efficacy of imidacloprid sprays against jassid in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Treatments	Mean number of jassids/3 leaves/plant										Overall mean
	Season 1 (2022-23)					Season 2 (2023-24)					
	1DBS	3 DAS	7 DAS	10 DAS	Mean	1 DBS	3 DAS	7 DAS	10 DAS	Mean	
T1	3.50	0.50	1.20	1.30	1.00	3.90	0.47	1.13	1.50	1.03	1.02
T2	3.63	0.87	1.13	1.53	1.18	3.93	0.60	1.17	2.00	1.26	1.22
T3	3.57	1.57	1.93	3.07	2.19	4.10	1.97	2.87	3.20	2.68	2.43
T4	3.60	0.60	1.30	2.40	1.43	3.97	1.03	1.07	2.40	1.50	1.47
T5	3.53	3.03	2.93	3.50	3.16	4.17	3.93	3.93	4.10	3.99	3.57

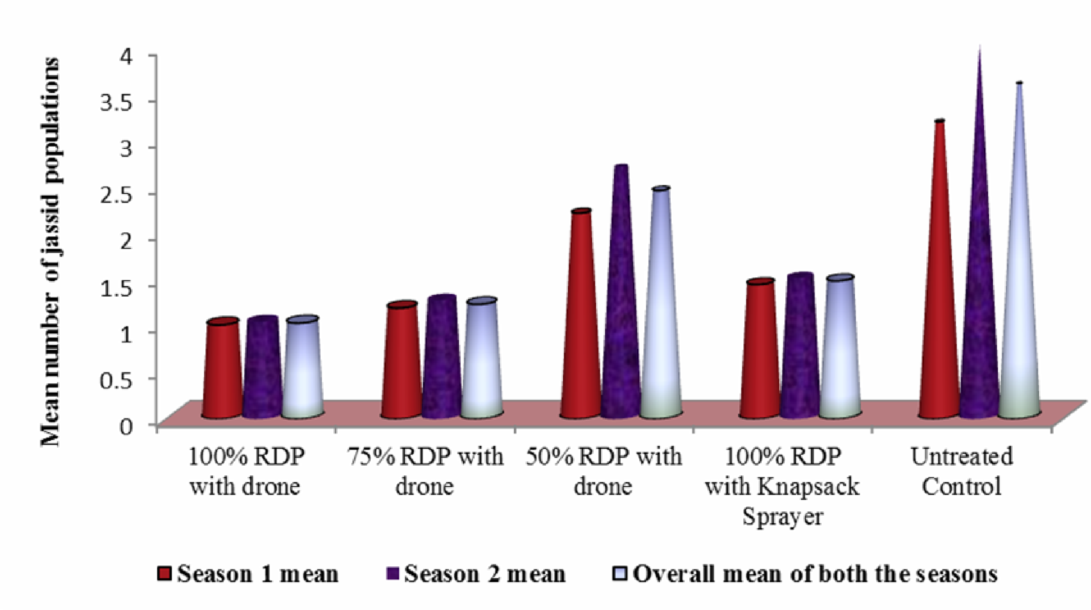

Fig. 4. Efficacy of imidacloprid sprays against jassid in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Table 10 : Comparative efficacy of imidacloprid sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons.

Spray Type 1	Spray Type 2	Mean ± SD of treatments		t cal.	p value (<0.05)	percent difference spray type 1 over 2
		Spray Type 1	Spray Type 2			
T1	T2	1.02 ± 0.22	1.22 ± 0.13	2.46	0.02	16.39 %
T1	T3	1.02 ± 0.22	2.43 ± 0.30	11.89	0.00	58.02 %
T1	T4	1.02 ± 0.22	1.47 ± 0.13	5.51	0.00	30.61 %
T1	T5	1.02 ± 0.22	3.57 ± 0.53	14.14	0.00	71.43 %
T2	T3	1.22 ± 0.13	2.43 ± 0.30	11.64	0.00	49.79 %
T2	T4	1.22 ± 0.13	1.47 ± 0.13	4.28	0.00	17.01 %
T2	T5	1.22 ± 0.13	3.57 ± 0.53	13.75	0.00	65.83 %
T3	T4	2.43 ± 0.30	1.47 ± 0.13	9.23	0.00	-65.31 %
T3	T5	2.43 ± 0.30	3.57 ± 0.53	5.92	0.00	31.93%
T4	T5	1.47 ± 0.13	3.57 ± 0.53	12.27	0.00	58.82%

Efficacy of lambda-cyhalothrin sprays against jassids of brinjal

In *rabi* 2022-2023, data on pre-treatment revealed that initial jassid population was consistent ranging from 3.90 to 4.27 per 3 leaves per plant and no significant difference was observed among the treatments (Table 11 and figure 6).

Mean population of jassid after exposure to lambda-cyhalothrin 5% EC spray on the third day showed that treatment T_1 with 100% RDP using a drone sprayer had the lowest jassid population (0.97 jassids/ 3 leaves/ plant), followed by T_2 with 75% RDP using a drone sprayer (1.07 jassids/ 3 leaves/ plant). T_4 with 100% RDP through knapsack sprayer (1.20 jassids/ 3 leaves/ plant) performed better than T_3 with 50% RDP using a drone sprayer (2.27 jassids/ 3 leaves/ plant). T_5 had highest jassid population of 3.87 jassids per 3 leaves.

At seven days after spraying lambda-cyhalothrin 5% EC spray caused minimum jassid count (1.53 jassids/ 3 leaves/ plant) in 100% RDP with a drone sprayer (T_1) with 1.53 jassids/ 3 leaves/ plant outperforming treatment T_4 with a knapsack sprayer (2.57 jassids/ 3 leaves/ plant) and the untreated control (3.90 jassids/ 3 leaves/ plant). Treatment T_2 with a drone sprayer at 75% RDP (1.80 jassids/ 3 leaves/ plant) was more effective than T_4, T_5 and T_3 at 50% RDP with a drone sprayer (3.17 jassids/ 3 leaves/ plant) in controlling jassids.

The data showed that ten days after lambda-cyhalothrin 5% EC spraying, the mean jassid population was 1.23 times higher in the untreated control T_5 (4.03 jassids/3 leaves/plant) compared to T_1 (3.27 jassids/3 leaves/plant with drone sprayer). Jassid population slightly decreased to 3.20 jassids/3 leaves/plant in T_2 with drone sprayer at 75% RDP, while T3 had a higher population at 4.00 jassids/3 leaves/plant compared to T_4 with knapsack sprayer at 100% RDP (3.90 jassids/3 leaves/plant).

The mean jassid population in the *rabi* of 2022-23 was monitored on 3rd, 7th and 10th day after lambda-cyhalothrin 5% EC spray and the results showed that lowest jassid population in T_1- 100% RDP with drone sprayer (1.92 jassids/ 3 leaves/ plant) followed by T_2 with 2.02 jassids per 3 leaves per plant using a drone sprayer with 75% RDP. T_3 had 3.14 jassids per 3 leaves per plant with 50% RDP, less effective than T_4 with 2.56 jassids per 3 leaves per plant using a knapsack sprayer with 100% RDP. The highest jassid count of 3.93 jassids per 3 leaves per plant was observed in the untreated control of T_5.

During *rabi* 2023-2024 data showed consistent jassid population distribution with no significant difference among treatments before spraying with lambda-cyhalothrin 5% EC. Drone sprayer with 100% recommended dose of pesticide (T_1) led to the minimal jassid population (1.07 jassids/ 3 leaves/ plant) on the third day after exposure to lambda-cyhalothrin 5% EC spray. The next best result was seen with T_2- 75% RDP with drone sprayer (1.27 jassids/ 3 leaves/ plant), while using a knapsack sprayer with 100% RDP- T_4 (1.63 jassids/ 3 leaves/ plant) was better than using a drone sprayer with 50% RDP (T3- 2.57 jassids/ 3 leaves/ plant). The untreated control plot (T_5) had the highest jassid population of 4.37 jassids/ 3 leaves/ plant.

The average population of jassids on seven days after spraying with lambda-cyhalothrin 5% EC spray was found to be least in treatment T1- 100% RDP with drone sprayer (2.23 jassids/ 3 leaves/ plant), surpassing T_4- 100% RDP with knapsack sprayer (2.80 jassids/ 3 leaves/ plant) and T_5 - untreated control (4.03 jassids/ 3 leaves/ plant). While, T_2- 75% RDP with drone sprayer (2.57 jassids/ 3 leaves/ plant) is superior over T_4, T_5 and T_3- 50% RDP with drone sprayer (3.53 jassids/ 3 leaves/ plant) in suppressing the jassids.

The data on ten days after spraying with lambda-cyhalothrin 5% EC the mean number of jassids was 1.54 and 1.52 times higher in T_5 (4.57 jassids/3 leaves/ plant) compared to T_1 (2.97 jassids/3 leaves/plant) and T_2 (3.00 jassids/3 leaves/plant) respectively. T_3 (50% RDP with drone sprayer) had a higher jassid population (4.73 jassids/3 leaves/plant) than T_4 (100% RDP with knapsack sprayer-4.40 jassids/3 leaves/ plant).

In *rabi* season of 2023-24, the jassid population varied among different treatments after the first spray of lambda-cyhalothrin 5% EC. The number of jassids per three leaves was lowest in T_1 (100% RDP with drone sprayer) at 2.09 jassids/3 leaves/plant, followed by T_2 (75% RDP with drone sprayer) at 2.28 jassids/3 leaves/plant. T_3 (50% RDP with drone sprayer) had a higher jassid population at 3.61 jassids/3 leaves/plant, while T4 (100% RDP with knapsack sprayer) was more effective at 2.94 jassids/3 leaves/plant in controlling jassids. The untreated control in T_5 had the highest jassid count at 4.32 jassids/3 leaves/plant.

Glance of overall mean of both the seasons (2022-23 & 2023-24) showed that after spraying of lambda-cyhalothrin 5% EC the lowest jassid population recorded in T_1- 100% RDP with drone sprayer (2.01 jassids / 3 leaves/ plant) followed by T_2- 75% RDP with drone sprayer (2.15 jassids / 3 leaves/ plant). However, T_3 - 50% RDP with drone sprayer (3.38 jassids / 3 leaves/ plant) was inferior to T_4- 100% RDP with knapsack sprayer (2.75 jassids / 3 leaves/ plant) in suppressing the jassids. While maximum jassids were recorded in T_5 - untreated control (4.13 jassids / 3 leaves/ plant).

Comparative efficacy of lambda-cyhalothrin

sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons

Comparitive efficacy of drone over conventional sprayings against jassid populations are depicted in table 12 and figure 7. 100% RDP with drone sprayer (T_1) could reduce the pest population by 26.91 % over conventional sprayer (T_4- 100% RDP with knapsack sprayer) as per the t statistic t cal. (4.08) and p<0.05 proving that 100% RDP with drone sprayer (T_1) is best treatment than the conventional sprayers. Similarly when 75% RDP of lambda-cyhalothrin is sprayed through drone (T_2) recorded 21.82 % reduction in jassid population (p < 0.00, t cal. 3.00) over T_4- 100% RDP with knapsack sprayer which is the next best treatment after T_1. On the other hand T_3 - 50% RDP with drone sprayer resulted in 22.91 % increase in jassid population *i.e,* p < 0.00, t cal. 3.05 over T4- 100% RDP with knapsack sprayer, affirming that 50% RDP of lambda- cyhalothrin through drone sprayer is ineffective than 100% RDP with knapsack sprayer. However all the treatments T_1 (51.33%), T_2 (47.94%), T_3 (18.16%) and T_4 (33.41%) were significantly superior in reducing jassid populations over untreated control T_5.

Table 11 : Efficacy of lambda cyhalothrin sprays against jassid in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Treatments	Mean number of jassids/3 leaves/plant										Overall mean
	Season 1 (2022-23)					Season 2 (2023-24)					
	1DBS	3 DAS	7 DAS	10 DAS	Mean	1 DBS	3 DAS	7 DAS	10 DAS	Mean	
T1	3.90	0.97	1.53	3.27	1.92	4.30	1.07	2.23	2.97	2.09	2.01
T2	4.07	1.07	1.80	3.20	2.02	4.23	1.27	2.57	3.00	2.28	2.15
T3	4.03	2.27	3.17	4.00	3.14	4.33	2.57	3.53	4.73	3.61	3.38
T4	3.97	1.20	2.57	3.90	2.56	4.27	1.63	2.80	4.40	2.94	2.75
T5	4.27	3.87	3.90	4.03	3.93	4.43	4.37	4.03	4.57	4.32	4.13

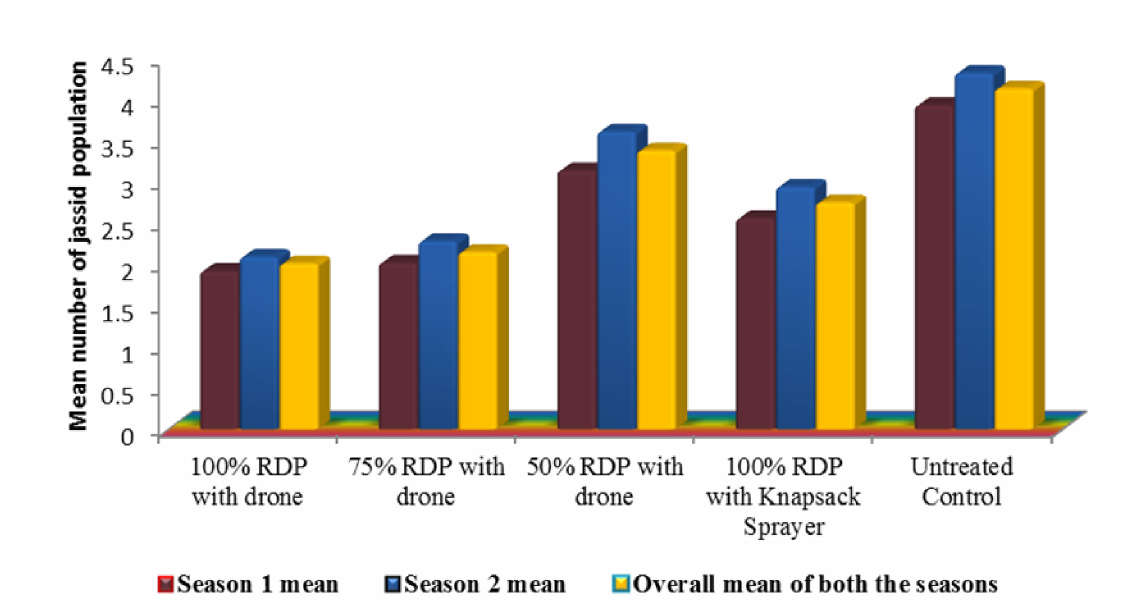

Fig. 5 : Efficacy of lambda cyhalothrin sprays against jassid in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Table 12 : Comparative efficacy of lambda cyhalothrin sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons.

Spray Type 1	Spray Type 2	Mean ± SD of treatments		t cal.	p value (<0.05)	percent difference spray type 1 over 2
		Spray Type 1	Spray Type 2			
T1	T2	2.01 ± 0.20	2.15 ± 0.33	1.18	0.25	6.51 %
T1	T3	2.01 ± 0.20	3.38 ± 0.36	10.39	0.00	40.53 %
T1	T4	2.01 ± 0.20	2.75 ± 0.54	4.08	0.00	26.91 %
T1	T5	2.01 ± 0.20	4.13 ± 0.33	15.25	0.00	51.33 %

T2	T3	2.15 ± 0.33	3.38 ± 0.36	7.91	0.00	36.39 %
T2	T4	2.15 ± 0.33	2.75 ± 0.54	3.00	0.01	21.82 %
T2	T5	2.15 ± 0.33	4.13 ± 0.33	12.27	0.00	47.94 %
T3	T4	3.38 ± 0.36	2.75 ± 0.54	3.05	0.01	-22.91 %
T3	T5	3.38 ± 0.36	4.13 ± 0.33	4.44	0.00	18.16 %
T4	T5	2.75 ± 0.54	4.13 ± 0.33	6.54	0.00	33.41 %

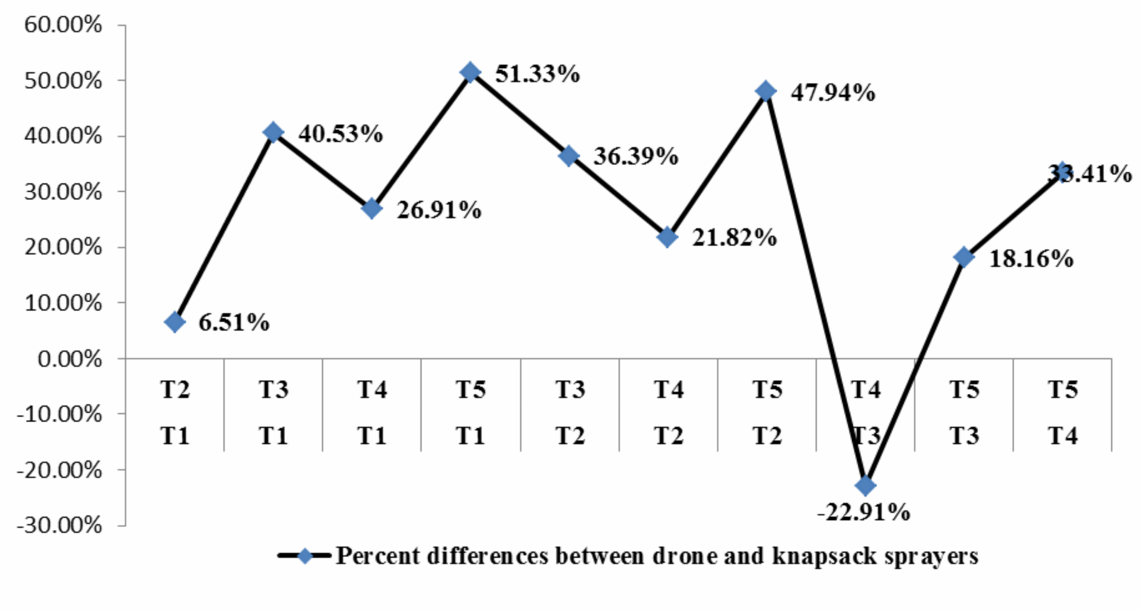

Fig. 6 : Comparative efficacy of lambda cyhalothrin sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons.

Efficacy of thiamethoxam sprays against jassids of brinjal

During *rabi* 2022-2023, initial population of jassids before sprayings exhibited a consistent distribution among the treatments without any significance difference ranging from 3.37 to 3.63 jassids per 3 leaves per plant (table 13 and figure 8). Treatment T_1 (100% RDP using a drone sprayer) had the lowest jassid population (0.33 jassids/3 leaves/plant) at three days after spraying with thiamethoxam 25% WG spray, followed by T_2 with 75% RDP using a drone sprayer (0.53 jassids/3 leaves/plant). T_4 with 100% RDP using a knapsack sprayer had a jassid population of 0.93 jassids/3 leaves/plant which better than T_3 with 50% RDP using a drone sprayer (2.63 jassids/3 leaves/plant). Whilst, untreated control plot T_5 had the highest jassid population of 3.37 jassids/3 leaves/plant.

Seven days after spraying with thiamethoxam 25% WG, the lowest average jassid population was observed in T_1 (100% RDP with a drone sprayer) with 1.27 jassids per 3 leaves per plant which was lower than T_4 (100% RDP with a knapsack sprayer) with 1.80 jassids per 3 leaves per plant and T_5 (untreated control) which had 3.37 jassids per 3 leaves per plant. Additionally, T_2 (75% RDP with a drone sprayer) 1.53 jassids per 3 leaves per plant showed a better performance in suppressing jassids compared to T_4, T_5 and T_3 2.63 jassids (50% RDP with a drone sprayer).

The jassid population in all the treatments tested at ten days after spraying with thiamethoxam 25% WG revealed that the mean number of jassids were 1.52 times higher than in T5 (untreated control – 3.40 Jassids / 3 leaves/ plant) over T_1 (100% RDP with drone sprayer – 2.23 jassids/ 3 leaves/ plant). However, the jassid population declined to 2.03 jassids/ 3 leaves/ plant in T_2 (75% RDP with drone sprayer). Conversely, the jassid population in T_3- 50% RDP with drone sprayer (3.40 jassids/ 3 leaves/ plant) was higher than in T_4- 100% RDP with knapsack sprayer (2.57 jassids/ 3 leaves/ plant).

Significant differences in mean jassid populations were observed in the *rabi* 2022-23 season after applying thiamethoxam 25% WG. Treatment T_1 with 100% RDP via drone sprayer had the lowest jassid population (1.28) followed by T_2 (1.37) and T_4 (1.77) with varying RDP percentages. Treatment T_3 with 50% RDP showed the least efficacy (2.89) while, the untreated control (T5) had the highest jassid density at 3.38

Season 2 *rabi* 2023-2024 indicated that the initial population of jassids before any treatment exhibited a consistent distribution showing no significance difference ranging from 3.93 to 4.13 jassids per 3 leaves per plant. The jassid population varied on the third day after exposure to thiamethoxam 25% WG spray across different treatments. Treatment T_1 had the lowest population (0.93 jassids/3 leaves/plant) using a drone sprayer with 100% RDP succeeded by T_2 (1.07 jassids/3 leaves/plant) with 75% RDP. T_4 (1.60 jassids/3 leaves/plant) using a knapsack sprayer outperformed T_3 with 50% RDP using a drone sprayer (2.13 jassids/3 leaves/plant) while the highest jassid population was observed in the untreated control plot (T_5) with 3.93 jassids per 3 leaves per plant.

After 7 days of spraying with Thiamethoxam 25% WG spray, the lowest average population of jassids was in treatment T_1 with a drone sprayer (1.50 jassids/3 leaves/plant). Treatment T2 with a drone sprayer (1.67 jassids/3 leaves/plant) outperformed T_3 (2.70), T_4 (2.43) and T_5. While, the highest jassid population of 3.87 jassids/3 leaves/plant was observed in untreated control (T_5).

The assessment of the jassid population conducted ten days post- application of thiamethoxam 25% WG indicated that the average number of jassids was 1.66 times greater than in T_5 (untreated control – 4.03 jassids/3 leaves/plant) compared to T_1 (100% RDP with drone sprayer – 2.43 jassids/3 leaves/plant). Conversely, the jassid population diminished to 2.63 jassids/3 leaves/plant in T_2 (75% RDP with drone sprayer). Nonetheless, the jassid population recorded in T_3 (50% RDP with drone sprayer – 3.93 jassids/3 leaves/plant) exceeded that of T_4 (100% RDP with knapsack sprayer – 3.03 jassids/3 leaves/plant).

The average population of jassids during the *rabi* season of 2023-24 exhibited significant variation across different treatments following the application of thiamethoxam 25% WG. The lowest jassid population was observed in T_1-100% RDP utilizing a drone sprayer (1.62 jassids/3 leaves/plant) succeeded by T_2-75% RDP with a drone sprayer (1.79 jassids/3 leaves/plant). Conversely, T_3-50% RDP with a drone sprayer (2.92 jassids/3 leaves/plant) demonstrated lower efficacy in controlling jassids compared to T_4-100% RDP employing a knapsack sprayer (2.36 jassids/3 leaves/plant). The highest jassid population was noted in T_5- the untreated control, which recorded the greatest jassid count (3.94 jassids/3 leaves/plant).

A comprehensive analysis of the average values from both seasons (2022- 23 and 2023-24) showed that applying thiamethoxam via drone sprayer significantly reduced the jassid population. T_1 with 100% RDP had the lowest jassid count (1.45) followed by T_2 with 75% RDP (1.58). In comparison, T_3 with 50% RDP had a higher jassid count (2.91) than T_4 with 100% RDP using a knapsack sprayer (2.06). The untreated control T_5 had the highest jassid count (3.66).

Comparative efficacy of thiamethoxam sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons

The comparative effectiveness of drone applications versus traditional spraying methods in controlling jassid populations is illustrated in Table 14 and figure 9. The utilization of a drone sprayer delivering 100% recommended dose of pesticide (T_1) achieved a notable reduction of 29.61% in pest populations compared to the conventional knapsack sprayer (T_4- 100% RDP with knapsack sprayer), as indicated by a t statistic of t cal. (4.80) and $p<0.05$, confirming that the drone application at 100% RDP (T_1) is the most effective treatment relative to conventional methods. Likewise, the application of 75% RDP of thiamethoxam via drone (T_2) resulted in a 23.30% decrease in jassid populations ($p < 0.00$, t cal. 3.52) when compared to T_4- 100% RDP with knapsack sprayer positioning it as the second most effective treatment following T1. Conversely, T_3 - 50% RDP with drone sprayer led to a 41.26% increase in jassid populations with $p < 0.00$, t cal. 6.37 in comparison to T_4- 100% RDP with knapsack sprayer indicating that a 50% RDP of thiamethoxam applied through drone is less effective than the full dosage delivered via knapsack sprayer. Nevertheless, all treatments T_1 (60.38%), T_2 (56.83%), T_3 (20.49%) and T_4 (43.72%) demonstrated statistically significant superiority in reducing jassid populations when juxtaposed with the untreated control group T_5.

Table 13 : Efficacy of thiamethoxam sprays against jassid in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Treatments	Mean number of jassids/3 leaves/plant										Overall mean
	Season 1 (2022-23)					Season 2 (2023-24)					
	1DBS	3 DAS	7 DAS	10 DAS	Mean	1 DBS	3 DAS	7 DAS	10 DAS	Mean	
T1	3.40	0.33	1.27	2.23	1.28	3.97	0.93	1.50	2.43	1.62	1.45

T2	3.37	0.53	1.53	2.03	1.37	4.03	1.07	1.67	2.63	1.79	1.58
T3	3.47	2.63	2.63	3.40	2.89	3.93	2.13	2.70	3.93	2.92	2.91
T4	3.53	0.93	1.80	2.57	1.77	4.13	1.60	2.43	3.03	2.36	2.06
T5	3.63	3.37	3.37	3.40	3.38	4.07	3.93	3.87	4.03	3.94	3.66

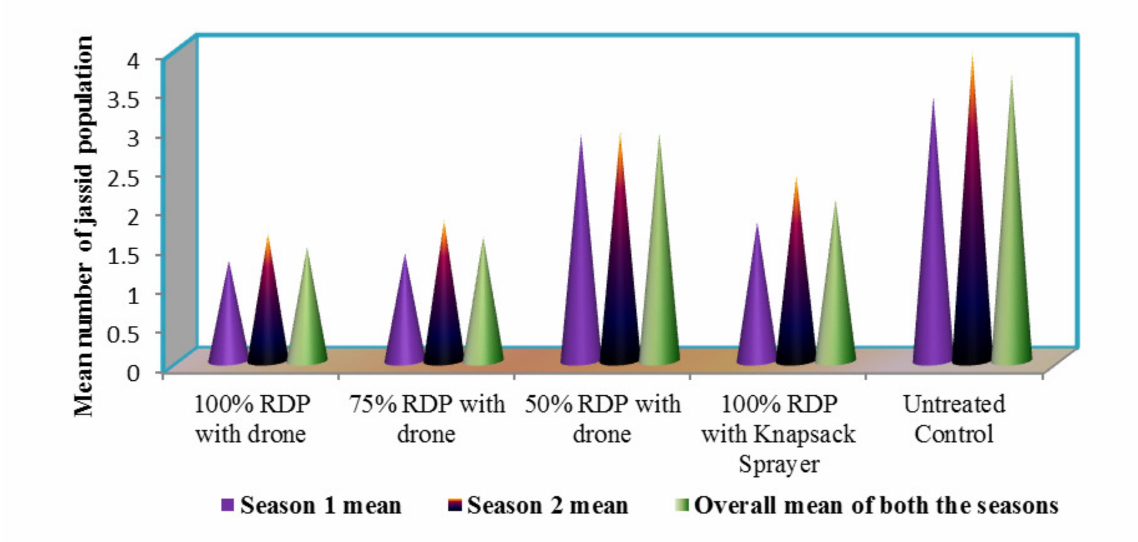

Fig. 7 : Efficacy of thiamethoxam sprays against jassid in brinjal through drone and conventional sprayer during *rabi* 2022 and 2023.

Table 14 : Comparative efficacy of thiamethoxam sprayed with drone sprayer over knapsack sprayer against jassids in brinjal during both the seasons.

Spray Type 1	Spray Type 2	Mean ± SD of treatments		t cal.	p value (<0.05)	percent difference spray type 1 over 2
		Spray Type 1	Spray Type 2			
T1	T2	1.45 ± 0.29	1.58 ± 0.33	0.92	0.37	8.23 %
T1	T3	1.45 ± 0.29	2.91 ± 0.31	10.83	0.00	50.17 %
T1	T4	1.45 ± 0.29	2.06 ± 0.28	4.80	0.00	29.61 %
T1	T5	1.45 ± 0.29	3.66 ± 0.22	19.17	0.00	60.38 %
T2	T3	1.58 ± 0.33	2.91 ± 0.31	9.22	0.00	45.70 %
T2	T4	1.58 ± 0.33	2.06 ± 0.28	3.52	0.00	23.30 %
T2	T5	1.58 ± 0.33	3.66 ± 0.22	16.49	0.00	56.83 %
T3	T4	2.91 ± 0.31	2.06 ± 0.28	6.37	0.00	-41.26 %
T3	T5	2.91 ± 0.31	3.66 ± 0.22	6.23	0.00	20.49 %
T4	T5	2.06 ± 0.28	3.66 ± 0.22	14.13	0.00	43.72 %

The comprehensive effectiveness of the evaluated insecticides on the average population of jassids administered via drone and knapsack sprayers during both the seasons (*rabi* 2022-23 & 2023-24), is delineated in table 4.25 and figure 4.25. Imidacloprid 17.8% SL and thiamethoxam 25% WG exhibited comparable efficacy and were determined to be the most effective formulations when applied at rates of 125 ml/ha and 200 g/ha, respectively in controlling jassids. However, lambda-cyhalothrin 5% EC applied at a dose of 300 ml/ha recorded moderate level of control jassids in brinjal crop. Conversely, azadirachtin 10000 ppm, @ 1500 ml/ha, demonstrated inferior effectiveness relative to the aforementioned treatments.

Nonetheless, all chemical agents displayed efficacy in mitigating the population of jassids within brinjal crop, particularly when administered through drone technology (both T_1 and T_2), in comparison to traditional knapsack spraying (T_4). However, a reduction in the dosage of the chemical to 50% of the recommended dose per hectare (T_3) resulted in an escalation of the pest population, thereby increasing damage when compared with spraying through conventional knapsack sprayer. Nevertheless, all chemical treatments yielded statistically significant reductions in populations relative to the untreated control (T_5).

Table 15 : Bioefficacy of insecticides sprayed through drone and conventional sprayers against jassids in brinjal.

Treatments	Overall mean number of jassid population				
	T1	**T2**	**T3**	**T4**	**T5**
Azadrachtin	2.34	2.69	4.03	3.22	5.11
Imidacloprid	1.02	1.22	2.43	1.47	3.57
Lambda cyhalothrin	2.01	2.15	3.38	2.75	4.13
Thiamethoxam	1.45	1.58	2.91	2.06	3.66

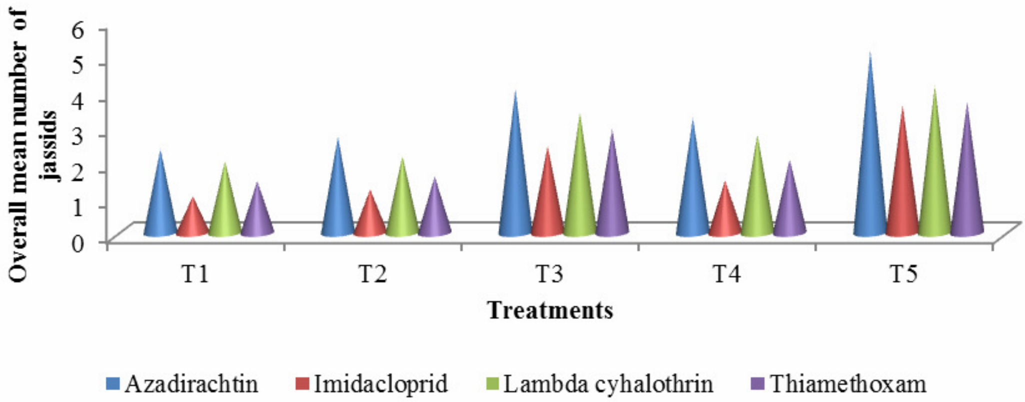

Fig. 8 : Bioefficacy of insecticides sprayed through drone and onventional sprayers against jassids in brinjal.

The above cited results are in conformity with the earlier findings made by Huang *et al.* (2009), Sun *et al.* (2016) and Lou *et al.* (2018) on the efficacy of drones in pesticide spraying for managing insect pests and vectors. Subsequently, Wang *et al.* (2019a) determined that 70% imidacloprid WDG against wheat aphids via a UAV sprayer was superior to traditional knapsack sprayers. In a similar vein, Wang *et al.* (2019b) employed an innovative UAV to regulate wheat aphids with varying spray capacities of imidacloprid and lambda- cyhalothrin.

Innovative compact pesticide system for drones was designed by Martinez *et al.* (2020) for management of insect pests in olive and citrus orchards, improving application quality and cost-effectiveness. Litchi stink bug population reduced by 95% and water usage decreased by 12.5% saved over 50% labor and cut pesticide usage by 70% with a drone system developed by Ching-ju *et al.* (2021). *Bacillus thuringiensis* was sprayed through drones for decreasing bagworm larvae population (96%) by Mohamed *et al.* (2021). In the same year, Xiaojing *et al.* (2021) confirmed that UAV spraying with spinetoram was more effective in mitigating cowpea thrips compared to knapsack electric sprayers.

Analogously, UAVs outperformed knapsack sprayers in managing pests like *B. tabaci* due to better spray droplet size, density and effectiveness as per the findings of Parmar *et al.* (2022). In the same time frame, drone spraying technology is more effective than manual spraying in paddy fields by 9.08% as documented by Rosedi and shamsi (2022). Insecticide droplet deposition, density, coverage and penetrability across various strata of vegetation was found to be best in Drone spraying methods over manual spraying for red gram insect pests as indicated by the findings of Yallappa *et al.* (2022). Likewise, UAV- mediated spraying reduced quantities of pesticides and resulted superior control of peach moth and chestnut weevil in comparison to traditional spraying techniques as described by Arakawa and Kamio (2023).

Drones equipped with fan nozzles engaged by Rasheed *et al.* (2023) to spray flubendiamide insecticide at a rate of 36 l/ha lead to a successful reduction of the bagworm *M. plana* population by 82.50% within 5 days. Distinctive UAV sprayer developed by Sambaiah *et al.* (2023) for application of Flonicamid at 90g/acre with 75% pesticide dose, showed higher efficacy than traditional methods for controlling leafhoppers in cotton fields. Concurrently, Wu *et al.* (2023) developed a remarkable UAV that achieved better droplet deposition than knapsack sprayers, leading to enhanced efficacy of 83% compared to 73% with traditional methods for controlling insect pests on chrysanthemum.

The results on bio-efficacy of insecticides against sucking pests of brinjal are in conformity with the earlier findings made by Begum *et al* (2016), Ali *et al.* (2016) and Awaneesh *et al.* (2017) who reported that Imidacloprid 17.8 SL @ 40 g a.i./ha and Thiamethoxam 25 WG @ 100g/ha effectively reduced jassid population in brinjal and thiacloprid 21.7% SC was least effective against sucking pest population reduction in brinjal.

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