

RESIDUAL STUDIES OF PROMISING PESTICIDES IN BRINJAL

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in
Vegetable Science

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DECLARATION

I, hereby declared that the presented work in the thesis entitled “**Residual studies of promising pesticides in Brinjal**” in fulfillment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Dipika Mal**, working as **Associate Professor** in the **Department of Horticulture, School of Agriculture**, Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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Residual studies of promising pesticides in Brinjal

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Abstract

The present investigation entitled “Residual studies of promising pesticides in Brinjal” was conducted in the main agricultural field, Department of Vegetable Science, Lovely Professional University, Phagwara, Punjab, during the *kharif* seasons of 2023 and 2024, aiming to achieve the following objectives: i) To identify the best treatment for the growth, yield and quality of brinjal, ii) To estimate the residual effect of the treatments in brinjal, iii) To evaluate the efficacy of pesticides against shoot and fruit borer in brinjal, iv) To study the Benefit Cost ratio of treatments. The investigation consisted of nine treatments applied at recommended doses, including T₀ (Control-water spray), T₁ (Chlorpyrifos 20% EC), T₂ (Triazophos 40% EC), T₃ (Karanj oil 1%), T₄ (Neem oil 1%), T₅ (Acetamiprid 20% SP), T₆ (Deltamethrin 2.8% EC), T₇ (Cartap-hydrochloride 50% SP) and T₈ (Carbofuran 3% CG), using a randomized block design with three replicates over two years of research. The seedlings were transplanted into 27 plots, each measuring 1.80 x 4.50 meters, with a spacing of 60 x 45 cm, during the first week of July on both 2023 and 2024. Observations were recorded on various growth, yield and quality characteristics, including plant height (cm), shoot length (cm), root length (cm), number of leaves, number of branches per plant, stem diameter (cm), days to flower initiation, days to 50 percent flowering, number of flowers per plant, days to fruit formation, days to harvesting, leaf area (cm²), leaf area index (LAI), number of shoot damage, incidence of shoot borer (%), number of fruits per plant, fruit length (cm), fruit width (cm), fruit yield per plant (kg), fruit yield per plot (kg), yield per hectare (t), yield increase over control per hectare (%), incidence of fruit borer (%), TSS (°Brix), titratable acidity (%), crude protein (%) and chlorophyll index of leaves (SPAD-502). Observations on residual studies consisted of residual analysis and the dissipation rate of insecticides in brinjal fruit. Observations on seasonal incidence were based on weekly recordings of shoot and fruit borer population along with correlation analysis with meteorological parameters such as temperature, humidity, rainfall and sunshine hours.

Observations on efficacy of pesticides included percent shoot infestation (%) and fruit infestation (%). Observations on the economics of cultivation consisted of total cost of cultivation (Rs/ha), gross return (Rs/ha), net return (Rs/ha) and benefit-cost ratio (B:C). The findings indicated that in terms of growth and yield treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (Deltamethrin 2.8% EC) performed better compared to T₀ (Control). In terms of quality, observations revealed that there was a non-significant effect of different insecticidal treatments on brinjal. The residual analysis results indicated that insecticide residues decreased below the detection limit (BDL) on the following days: the seventh day for acetamiprid, deltamethrin, and cartap hydrochloride; the tenth day for triazophos and chlorpyrifos; and the fifteenth day for carbofuran. No residues were detected in botanical insecticides and the control treatment. The pooled analysis revealed that shoot damage was initially 2.10 per cent during the 4th week after transplanting (26th SMW). The damage gradually increased and peaked at 29.75 per cent during the 36th SMW. The Pooled data on fruit infestation levels on a number basis ranged from 4.08% (31st SMW) to 41.27% (38th SMW), with peak infestation at 33.16 °C (max), 24.23 °C (min), 93.09% morning RH, 67.78% evening RH, 1.22 mm rainfall, and 5.26 sunshine hours. The fruit infestation on a weight basis ranged from 1.44% to 37.25%, with the highest at 38th SMW. The correlation of shoot infestation, fruit infestation on a number basis and weight basis revealed the weather parameters were negatively correlated with maximum and minimum temperature and rainfall, but positively correlated with morning and evening relative humidity and sunshine hours. The order of efficacy of the eight insecticides against shoot and fruit borer infestation was as follows: Cartap-hydrochloride 50% SP > Deltamethrin 2.8% EC > Acetamiprid 20% SP > Chlorpyrifos 20% EC > Triazophos 40% EC > Karanj oil 1% > Neem oil 1% > Carbofuran 3% CG. The most effective treatment in terms of benefit-cost ratio was T₇ (Cartap-hydrochloride 50% SP) followed by treatment T₆ (Deltamethrin 2.8% EC), in comparison to the treatment T₀ (Control). In conclusion, it is recommended that farmers avoid the indiscriminate application of insecticides and adopt judicious use practices to enhance crop productivity while ensuring environmental safety and minimizing the risk of hazardous chemical residues.

Dr. Dipika Mal
(Supervisor)

Dr. Satish Krushna Gharde
(Co-Supervisor)

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Dedicated
to MY
BELOVED PARENTS

VISHAL THAKUR..... 

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LIST OF SYMBOLS AND ABBREVIATIONS

Sr. No.	Symbols and Abbreviations	Meaning
1.	EC	Emulsifiable Concentrate
2.	SC	Soluble Concentrate
3.	OD	Oil Dispersion
4.	WP	Wettable Powder
5.	SL	Soluble Liquid
6.	SP	Soluble Powder
7.	CS	Capsule Suspension
8.	WDG	Water Dispersible Granule
9.	CG	Crystal Granule
10.	Kg	Kilogram
11.	g	Gram
12.	ml	Mililitre
13.	L	Litre
14.	mm	Milimetre
15.	nm	Nanometer
16.	mg	Milligram
17.	µm	Micrometer
18.	µl	Microlitre
19.	T	Tonnes
20.	Mt	Metric ton
21.	Q	Quintal
22.	et al.	Et alii (and other)
23.	FAO	Food and Agricultural Organization
24.	sp.	Species
26.	%	Per cent
27.	/	Per
28.	Ha	Hectare
29.	Var	Variety
30.	&	And
31.	Cm	Centimeter
32.	@	At the rate

33.	Cc	Cubic centimeter
34.	i.e.	Id est (that is)
35.	Ppm	Parts per million
36.	Ltd	Limited
37.	Pvt	Private
38.	LC	Lethal Concentration
39.	Conc.	Concentration
40.	Fig.	Figure
41.	Hrs	Hours
42.	viz.	Videlicet (namely)
43.	RP-HPLC	Reversed Phase-High Performance Liquid Chromatography
44.	w/v	Weight/volume
45.	RBD	Randomized Block Design
46.	v/v	Volume/volume
47.	UV-VIS	Ultraviolet-Visible Spectroscopy
48.	CV	Coefficient of variation
49.	B:C	Benefit cost ratio
50.	Q	Quintal
51.	EU	European Union
52.	MRL	Maximum Residue Limit
53.	Rs.	Rupees
54.	BDL	Below Detection Limit
55.	LOQ	Limit of Quantification
56.	LOD	Limit of Detection
57.	CD	Critical difference
58.	DAS	Days after spraying
59.	Conc.	Concentration
60.	Fig.	Figure
61.	NS	non-significant
62.	°C	Degree Celsius
63.	LC-MS/MS	Liquid Chromatography - Mass Spectrometry
64.	SE _m (±)	Standard error of mean
65.	r	Correlation coefficient
66.	a.i.	Active ingredient

Brinjal (*Solanum melongena* L.), widely recognized as eggplant and aubergine, is one of the most commonly consumed vegetable crops in India. Eggplant is cultivated throughout the country (Alam and Salimullah, 2021). It is one of the most significant vegetables in many tropical nations, including India, Bangladesh, Pakistan, China, Japan and Southeast Asian countries such as Indonesia, Thailand, Malaysia and the Philippines. It is also often grown in several African nations as well as in France, Italy, Spain, Bulgaria, and the United States. It is typically recognized as a poor man's crop or vegetable since it is well-liked by small-scale farmers and people with low incomes; apart from that, brinjal is referred to as the 'King of vegetables' (Tripathi *et al.*, 2023).

The delicate, tropical perennial brinjal is often grown as a tender or semi-hardy annual in temperate climates. It can grow to a height of 40 to 150 cm and also has large, coarsely lobed leaves measuring 10 to 20 cm in length and 5 to 10 cm in width. Inflorescence is typically solitary, though it can sometimes develop a cluster of 2-5 flowers. Inflorescence's solitary or clustered nature is a varietal characteristic. The flower is complete, actinomorphic, and hermaphroditic. The calyx is five-lobed, gamopetalous, with the margins of the lobes incurved (Kumar *et al.*, 2019). The corolla's throat inserts five free stamens. Anthers are conical, unattached, and exhibit apical dehiscence. The ovary is hypogenous, bicarpellary, and exhibits basal placentation. Heterostyly is a prevalent characteristic. Reports based on the length of the style have identified four distinct types of flowers. These include long-styled flowers with large ovaries, medium-styled flowers with medium-sized ovaries, pseudo-styled flowers with rudimentary ovaries and true short-styled flowers with very rudimentary ovaries. The fruit of brinjal, which is botanically classified as a berry, contains many small, tender seeds that are eatable but have a bitter taste, as it is a relative of tobacco and contains nicotinoid alkaloid. Brinjal has a high-water content (92.7%) and is also abundant in fiber (1.3%), calcium (18 mg/100 g), phosphorus (47 mg/100 g), carotene (74 mg/100 g), vitamin B (0.9 mg/100 g), and vitamin C (12 mg/100 g), while being low in calories (24 kcal) (Sarker *et al.*, 2020). It has the potential for lowering blood cholesterol. It is used in ayurvedic medicine to treat obesity, hypertension, and diabetes. In rural areas, dried brinjal plants are utilized as fuel.

India stands second in vegetable production in the world, following China. The area under vegetable cultivation in India is 11,750.76 thousand hectares, with a total production of 219,674.29 thousand metric tonnes (DA&FW, 2024). Among these, brinjal is cultivated on 683.67 thousand hectares, producing a total of 12,886.14 thousand metric tonnes. In the Punjab

region, brinjal is cultivated on 7880 hectares, yielding approximately 202.12 thousand metric tonnes (DA&FW, 2024). Insect infestations are the primary biotic challenge to India's vegetable production. Many of them not only cause direct harm but also serve as vectors for numerous viral infections. These pests cause uneven ripening by sucking nutrients out of the plants they feed on. The incidence of sucking pests causes 30-40% of the crop losses in vegetables (Haider and Rai, 2021). *Leucinodes orbonalis* is among the most damaging pests of brinjal, capable of reducing yields by 85-90% (Alam *et al.*, 2022). The brinjal crop is vulnerable to various types of insect pests capable of causing damage throughout its life cycle. The shoot and fruit borer of brinjal, scientifically known as *Leucinodes orbonalis* (Gennadius) and belonging to the Lepidoptera: Crambidae family, is a significant insect pest that causes serious damage to the crop. The BSFB causes significant damage to both the shoot (ranging from 8% to 37%) and fruits (ranging from 17% to 93%), resulting in serious impacts that make brinjal cultivation economically unsustainable (Halder *et al.*, 2022). Vegetable crops commonly utilize pesticides of various classes for crop protection due to the intense insect infestations throughout the crop season for better yield and quality (Sharma *et al.*, 2019).

The most limiting factor in maximizing the production potential of brinjal crops is an insect pest outbreak. Despite a wide range of infestation severity, different insects are prone to damaging the crop. The most important insect pests of brinjal includes *Leucinodes orbonalis* G., *Bemisia tabaci* G., *Tetranychus urticae*, *Planococcus citri*, *Aphis gossypii*, *Amrasca biguttula biguttula* (Ishida.) and *Epilachna* beetles. The pesticides are extensively utilized to overcome the challenge of insect pests in brinjal. Various groups of insecticides are used to treat brinjal at different growth stages, which increases the risk of ecological contamination. Farmers assume that, for higher production, spraying pesticides during crop production is a critical practice that must be followed. Thereby, they indiscriminately spray pesticides on crops, even while they are in the fruiting stage. Because pesticides are frequently applied to crops, especially during the fruit development stage, and due to the non-implementation of safe waiting periods, pesticide residues accumulate in fruits and vegetables.

Farmers use frequent, intensive insecticide to combat various insects such as fruit shoot borer, jassids and aphids, etc. According to informal interviews conducted with eggplant producers in the Philippines, spraying occurred 60-80 times throughout all stages of a typical fruit development period lasting at least four months (Del Prado-Lu, 2015). Similarly, in various regions of India, farmers applied approximately 26.7 L/ha of 'cocktail' pesticides, including chlorpyrifos, cypermethrin and monocrotophos, averaging 20-30 applications per crop season (Choudhary and Gaur, 2009). Hand removal of infested shoots and fruits has proven to be

beneficial and profitable; however, it is rarely used technique due to being laborious and time-consuming.

Pesticide residue is one of the major drawbacks of pesticide use and it also has the potential of causing a risk to human health as it still remains in fresh produce (Delcour *et al.*, 2015). Pesticide residues can make their way into the human body through various means, such as food, water and the environment. Pesticide residues pose a significant barrier to the worldwide trade of food products. Food processors and researchers have long been concerned with the effect of processing on pesticide residues in food products. The chemical characteristics of the pesticides, the type of food product, the step of processing and the duration of the compound's contact with the food significantly affect the amount of the residues that are eliminated during processing (Thanki *et al.*, 2012). Therefore, evaluating pesticide residues in vegetables before consumption is necessary. To ensure food safety, the ability to identify and quantify residues on fresh produce is essential. However, limited information is available on the residues of various pesticides in brinjal under Indian conditions, with particular reference to Punjab, which is essential to ensure the well-being of consumers and the ecosystem. Thus, the following objectives were taken into consideration when planning the current investigation:

Objectives:

- i. To identify the best treatment for growth, yield and quality of brinjal
- ii. To estimate the residual effect of the treatments in brinjal
- iii. To evaluate the efficacy of pesticides against shoot and fruit borer in brinjal
- iv. To study the Benefit Cost ratio of treatments

This section presents a short description of the existing scientific literature on important aspects of the recent investigation, “**Residual studies of promising pesticides in Brinjal**”. A review of the available studies on brinjal revealed that research on the crop is limited, making it necessary to include related findings from other crops to provide a comprehensive understanding of the topic.

Objectives:

- i. To identify the best treatment for growth, yield and quality of brinjal
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Impact of pesticides on growth, yield and quality of Brinjal

Sammaiah *et al.* (2011) studied the impact of several pesticides on the growth and yield characteristics of the eggplant (*Solanum melongena* L.) in the Warangal region. The investigation consisted of various treatments, viz., Endosulfan, Rogor and a combination of Rogor and Kitazin (Rogor + Kitazin), to evaluate the growth, yield and photosynthesis of brinjal. The findings suggested that the combination application of Rogor + Kitazin had a positive impact on growth characteristics including plant height, number of flowers, number of branches, as well as on yield parameters such as average fruits and fruit weight.

Dwivedi *et al.* (2014) observed the impact and eco-friendly management of *Leucinodes orbonalis*. A field experiment was performed to examine the effectiveness of six pesticides in eggplant (*Solanum melongena* L.) under the conditions of Kanpur region of Uttar Pradesh. The research included various treatments, viz., T₁: Azadirachtin, T₂: Dimethoate, T₃: Spinosad, T₄: Imidacloprid, T₅: *Bacillus thuringiensis*, T₆: Indoxacarb, T₇: Control. The findings indicated that treatment T₄: Imidacloprid (4.60) showed the highest efficacy against shoot and fruit borer followed by T₆: Indoxacarb (6.62) and T₂: Dimethoate (8.23). The maximum fruit yield of 220.61 q ha⁻¹ was observed with the application of T₄: Imidacloprid, followed by T₆: Indoxacarb (217.88 q/ha) and T₂: Dimethoate (216.22 q/ha).

Kameshwaran and Kumar (2015) examined the effectiveness of novel pesticides against *Leucinodes orbonalis* in the Karaikal region, utilizing the brinjal variety PLR2 under irrigated conditions in both the seasons. The researchers administered four consecutive rounds of foliar treatments. The minimum mean percentage of shoot damage was observed with the application of chlorantraniliprole, followed by emamectin benzoate and carbaryl combined with wettable sulphur, in comparison to control. The application of chlorantraniliprole followed by emamectin benzoate also demonstrated superiority over other treatments in reducing fruit infestation by both number and weight. In comparison to control (14.20 and 18.46 t/ha), application with chlorantraniliprole resulted in the maximum yield (27.08 t/ha and 36.10 t/ha).

Priyanka (2015) studied the effect of ethion on growth parameters of eggplant. A study was performed to observe the impact of pesticide application on brinjal in Muzaffarnagar, U.P., India. The study investigated the effects of pesticides on various morphological characteristics of eggplant. The treatments consisted of four concentrations of ethion pesticide, viz. T₀ (control), T₁ (ethion at a concentration of 0.01%), T₂ (ethion at a concentration of 0.15%), T₃ (ethion at a concentration of 0.25%), and T₄ (ethion at a concentration of 1.00%), observed at different days interval. The results revealed that T₁ (ethion at a concentration of 0.01%) significantly enhances growth parameters including length of shoot (89.20 cm), length of root (15.50 cm), plant height (104.70 cm), number of branches (6.99), number of leaves (25.25) and leaf area (38.80 cm²) at an interval of 90 days after sowing, while T₄ (ethion at a rate of 1.00%) showed the lowest growth in brinjal.

Priyanka (2016) performed a study on the influence of cypermethrin insecticides on the morphological characteristics of brinjal (*Solanum melongena* L.). The investigation examined the effects of cypermethrin pesticides at different concentrations on the morphological characteristics of brinjal in Muzaffarnagar, U.P., India. The treatments consisted of four concentrations of cypermethrin pesticide, viz. T₀ (control), T₁ (cypermethrin at a concentration of 0.01%), T₂ (cypermethrin at a concentration of 0.15%), T₃ (cypermethrin at a concentration of 0.25%), and T₄ (cypermethrin at a concentration of 1.00%), observed at different durations of 15, 30, 45, 60, 75, and 90 days. The results revealed that T₁ (cypermethrin at a rate of 0.01%) significantly enhances growth parameters such as length of shoot (90.20 cm), length of root (15.70 cm), plant height (105.90 cm), number of branches (7.00), number of leaves (25.54) and leaf area (39.43 cm²) at an interval of 90 days after sowing while T₄ (cypermethrin at a rate of 1.00%) showed the lowest growth in brinjal.

Gaikwad et al. (2017) observed the impact of pesticide persistence on the yield and biochemical parameters of eggplant. The experiment was performed in the two seasons to examine physiological effects of four treatments of pesticides (T₁: thiodacrb, T₂: spinosad, T₃: profenophos and T₄: chlorantranilliprole) sprayed on four different brinjal varieties (V₁: Malapur Local, V₂: Kalpataru, V₃: Manjula and V₄: Manjari). They observed that V₄T₃ had the best commercial yield. They concluded that low dosages of pesticides had no negative effects on any brinjal variety's growth, magnesium content, total chlorophyll content and yield.

Goswami et al. (2018) observed the impact of different insecticides on the quality, nutritional profile and total antioxidant capacity of brinjal (*var.* Muktakeshi) in South 24 Parganas, West Bengal, during the *Rabi* season. The field trial followed a Randomized Block Design with four replications, included four insecticidal treatments: Triazophos, Carbaryl, Cypermethrin and Azadirachtin, along with control. The findings suggested that, at recommended doses, most treatments had negligible impact on nutritional and antioxidant parameters compared with the control. Notably, Triazophos-treated fruits showed significant ($p < 0.05$) increases in crude protein and total soluble sugar content.

Singh et al. (2018b) investigated the effectiveness of certain insecticides and biopesticides against *Leucinodes orbonalis* in brinjal at Faizabad, Uttar Pradesh, using a randomized block design. The effectiveness of various insecticidal applications, including biopesticides, was evaluated over a two-year period, with each treatment replicated three times. He found that T₇: Eamectin benzoate treatment exhibited the lowest damage and resulted in highest fruit yield (253.12q ha⁻¹), in comparison to T₁₄: Control. In suppressing the infestation of *L. orbonalis*, T₄: NSKE was the most efficient among the biopesticide treatments.

Rakibuzzaman et al. (2019) observed the influence of botanical pesticides on the morphological attributes and yield characteristics of brinjal in Dhaka, Bangladesh. The experiment included various treatments of botanical pesticides, such as T₀: Control, T₁: Natura One, T₂: Neem Oil and T₃: Neem Oil + Natura One, along with an untreated control. The findings suggested that T₃ had lower levels of damaged shoots and fruits (0.2 and 0.2 per plant, respectively) and infested shoot and fruit percentage (11.90 and 16.90, respectively). The treatment T₃ also showed maximum plant height (85.30 cm), total branches (14.70), total number of leaves (41.00), chlorophyll content (48.50%), flower count (23.00), fruit count (13.00), fruit yield/plant (2.25 kg), total fruit yield (57.3 t ha⁻¹) and increased yield percentage

(13.47%) compared to control. The overall findings concluded that both botanical insecticides applied directly to leaves have the potential to reduce insect damage and increased yield.

Nikam and Barwant (2020) observed the effect of commonly used pesticide on the plant vigor and photosynthetic pigment brinjal (*Solanum melongena* L.). The current study examined the impact of high amount application of two widely used pesticides (Neon and Chlorpyrifos) on the growth characteristics of brinjal, mainly seedling vigour, and photosynthetic pigments. The results demonstrated that root length, shoot length, and photosynthetic pigments showed an increase at lower concentrations of pesticide application in comparison to the untreated control. Alternatively, when applied at increased levels, all growth parameters experienced a significant decrease as compared to the lower concentration of pesticide application.

Ullah et al. (2022) examined the effect of several botanical extracts and a chemical pesticide on brinjal shoot and fruit borer, as well as their influence on natural enemies. The study consists of eight treatments viz., T₁ (neem oil at a rate of 2%), T₂ (neem oil at a concentration of 5%), T₃ (eucalyptus leaf extracts at a concentration of 3%), T₄ (eucalyptus leaf extracts at a concentration of 6%), T₅ (garlic bulb extracts at a concentration of 4%), T₆ (garlic bulb extracts at a concentration of 8%), T₇ (cypermethrin 25 EC) and T₈ (control). The findings suggested that the least shoot and fruit damage was observed in T₇ (cypermethrin 25 EC) applied plots (2.03%), followed by T₂ (neem oil at a concentration of 5%). The T₈ (control) showed the highest incidence of shoot and fruit infestation, followed by T₅ (garlic bulb extracts at a concentration of 4%). He also found that T₇ (cypermethrin 25 EC) treated plots observed the highest flower count, followed by T₂ (neem oil at a concentration of 5%), while T₈ (control) showed the lowest, followed by T₅ (garlic bulb extracts at a concentration of 4%). The findings suggested that the maximum fruit yield was observed in T₇ (cypermethrin 25 EC) applied plots (3731.5 kg/ha), whereas the minimum fruit yield (753.3 kg/ha) was found in T₈ (control). The investigation concluded that botanical extracts, particularly neem oil (5%), significantly lowered shoot and fruit damage, confirming their potential application against *Leucinodes orbonalis*.

Doke et al. (2024) observed the impact of several pesticides on *Leucinodes orbonalis* of the eggplant in the Prayagraj region of Uttar Pradesh. The investigation was performed using a Randomized Block Design, including different insecticidal applications with three replications in addition to an untreated control plot. The treatments consist of different insecticides such as Novaluron at a concentration of 10% EC @ 0.5 ml/lit., Spinetoram at a concentration of 11.7% SC at rate of 0.4 g/L, Emamectin benzoate at a concentration of 5% SG @ 0.4 g/lit., Chlorantraniliprole at a concentration of 18.5 SC @ 0.5 ml/lit., Flubendiamide at a concentration of 39.35% SC at rate of 0.5 ml/L., Neem oil at a concentration of 2% @ 20 ml/lit., *Beauveria bassiana* at a concentration of 1×10^8 CFU at a rate of 2.5 g/lit. and an untreated control. The findings suggested that treatment Chlorantraniliprole recorded highest efficacy and maximum yield (241.75 q ha^{-1}) as compared to the untreated control (59.06 q/ha).

Dumra et al. (2024) conducted a relative analysis of subtoxic dosages of several pesticides on the quality characteristics of brinjal and ovipositional behaviour of whitefly. The present study investigated biochemical changes in treated brinjal leaflets and their association with oviposition tendency. The results of biochemical assays revealed that, except for the lower dosages of fenpropathrin at 30% EC and deltamethrin at 2.8% EC, all insecticidal applications decreased the levels of amino acids as well as total sugars. In addition, the application of insecticides led to a decline in total phenol concentration and a substantial modification in the crude protein content.

Maliha and Uddin (2024) evaluated the influence of botanical insecticides on morphological and yield characteristics of brinjal in Dhaka, Bangladesh, using the Charki cultivar. The investigation consisted of various treatments of neem oil at the optimum dosage of 5 ml/litre, including T₀: untreated control, T₁: one spray, T₂: two sprays, T₃: three sprays at intervals of 15 days. The results showed that treatment T₃ (three applications of neem oil at the optimum dosage of 5 ml/litre) was the most efficient treatment for the morphological and yield characteristics. The findings indicated that the treatment T₃ (three applications of neem oil at the optimum dosage of 5 ml/litre) exhibited the maximum plant height (85.30 cm), total number of leaves (41.00), total number of branches (14.70), lowest shoot damage (11.90%), highest fruits per plant (13.30), total fruit weight (2.25 kg) and total yield (57.30 t/ha). The findings indicated that treatment T₀: untreated control was the least effective treatment with minimum yield (50.50 t/ha).

Panwar *et al.* (2024) observed the effectiveness of certain botanical pesticides on *Leucinodes orbonalis* in brinjal in the Prayagraj region of Uttar Pradesh. The study consisted of seven insecticidal treatments and an untreated control. The findings suggested that the lowest levels of percent shoot and fruit damage were observed in Chlorantraniliprole at 18.5 EC (11.79 and 8.01), followed by Spinosad at 45 SC (13.52 and 10.52) and Emamectin benzoate at 5% SG (14.91 and 11.41), compared to the control with no insecticidal application (27.22 and 32.12). The highest crop production (220.95 q/ha) was obtained with the Chlorantraniliprole at 18.5 EC formulation, compared to the control with no insecticidal application (55.16 q/ha).

Sood *et al.* (2024) investigated the effectiveness of synthetic and biopesticides on the yield characteristics of brinjal in the Palampur region of Himachal Pradesh. The study consisted of various bioproducts and synthetic insecticidal treatments, including T₀ (Control), T₁ (Agniastra at 5%), T₂ (Brahmastra at 5%), T₃ (Cow urine at 10%), T₄ (Darekastra at 10%), T₅ (Jeevamrit at 10%), T₆ (Panchgavya at 10%), T₇ (Tamralassi at 5%), T₈ (Emamectin benzoate 5 SG at 0.002%), to observe their effect on the yield of brinjal. The findings concluded that T₈ (Emamectin benzoate 5 SG at 0.002%) was recorded as effective in comparison to other treatments with a maximum total fruit yield and marketable fruit yield (43.97 and 42.57 q/ha, respectively).

Other Crops

Shakir *et al.* (2016) investigated the influence of certain insecticides on growth characteristics and photosynthetic pigments in tomato. The present research examined the impact of different concentrations of various frequently used insecticides, viz., T₁: emamectin benzoate, T₂: alpha-cypermethrin, T₃: lambda-cyhalothrin, T₄: imidacloprid and T₅: untreated control, on the growth characteristics of tomato plants. The results indicated that the pesticides had a negative effect on seed germination, particularly during the early phases of contact with it. when the evaluated pesticides were administered at higher concentrations than the recommended dose, they all inhibited the development of tomatoes. However, at lower concentrations, the insecticides had a stimulating impact on growth characteristics compared to untreated control. Higher dosages resulted in a drop in pigment concentrations, whereas lower doses led to an increase.

Naha *et al.* (2020) observed the impact of insecticides on the growth characteristics of coriander. The current study examined the influence of several insecticides such as cypermethrin, chlorpyrifos and fenvalerate on the morphological characteristics of *Coriandrum sativum*. The research was carried out in the Silchar region of Assam, using randomized block design (RBD) replicated three times to observe various morphological characteristics, including germination percentage, length of shoot, biomass and moisture content of brinjal in comparison to untreated control. The results suggested that the plants showed an increase in length of shoot (11.41 ± 0.08 cm) with the application of cypermethrin @ 2.5 ml/lit., followed by fenvalerate (12.43 ± 0.2 cm), compared to the untreated control (9.12 ± 0.06 cm). Therefore, this study determines that the ideal pesticide concentration is 5.0 ± 2.5 ml/lit., which does not damage the growth and yield of coriander.

Residual studies of insecticides in brinjal

Iqbal *et al.* (2007) performed a field trial to quantify the residues of various synthetic pesticides in brinjal by using High Performance Thin Layer Chromatography technique. The treatments consisted of different insecticides, including T₀ (Chlorpyrifos), T₁ (Dichlorvos), T₂ (Carbofuran), T₃ (Acephate) and T₄ (Imidacloprid). Data were gathered at 0, 3, and 7 days after the application of these treatments, which were given directly to the brinjal crop. The samples were cleaned with activated charcoal after being treated with the organic solvent ethyl acetate. Except for Imidacloprid, all the samples were confirmed to contain traces of pesticides. On the 0th day (2 hrs after pesticide application), the deposit was observed to be the highest, followed by the 3rd day, which showed a smaller quantity of deposits. By the 7th day, the quantity of deposits in the fruit samples of brinjal was found to be minimal. As a result, after three days, the brinjal was considered safe for the public consumption without causing any risk to health.

Bhushan *et al.* (2014) examined insecticides used for brinjal crops to recommend maximum residue limits and pre-harvest intervals (PHIs) for food safety. The researchers applied 500 g ai ha⁻¹ of triazophos twice and evaluated its dissipation and initial residues. The fruit samples of brinjal were analyzed using the validated QuEChERS technique, which included GC-ECD, GC-TSD, and GC-MS/MS. The findings concluded that the researchers found initial residues of 1.108 mg/kg, which decreased to 0.666 mg/kg after 1 day of spraying. In 7 days, Triazophos deposits were below detectable levels of 0.05 mg/kg, with an estimated half-life of 1.14 days. For food safety, a pre-harvest interval of one day was advised at a MRL of 3 mg kg⁻¹.

Chowdhury *et al.* (2014) analyzed pesticide residues in vegetables grown in the Gazipur region of Bangladesh. The investigation utilized the HPLC method equipped with a photodiode array (PDA) detector to examine specific organochlorines, organophosphorus compounds, carbamates and pyrethroid insecticides in ten vegetable samples (VS). The findings indicated that no vegetable sample was affected by organochlorine insecticides. The researchers detected ethion residue in the Vegetable sample-5 sample (lady's finger) at amount of 1.80 mg kg⁻¹. Vegetable sample-1 (Brinjal) and Vegetable sample-5 (Lady's finger) exhibited contamination with fenitrothion traces at amount of 0.166 and 0.170 mg kg⁻¹, respectively.

Rana *et al.* (2016) investigated the dissipation behaviour of triazophos on eggplant and tomato fruits grown in sandy loam soil under the conditions of middle Gujarat. In brinjal, residues declined from 1.099 mg/g to 0.639 mg/g within one day and further to 0.078 mg/g by the 10th day after the second spray, corresponding to 41.9-93.0% dissipation. The half-life was 2.9 days in brinjal and 5.39 days in tomato.

Patil *et al.* (2018) examined the dissipation pattern of insecticides on brinjal crops. The experiment consisted of the application of triazophos at 500 and 1000 g a.i. ha⁻¹ at a 10-day interval. The results indicated that triazophos residue levels on brinjal decreased over time. At optimal rate, the initial residue of 0.90 declined to 0.08 mg/kg on 7th day after spraying and fell below detectable limits by the 10th day. At the higher rate, the residues decreased from 1.95 to 0.06 mg/kg on the 10th day of spraying, respectively. The calculated half-life values were 2.10 and 2.04 days for the prescribed and doubled the prescribed dosage.

Ahmed *et al.* (2021) conducted an investigation to quantify the residues of synthetic insecticides in eggplant. They applied two insecticidal treatments, cypermethrin and chlorpyrifos, at the prescribed dosages of 1 ml/litre and 3 ml/litre, respectively, to the brinjal field. The findings suggested that the cypermethrin residues in brinjal initially measured 0.508 mg/kg, remaining above the European Union's maximum residue limit (0.5 mg/kg) for the first three days post-application. Levels declined to 0.098-0.012 mg/kg between the fourth and seventh day, staying within permissible limits thereafter. Chlorpyrifos, with an initial deposit of 0.029 mg/kg, exceeded the EU limit for up to seven days, with no detectable residues on the eighth day. Based on these results, the minimum safe harvest intervals were determined to be four days for cypermethrin and eight days for chlorpyrifos.

Singh *et al.* (2021b) investigated the dissipation dynamics of spiromesifen on brinjal at the prescribed amount of 96 g active ingredient per hectare (PD) and twice prescribed amount of 192 g active ingredient per hectare (2PD) using UHPLC-MS/MS. The findings indicated that spiromesifen remained detectable for up to three days at PD and five days at 2PD. The half-life kinetics (DT_{50}) was 3.64 days at PD and 4.10 days at 2PD, respectively. Nevertheless, spiromesifen residues detected in soil on the 0th (after 2 hours) day and on the tenth day were found to be below the limit of quantification (BQL).

Takla *et al.* (2021) conducted an investigation to estimate the residues of botanical pesticides in brinjal. The study was conducted in Qalubia Governate and involved the application of neem oil at the dosage of 1 litre per 100 litres of water. Neem oil residues were quantified using Gas Chromatography-Mass Spectrometer and samples were collected at different intervals. The findings concluded that residues were detected in eggplant samples collected from the field 12 and 24 days after spraying. However, no residues of toxic substances or compounds were present in the fruit samples.

Kaur *et al.* (2022b) evaluated the residues of fenazaquin in brinjal fruits. The rate of dissipation and persistence of fenazaquin at a concentration of 10% were estimated using high-performance liquid chromatography, and the findings were validated using liquid chromatography-mass spectrometry. During the first experimental year, fenazaquin residues on brinjal fruits measured 0.046, 0.098, and 0.174 mg/kg at application rates of 25, 50, and 125 g active ingredient per hectare, respectively. In the second year, initial deposits were obtained as 0.048, 0.102, and 0.170 mg/kg for the same dosages. The dissipation process demonstrated half-life kinetics ranging from 0.65 to 1.78 days at dosages of 25, 50 and 125 g active ingredient per hectare. The insecticide residues fell below quantification limit (<0.01 mg/kg) on third, fifth and seventh days at different doses of insecticide during the first and second years of experiment. The study recommends a waiting period of four days to reduce the harm before consuming fruits of brinjal.

Sangamesh *et al.* (2023) evaluated the quantification of synthetic insecticide in brinjal fruits. Brinjal are being treated with various formulations of imidacloprid, resulting in a significant accumulation of residues in the fruits. In this investigation, the researchers have confirmed the effectiveness of a method for rapidly detecting imidacloprid residual traces using LC-MS/MS. This study demonstrated that at application rates of 20 and 40 g active ingredient per hectare, initial amounts of imidacloprid (17.80% SL) in eggplant were 0.685 and 1.399 mg/kg. Half-

life of imidacloprid in eggplant was 1.69 days and 2.30 days at different application rates. The treatment with imidacloprid (17.80% SL) resulted in rapid initial dissipation and remained effective for a duration of 15-25 days.

Sahoo and Dube (2023) examined the dissipation pattern and risk evaluation of synthetic insecticides in brinjal and tomato in the Pusa region of Bihar. The investigation consisted of three applications of thiamethoxam at two different dosages, namely 50 and 100 g active ingredient per hectare and samples of brinjal and tomato were taken individually from both treated and untreated control fields at different durations. The modified QuEChERS technology processed the brinjal and tomato samples, followed by UHPLC analysis. The results revealed that the mean initial deposits of thiamethoxam in brinjal after the third application at both rates were 0.42 and 0.78 mg kg⁻¹. In tomato, initial deposit was 0.47 and 0.85 mg/kg. At the dosage of 50, amount of thiamethoxam residue dissipated below the detection limit (0.05 mg/kg) on the seventh day for brinjal and fifth day for tomato. The investigation recommended a waiting period of 48 hours before consuming the fruits of brinjal and tomatoes treated with the recommended dosage of thiamethoxam.

Abdelfatah et al. (2024) examined the determination of various pesticide residues, as well as their biochemical effects on brinjal, using QuEChERS and HPLC (DAD) analytical methods under greenhouse conditions. The investigation consisted of three synthetic pesticides: pymetrozine, acetamiprid and pyriproxyfen. The QuEChERS method findings indicated that the recoveries ranged from 86 percent to 105 percent, with a relative standard deviation ranging from 1.52 percent to 10.26 percent. The HPLC method resulted in the half-lives of pymetrozine, acetamiprid and pyriproxyfen being 1.15, 1.62 and 4.64 days, respectively. The PHI (pre-harvest interval) for the three pesticides was three, five and seven days, respectively. The biochemical analysis showed that the insecticides used in the experiment significantly decreased the amounts of nitrogen, phosphorus, potassium, chlorophyll a and chlorophyll b in the eggplant leaves compared to the untreated control. Pymetrozine and acetamiprid showed a considerable decrease in the levels of carbohydrates, vitamin C, TSS and total soluble sugars in the fruits of brinjal compared to the untreated control. However, there was no substantial decline in the levels of total nitrogen, crude protein, or iron content. Pyriproxyfen exhibited a significant reduction in all parameters, except for the percentage of acidity, and showed the most significant reduction in comparison to the untreated control. The findings suggested that brinjal can be safely harvested 3-7 days after the application of tested insecticides.

Gandabhai et al. (2024) evaluated the effectiveness of several pesticides in controlling pests and the presence of residues at harvest in brinjal fruits. The study examined the efficacy of various insecticidal treatments, including T₁ (thiamethoxam 25 WG at a concentration of 0.01%), T₂ (thiacloprid 21.7 SC at a concentration of 0.0032%), T₃ (buprofezin 25 EC at a concentration of 0.05%), T₄ (spinosad 48 SC at a concentration of 0.017%), T₅ (chlorantraniliprole 18.5 SC at a concentration of 0.007%) and T₆ (fenpropathrin 30 EC at a concentration of 0.01%) and T₇ (untreated control). The results showed that the best-performing treatment against *Leucinodes orbonalis* was T₅ (chlorantraniliprole), followed by T₄ (spinosad), compared to the other treatments. The initial residues were 10.382, 5.602, 5.097, 4.886, 3.984 and 3.332 mg kg⁻¹ for buprofezin, fenpropathrin, chlorantraniliprole, thiamethoxam, spinosad and thiacloprid. On the fourth day after application, the residues were observed as 0.539, 0.154, 0.127, 0.099, 0.076 mg kg⁻¹ for fenpropathrin, chlorantraniliprole, thiacloprid, thiamethoxam, buprofezin, whereas spinosad was found below detection limit on the fourth day. The dissipation rates were 100%, 99.26%, 97.97%, 96.97%, 96.18%, 90.37% for spinosad, buprofezin, thiamethoxam, chlorantraniliprole, thiacloprid, fenpropathrin on the fourth day after application.

Other crops

Singh et al. (2015) examined the degradation pattern of synthetic pesticide triazophos in capsicum. The investigation involved the application of triazophos 40 EC at the prescribed dosage of 500 g active ingredient per hectare and twice the prescribed dosage of 1000 g active ingredient per hectare. The findings indicated that the mean initial residues in capsicum were 3.61 mg/kg at the lower dosage and 6.26 mg/kg at the higher dosage. On the third day of application, the residues showed a degradation rate of around 62.33% at prescribed dosage and 65.02% at twice the prescribed dosage. At both dosages, approximately 90% of triazophos residues disappeared on the seventh day after application. The findings concluded that triazophos-treated capsicum is safe for consumption after the waiting period of seven days at both dosages.

Pandit *et al.* (2016) reported the degradation behaviour of the synthetic insecticide in okra. The experiment consisted of the application of imidacloprid insecticide at the prescribed dosage of 24.5 g active ingredient per hectare, twice the prescribed dosage of 49.0 g active ingredient per hectare, along with control. The findings demonstrated that the degradation rate ranged from 38% to 48% in leaves and 31% to 44% in brinjal fruits one day after spraying at the prescribed dosage and twice the prescribed dosage. The residues were not detected 15 to 20 days after application in leaves and seven days after application in okra fruits at both doses. The half-lives of the insecticidal treatment ranged from 2.66 to 3.28 days in leaves and 1.76 to 2.07 days in okra fruits.

Akoijam *et al.* (2023) examined the degradation behaviour of various pesticides in cabbage. The investigation involved different pesticides, viz., chlorantraniliprole, fipronil and deltamethrin, which were applied two times at the optimum doses with an interval of seven days. The prescribed dosages were 12.5 g active ingredient per hectare for deltamethrin, 50 g active ingredient per hectare for fipronil and 30 g active ingredient per hectare for chlorantraniliprole. The presence of fipronil was detected for a duration of seven days, with a deposit of 0.01 mg/kg. Nevertheless, the chlorantraniliprole and deltamethrin deposits were detected for up to five days, with concentrations of 0.11 and 0.03 mg/kg. The half-lives were obtained as 1.81, 1.07 and 1.42 days for Chlorantraniliprole, fipronil and deltamethrin, respectively.

Seasonal incidence of shoot and fruit borer

Maru and Kumar (2018) examined the infestation of BSFB in relation to meteorological factors in the Allahabad region. The results showed that *Leucinodes orbonalis* first appeared on the shoot during the 40th standard meteorological week and peaked during the 43rd standard meteorological week. On the other hand, *Leucinodes orbonalis* first appeared on the fruit during the 42nd standard meteorological week and peaked during the 45th standard meteorological week. *Leucinodes orbonalis* resulted in considerable positive correlation between the shoot infestation and maximum temperature ($r = 0.591$), as well as the number of sunshine hours ($r = 0.657$). The shoot infestation showed a negative correlation with the evening RH ($r = -0.610$). Fruit infestation by *Leucinodes orbonalis* showed significant positive correlations with maximum temperature ($r = 0.488$ number; 0.493 weight) and sunshine duration ($r = 0.641$ number; 0.645 weight) and negative correlations with evening relative humidity ($r = -0.650$ number; -0.655 weight).

Kolhe et al. (2020) examined the occurrence of *Leucinodes orbonalis* on brinjal in the Trans Yamuna region of Allahabad. The findings indicated that the occurrence of borers gradually increased and peaked (33.5%) of the larval population during the 3rd week of October. Subsequently, a decrease in population was observed, possibly due to unfavourable weather conditions. The percentage of infestation on shoots was observed (4.6%) during the 39th standard week (third week of September). The population of borers gradually increased and peaked (40.5%) of the larval count during the 2nd week of November. The decline in optimal meteorological conditions led to a subsequent decrease in trend, as the maximum and minimum temperatures decreased. The maximum temperature encouraged an increase in shoot and fruit borers, whereas a decrease in both maximum and minimum temperatures resulted in a reduction in their population.

Abirami et al. (2021) investigated the phenological occurrence of *Leucinodes orbonalis* and its correlation with meteorological parameters in the Tikamgarh region of Madhya Pradesh. The findings indicated that *Leucinodes orbonalis* first appeared in the 2nd week of October with 4.0% shoot damage and peaked in the 2nd week of November with 20.0% shoot damage. The 1st week of December recorded the peak fruit infestation (50.0%). Analysis of correlations revealed that the occurrence of BSFB was strongly and negatively associated with both minimum temperature and rainfall, with correlation coefficients of -0.77 and -0.56, respectively.

Salve et al. (2021) examined the occurrence of *Leucinodes orbonalis* in brinjal under Parbhani conditions. The findings suggested that the initial occurrence of BSFB was recorded at 9.15% for shoots and 42.10% for fruits during the 32nd and 39th Standard Meteorological Weeks (SMW), respectively. Shoot damage was strongly correlated with high evening relative humidity. Shoot and fruit damage were highly significant and negatively associated with rainfall, temperature and relative humidity but positively associated with evaporation and sunshine hours.

Vijayalakshmi et al. (2021) observed the influence of weather parameters on seasonal occurrence of BSFB in the Aruppukottai region of Tamil Nadu. The occurrence of *Leucinodes orbonalis* on shoots first appeared in the final week of July and reached its highest level (32.20%) in the 2nd week of October. The findings indicated that damage of fruits by BSFB was first recorded in the 2nd week of August and peaked at 40.86% in the 3rd week of October. Maximum temperature exhibited a positive correlation, whereas RH and rainfall exhibited a

negative correlation with the *Leucinodes orbonalis* damage. The statistically significant values indicated a relationship between prevailing meteorological conditions and the appearance of the borer population. The population increased and ultimately peaked at 40.86%, followed by a decline, which may be due to unfavourable meteorological conditions.

Kumari et al. (2022) examined the correlation between weather parameters and the phenological occurrence of *Leucinodes orbonalis* in eggplant under Rajasthan conditions. The results revealed that the shoot infestation (1.65%) was first observed in the third week of July and peaked at 29.10% in the last week of August. Fruit infestation, based on number and weight (3.20% and 10.80%), was first observed during the 1st week of October and peaked at 61.10% and 58.10% in the last week of October. The results demonstrated that *Leucinodes orbonalis* damage had a substantial positive correlation with maximum temperature.

Nayak et al. (2023) observed impact of meteorological parameters on the occurrence of *Leucinodes orbonalis* in eggplant in the Jobner region of Rajasthan. The investigation revealed that BSFB infestation on shoots reached its highest point in the 2nd week of September, while fruit damage peaked in the 3rd week of October. Over two years, shoot damage showed a strong positive correlation with maximum temperature. In year one, shoot and fruit borer infestation had a weak positive correlation with rainfall, whereas year two showed a strong negative correlation. The correlation of fruit infestation was obtained positive with maximum temperature both years and negative with average relative humidity, non-significantly in year one and significantly negative in year two.

Panda et al. (2023) examined the impact of meteorological factors on the phenological occurrence of *Leucinodes orbonalis* in eggplant in the Bhubaneswar region of Odisha. The number of BSFB was monitored from transplanting to harvest of the crop. Five random plants, excluding border plants, were picked and tagged for observational recording. To ascertain the percentage of afflicted shoots, brinjal plants exhibiting symptoms such as drooping, withering, and desiccating fragile shoots were recorded. The researchers correlated the population with the weather conditions and recorded the incidence of bore holes in fruits to estimate the percentage of fruit infections. The findings indicated that the peak occurrence of *Leucinodes orbonalis* was recorded during the 34th SMW (22-28 August), 5th Standard Meteorological Week (30 January-5 February), and 18th Standard Meteorological Week (1-7 May), with shoot infestation (38.44%, 11.10%, and 57.99%) respectively. The peak fruit infestation (47.55%, 27.07%, and 63.84%) was recorded during the 39th Standard Meteorological Week (26

September–2 October), 9th Standard Meteorological Week (27 February–5 March), and 18th Standard Meteorological Week (1–8 May), respectively. The BSFB exhibits a significant correlation with relative humidity. The findings indicated that occurrence of *Leucinodes orbonalis* varies in response to changes in temperature, rainfall and RH.

Singh *et al.* (2023a) investigated the impact of meteorological conditions on the phenological occurrence of *Leucinodes orbonalis* in central Punjab, India. The highest level of *Leucinodes orbonalis* infestation was observed during the 37th Standard Meteorological Week (SMW) of 2017 (38.70%), whereas the lowest level (28.50%) occurred in the 36th SMW of 2016. Correlation analysis revealed a significant positive association between BSFB damage and both maximum and minimum temperatures, along with sunshine duration. Meanwhile, evening RH and precipitation displayed a weak positive correlation with BSFB damage. In contrast, morning RH demonstrated a significantly negative correlation with pest damage.

Effectiveness of insecticides against *Leucinodes orbonalis* in brinjal

Sarnabati and Ray (2017) examined the impact of various synthetic pesticides on *Leucinodes orbonalis* in Manipur. The researchers evaluated different pesticides, including three organophosphates (acephate, dichlorvos, and fipronil), two neonicotinoids (imidacloprid and thiamethoxam), one synthetic pyrethroid (alphamethrin), one anthranilic diamide (coragen), a mixture of an organophosphate and pyrethroids (profenophos + cypermethrin) and a control. The findings showed that the lowest level of shoot damage was observed in coragen, followed by imidacloprid, compared to the control. The lowest fruit damage (7.27%) was observed in coragen, followed by imidacloprid (7.96%) in comparison to the untreated control.

Patel *et al.* (2018) examined the influence of newly developed pesticides on *Leucinodes orbonalis* under Kanpur conditions. The investigation included various treatments applied at optimum dosages: imidacloprid, indoxacarb, profenophos, spinosad, thiamethoxam, acephate and a control. The findings indicated that imidacloprid (10.31% and 8.72%), followed by indoxacarb (11.87% and 9.24%), recorded the lowest shoot and fruit damage in comparison to the untreated control (19.48% and 27.99%) in brinjal.

Reshma and Behera (2018) examined the impact of six pesticides on *Leucinodes orbonalis* in the Bhubaneswar region during *Kharif* and summer seasons. The insecticides used were rynaxypyr, spinosad, emamectin benzoate, flubendiamide, thiamethoxam and cartap hydrochloride. The findings indicated that flubendiamide, with the minimum shoot infestation (0.91% and 2.22%) after the third spray proved, highly efficient against *Leucinodes orbonalis*, compared to the control, which had the maximum shoot infestation (9.17% and 14.73%) during *Kharif* and summer seasons in brinjal.

Sahu et al. (2018) observed the effectiveness of different pesticides, including thiodicarb at three different application rates (0.28, 0.47 and 0.75 kg active ingredient per hectare), cartap hydrochloride (0.5 kg active ingredient per hectare), diflubenzuron (0.1 kg active ingredient per hectare), triazophos (0.5 kg active ingredient per hectare), carbofuran (1.0 kg active ingredient per hectare) and fipronil (0.1 kg active ingredient per hectare) on *Leucinodes orbonalis* in the Allahabad region of Uttar Pradesh. The findings suggested that thiodicarb exhibited superior efficacy when applied at its highest dosage of 0.75 kg active ingredient per hectare, resulting in the lower levels of shoot damage (1.41%) and fruit damage (20.86%). At this dosage, thiodicarb also yielded the highest fruit production of 48.45 q/ha in brinjal.

Chandan et al. (2019) examined the impact of seven newly introduced insecticides on *Leucinodes orbonalis* in the Bilaspur region of Chhattisgarh. Flubendiamide exhibited the lowest fruit damage (29.53%), followed by cyantraniliprole. Highest fruit damage (46.33%) was found in the emamectin benzoate treatment, making it the least effective. The findings concluded that flubendiamide was the most efficient treatment, resulting in the lowest fruit infestation and highest marketable yield (1,805.82 q/hectare).

Narayan et al. (2019) examined the performance of newly developed pesticides in controlling *Leucinodes orbonalis* in brinjal at Krishi Vidyapeeth, Parbhani, India. The findings suggested that chlorantraniliprole resulted in the lowest shoot damage, followed by cyantraniliprole, compared to the control. The findings suggested that chlorantraniliprole also had the lowest percentage of fruit infestation, based on number and weight basis, followed by cyantraniliprole. Additionally, the chlorantraniliprole treatment exhibited the highest marketable yield, followed by the cyantraniliprole treatments, in comparison to control.

Rahman et al. (2019) examined impact of novel pesticides on *Leucinodes orbonalis* under Bangladesh conditions. The findings indicated that the maximum shoot infestation (27.40%) and fruit infestation (55.93%) were observed in the control. However, the minimum shoot infestation (6.71%) and fruit damage (11.58%) were observed in the Pine 6 WG treatment. The findings showed that various pesticide treatments effectively reduced *Leucinodes orbonalis* damage and improved the marketable fruit yield.

Vinayaka et al. (2019) examined the effectiveness of seven insecticides against *Leucinodes orbonalis* in brinjal under Haryana conditions. The results concluded that Emamectin benzoate and Chlorantraniliprole recorded the lowest levels of shoot and fruit damage compared to other treatments. The other insecticidal treatments, including Azadirachtin and *Bacillus thuringiensis*, had the highest levels of shoot and fruit damage, whereas Spinosad, Lambda-cyhalothrin and Pyriproxyfen + Fenpropathrin showed a moderate level of effectiveness.

Biswas et al. (2020) examined the effectiveness of various insecticides against *Leucinodes orbonalis* in the Bhubaneswar region during the *Rabi* and summer seasons. The experiment included various insecticidal treatments applied at optimum dosages: rynaxypyr, spinosad, indoxacarb, abamectin, emamectin benzoate and flubendiamide. The findings concluded that the lowest levels of shoot (1.86 and 1.55%) and fruit infestation (14.19 and 10.88%) were recorded in flubendiamide, whereas untreated control recorded highest levels of shoot (15.67 and 11.71%) and fruit infestation (52.47 and 42.52%) in brinjal.

Paneru et al. (2020) examined the effectiveness of commercial pesticides in controlling *Leucinodes orbonalis* in the Dhading region of Nepal. The experiment included five treatments at optimal dosages: T₁: Spinosad; T₂: Chlorantraniliprole; T₃: Cypermethrin; T₄: Neem oil and T₅: Control. The findings revealed that spinosad resulted in the lowest shoot (0.741%) and fruit damage (4.1%), followed by chlorantraniliprole, cypermethrin, and neem oil. The research concluded that spinosad was the most efficient insecticide for controlling BSFB under field conditions.

Sakharam et al. (2020) investigated the impact of synthetic insecticides and botanicals on *Leucinodes orbonalis* during the *kharif* season at SHUATS, Uttar Pradesh. The investigation consisted of various treatments, viz., spinosad 45% SC, carbosulfan 25% EC, cypermethrin 25% EC, chlorpyrifos 20% EC, imidacloprid 17.8% SL and the botanicals neem oil 2% and NSKE at 5% for controlling BSFB. The study revealed that spinosad had the highest

effectiveness, with shoot damage at 10.98% and fruit damage at 8.61%, followed by carbosulfan and imidacloprid, compared to the untreated control.

Jagarlamudi and Kumar (2021) investigated the effectiveness of various insecticides with bio-pesticides on *Leucinodes orbonalis* under Prayagraj conditions during the *Kharif* season. The investigation comprised various treatments, including an untreated control, imidacloprid 17.8 SL, *Bacillus thuringiensis* var. *kurstaki*, cypermethrin 25 EC, indoxacarb 14.5 SC, azadirachtin 0.03% SC, flubendiamide 20 WG and cartap hydrochloride 50 SP. The findings suggested that flubendiamide (7.47%) resulted in the lowest level of shoot damage, followed by cypermethrin (8.22%) and indoxacarb (9.31%), compared to the untreated control (22.24%).

Khanal et al. (2021) examined the influence of biopesticides, microbials and synthetic pesticides on *Leucinodes orbonalis* in brinjal under Nepal conditions. The experiment evaluated various treatments, viz., jholmal, *Beauveria bassiana*, abamectin at a concentration of 5 %, *Bacillus thuringiensis* var. *kurstaki*, emamectin benzoate, azadirachtin (1500 ppm) and an untreated control. The findings suggested that the lowest fruit infestation (57.97% and 34.52%) was recorded fourteen days after 1st and 2nd applications of emamectin benzoate treatment. The findings also indicated that the emamectin benzoate treatment resulted in the maximum marketable yield (7.19 and 7.13 t ha⁻¹) in comparison to the untreated control.

Singh et al. (2021a) examined various pesticides against *Leucinodes orbonalis* in eggplant at Banda, Uttar Pradesh. The investigation included various pesticides applied at optimal dosages: T₁ (chlorantraniliprole), T₂ (emamectin benzoate), T₃ (spinosad), T₄ (chlorpyrifos), T₅ (cypermethrin), T₆ (rotational strategy), T₇ (mixture strategy: chlorpyrifos + cypermethrin) and T₈ (Control). The findings indicated that the spinosad treatment recorded the lowest levels of shoot infestation (2.03% and 2.00%) and fruit infestation (12.66% and 10.62%), with the maximum yield (25.39 t/ha and 26.99 t/ha), followed by chlorantraniliprole and emamectin benzoate, respectively.

Verma et al. (2021) examined the performance of synthetic pesticides and botanicals on *Leucinodes orbonalis* in brinjal in the Faizabad region of Uttar Pradesh during the *Kharif* season. The experiment involved ten treatments applied at optimal dosages: T₁ (Emamectin benzoate), T₂ (NSKE), T₃ (Spinosad), T₄ (Onion extract), T₅ (Karanja seed extract), T₆ (Garlic extract), T₇ (Cannabis leaf extract), T₈ (Tobacco extract), T₉ (Wood ash) and T₁₀ (Control). The findings indicated that the T₁ (Emamectin benzoate) treatment caused the least damage

and highest fruit yield (313.85 q/ha), followed by T₃ (Spinosad) and T₂ (NSKE) with yields of 300.58 and 284.33 q/ha, respectively, compared to the T₉ (Control) treatment.

Kumari and Shrivastava (2022) investigated the impact of novel pesticides on *Leucinodes orbonalis* in brinjal in the Gwalior region of Madhya Pradesh. The research included different insecticidal treatments applied at optimal dosages: T₁ (Chlorantraniliprole), T₂ (Indoxacarb), T₃ (Flubendiamide), T₄ (Carbosulfan), T₅ (Thiacloprid), T₆ (Spinosad) and T₇ (Emamectin benzoate) and T₈ (Control). The findings indicated that the T₆ (Spinosad) treatment showed the highest efficacy among all treatments, with the minimum shoot infestation (3.42%). The T₆ (Spinosad) treatment, followed by the T₂ (Indoxacarb) treatment, resulted in the lowest levels of fruit damage (3.11% and 3.28%). The T₃ (Flubendiamide) treatment resulted in the highest fruit damage (4.99%).

Reddy and Kumar (2022) examined the influence of various pesticides on *Leucinodes orbonalis* in brinjal under Allahabad conditions during the *kharif* season. The research utilized seven insecticidal treatments: chlorantraniliprole, flubendiamide, emamectin benzoate, spinosad, cypermethrin, lambda cyhalothrin and azadirachtin. The findings indicated that the chlorantraniliprole treatment resulted in the lowest levels of shoot damage (7.87%), followed by the flubendiamide treatment (9.03%) against *Leucinodes orbonalis* in brinjal. The treatments using spinosad and cypermethrin exhibited moderate efficacy, with percent shoot infestation 12.83% and 15.00%, respectively, in comparison to the untreated control.

Abirami et al. (2023) investigated the impact of botanical pesticides on *Leucinodes orbonalis* in brinjal in the Tikamgarh region of Madhya Pradesh during the *Kharif* season. The research consisted of nine treatments applied at optimal dosages: T₁ (Neem oil at 1%), T₂ (Karanja oil at 1%), T₃ (*Beauveria bassiana*), T₄ (*Metarhizium anisopliae*), T₅ (Neem oil-Bb-Neem oil), T₆ (Neem oil-Ma-Neem oil), T₇ (Karanja oil-Bb-Karanja oil), T₈ (Karanja oil-Ma-Karanja oil) and T₉ (Control). The findings suggested that the application of treatment T₁ (Neem oil at 1%) showed the maximum efficacy in managing the population of BSFB, as indicated by the lowest shoot and fruit damage (5.80% and 6.65%), respectively.

Chowdary and Tayde (2023) investigated the impact of certain biopesticides and chemicals on *Leucinodes orbonalis* in the Allahabad region. The investigation involved a total of two sprays with eight treatments. The treatments included various insecticides and botanicals applied at optimal dosages: emamectin benzoate, indoxacarb, chlorpyrifos, chlorantraniliprole, neem oil, *Metarhizium anisopliae* and *Beauveria bassiana*, which were sprayed twice at 15-

day intervals. The findings indicated that insecticidal and botanical treatments exhibited greater effectiveness in comparison to the untreated control in decreasing the occurrence of *Leucinodes orbonalis* on the 3rd, 7th and 14th days after application. The findings also indicated that the chlorantraniliprole treatment resulted in reduced infestation (8.26%) in shoots and (7.69%) in fruits.

Kumar et al. (2024) performed a comparative study to examine the influence of specific biopesticides and synthetic insecticides on *Leucinodes orbonalis* in brinjal in the Prayagraj region. The present investigation evaluated various treatments applied at optimal dosages: Neem Oil, Spinosad, Neem Oil 2% combined with Spinosad, Flubendiamide, NSKE 3%, Neem Oil 2% combined with Flubendiamide, Indoxacarb and a control plot with water spray. The findings indicated that T₃: Neem Oil 2% + Spinosad 45% SC had the lowest percentage of shoot and fruit infestation (12.09%, 7.09%), followed by T₆: Neem Oil 2% + Flubendiamide 20 WG (13.93%, 9.50%), T₂: Spinosad 45% SC (15.23%, 10.98%), T₄: Flubendiamide 20 WG (16.26%, 12.39%), T₇: Indoxacarb 14.5% SC (16.96%, 13.46%), T₁: Neem oil 2% (17.86%, 14.45%) and T₅: NSKE 3% (20.38%, 17.23%). The T₈: Control treatment resulted in the increased levels of shoot and fruit damage (28.37%, 32.60%).

Mahala and Yadav (2024) examined the impact of certain synthetic and botanical pesticides on *Leucinodes orbonalis* in brinjal under Allahabad conditions. It included different treatments applied at optimum dosages: T₁ (Neem oil), T₂ (*Metarhizium anisopliae*), T₃ (*Bacillus thuringiensis* var. *kurstaki*), T₄ (Spinosad), T₅ (Emamectin benzoate), T₆ (Chlorpyrifos), T₇ (Chlorantraniliprole) and T₈ (Control). The findings revealed that the pest population prior to the application of the spray exhibited a distribution that was not statistically significant. After the application of treatments, the results showed that T₅ (Emamectin benzoate) was highly effective against *Leucinodes orbonalis*. Its effectiveness was similar to that of T₇ (Chlorantraniliprole) on the 3rd, 7th and 14th days after spraying.

Tayyab et al. (2024) examined the influence of several botanical pesticides on *Leucinodes orbonalis* in brinjal under Pakistan conditions. The experiment consisted of different treatments applied at optimal dosages: T₁ (neem), T₂ (eucalyptus), T₃ (Karanja), T₄ (mahogany oil) and T₅ (control). The findings indicated that all pesticidal treatments effectively reduced shoot and fruit infestation after the first and second applications compared to the control. Neem oil recorded the lowest shoot infestation (12.5% and 9.8%) and fruit infestation (22.2% and 12.4%), while the untreated control showed the highest damage (shoot: 50.1% and 32.7%; fruit:

68.4% and 49.2%). The results concluded that all botanical insecticides were strongly recommended, particularly neem oil, which was proven to be the most effective in combating *Leucinodes orbonalis* in brinjal.

Benefit-cost ratio of insecticides and botanicals on brinjal

Sureshsing and Tayde (2017) investigated the effectiveness of various biorational pesticides for controlling the attack of *Leucinodes orbonalis* in eggplant. The research was performed at SHUATS in the Allahabad region during the *Kharif* season, which involved the evaluation of eight treatments at optimum doses against *Leucinodes orbonalis*, specifically Cypermethrin, Spinosad, Neem oil, Pongamia oil, NSKE, garlic bulb extract, Neem leaf extract and an untreated control. The results indicated that Spinosad (6.87), followed by Cypermethrin (8.57) and Neem oil (9.27), had the lowest shoot damage. The maximum production (195.22 q ha⁻¹) and B:C ratio (1:7.06) was observed in the Spinosad treatment.

Das et al. (2018) evaluated impact of several synthetic pesticides on *Leucinodes orbonalis* to increase the yield characteristics and benefit-cost ratio of eggplant in the Bihar region. The experiment consisted of different treatments applied at optimum doses: T₁ (Dimethoate), T₂ (Triazophos + Deltamethrin), T₃ (Emamectin Benzoate) and T₄ (Spinosad). The findings indicated that the application of insecticidal treatments resulted in lower levels of shoot and fruit infestations. Various treatments for managing *Leucinodes orbonalis* significantly impacted the profitability of brinjal. The plot treated with spinosad exhibited the highest benefit-to-cost ratio (4.01 and 4.06), compared to the control (2.52 and 2.88) in the years 2015-16 and 2016-17, respectively.

Shridhara et al. (2019) evaluated the newly developed pesticides in controlling the attack of *Leucinodes orbonalis* in the Raichur region. The study concluded that treatment with emamectin benzoate exhibited maximum yield of 25.90 t/ha, followed by flubendiamide with a total production of 23.70 t/ha and chlorantraniliprole with a production of 21.80 t/ha, compared to the control (10.40 t/ha). The treatment with emamectin benzoate exhibited the highest benefit cost ratio of 1:3.17, followed by flubendiamide, with a ratio of 1:2.96.

Machhindra et al. (2022) evaluated the impact of specific insecticides and botanicals on *Leucinodes orbonalis* in the Maharashtra region. The results revealed that Spinosad was the most efficient treatment, with 8.81% shoot infestation, 9.29% fruit infestation and a B:C ratio of 1:7.20, followed by Imidacloprid 17.80 SL, which had 10.95% shoot infestation, 11.14% fruit infestation and B:C ratio of 1:5.84. Emamectin benzoate 5 SG had a shoot infestation of 12.27%, fruit infestation of 12.67% and b:c ratio of 1:5.38. Karanja oil 2% had a shoot infestation of 14.81%, fruit infestation of 16.83% and b:c ratio of 1:3.35. Neem oil 2% had a 13.91% shoot infestation, 15.62% fruit infestation and b:c ratio of 1:3.87. NSKE 5% had 16.76% shoot infestation, 20.80% fruit damage and b:c ratio of 1:2.20. *Beauveria bassiana* had 16.20% shoot infestation, 18.25% fruit infestation and b:c ratio of 1:2.53. The untreated control had a shoot infestation of 24.39%, fruit infestation of 30.32%, and a benefit-cost ratio of 1:1.69.

Thokchom et al. (2022) investigated the toxicity of insecticides on the *Leucinodes orbonalis* in brinjal. Chlorantraniliprole exhibited the highest level of toxicity, with LC₅₀ values of 0.031% and 0.010% at 24 and 48 hours, respectively, against *L. orbonalis*. During both seasons, the formulation of chlorantraniliprole at concentration of 40 g active ingredient per hectare resulted in lower shoot damage (0.35% and 0.25%) and fruit damage (0.25% and 0.20%) compared to other treatments. In both the *Rabi* season of 2020 and the spring season of 2021, the fruit length (17.75 ± 0.45 cm and 17.50 ± 0.21 cm) was significantly higher in the plot treated with chlorantraniliprole @ 40 g a.i./ha. The application of chlorantraniliprole @ 40 g active ingredient per hectare was the cost-efficient treatment, with a b:c ratio of 1:5.63 and a maximum yield of 40.23 q/ha.

Vyas and Tayde (2022) evaluated the impact of chemical insecticides and biopesticides on *Leucinodes orbonalis* in brinjal. The investigation included certain chemical and botanical insecticides applied at optimum dosage: T₁ (*Beauveria bassiana*), T₂ (*Bacillus thuringiensis*), T₃ (Emamectin benzoate), T₄ (Spinosad), T₅ (Carbosulfan), T₆ (Chlorantraniliprole), T₇ (Neem oil) and T₈ (Untreated control). The most effective and cost-efficient treatment was Chlorantraniliprole (1:10.2), compared to the control (1:3.1).

Pandey et al. (2023) evaluated the effectiveness of newly developed pesticides against the *Leucinodes orbonalis* of eggplant Cv. Kavya. The research consisted of various insecticidal treatments, viz., T₁ (Emamectin benzoate), T₂ (*Bacillus thuringiensis*), T₃ (Neem oil), T₄ (Spinosad), T₅ (Chlorantraniliprole), T₆ (Cypermethrin), T₇ (Spinetoram), T₈ (Thiodicarb), T₉ (Chlorpyrifos) and T₁₀ (Untreated control). The results indicated that the plots treated with T₄ (Spinosad) recorded the highest increase in crop yield (97.78 q/ha) and net profit (Rs. 76565.65). During 2021–2022, plots treated with T₄ (Spinosad) showed the highest increase in crop yield and net profit values (99.5 q/ha and ₹67,325.5), compared to T₁₀ (Untreated control). The maximum incremental B:C ratio (3.50) was observed with T₁ (Emamectin benzoate) in both years.

Sowmya and Rajnikant (2023) examined the influence of several insecticides on *Leucinodes orbonalis* of eggplant under the conditions of Prayagraj (Uttar Pradesh). The investigation included different synthetic and botanical insecticidal treatments applied at optimum doses: T₁ (Spinosad), T₂ (Chlorantraniliprole), T₃ (Flubendiamide), T₄ (Emamectin benzoate), T₅ (Indoxacarb), T₆ (Neem oil), T₇ (*Beauveria bassiana*) and T₈ (untreated control). The most effective and cost-efficient treatment was Chlorantraniliprole 18.5% SC (220.5 q ha⁻¹) (1:8.3), in comparison to the untreated control (90.00 q/ha) (1:3.72).

Ghodake et al. (2024) examined the effectiveness of biorational pesticides against the *Leucinodes orbonalis* in brinjal in the Kolhapur region. The experiment included various insecticidal treatments: P₁ (*Metarhizium anisopliae*), P₂ (*Beauveria bassiana*), P₃ (*Lecanicillium lecanii*), P₄ (*Bacillus thuringiensis*), P₅ (Spinosad), P₆ (Azadirachtin 1500 ppm), P₇ (*Heterorhabditis indica*) and P₈ (Control). During the summer of 2022–2023, the results demonstrated that treatment P₅ achieved the maximum yield (50 q/ha), higher gross income (₹125000 hectare) and net profits (₹87882 hectare) in comparison to other treatments. Most economical application was treatment P₅ (3.36), followed by the treatment P₆ (3.15) in comparison to the control.

Upadhyay et al. (2024) investigated the effectiveness of certain chemicals and botanicals in controlling the *Leucinodes orbonalis* in brinjal in the Prayagraj region of Uttar Pradesh. The investigation involved eight insecticidal treatments: P₁ (Neem oil), P₂ (Chlorantraniliprole), P₃ (Spinosad), P₄ (Flubendiamide), P₅ (Indoxacarb), P₆ (Pongamia oil + Flubendiamide), P₇ (Neem oil + Flubendiamide) and P₈ (Control). The findings indicated that the highest production was observed in treatment P₂ (225 q/ha), whereas the minimum yield was recorded

in treatment P₈ (85 q/ha). The findings demonstrated that the most cost-effective insecticidal application was treatment P₂ (1:10.3), followed by treatment P₃ (1:8.5), compared to treatment P₈ (1:4.2).

The current research, entitled “**Residual studies of promising pesticides in Brinjal,**” was performed in the Department of Vegetable Science, Lovely Professional University, Phagwara, Punjab, during the years 2023 and 2024. The field investigation was performed in the main agricultural research field and the residues of specific pesticides were determined in the Central Instrumentation Facility (CIF) of the Lovely Professional University. The present section provides a detailed description of the various materials and methods followed and the statistical tools that were utilized during the research.

3.1 Experimental site and Location

The investigation was carried out at the main agricultural research field of Lovely Professional University, Phagwara, Punjab, as shown in Figure 3.1. The field is situated at a latitude of 31° 15' N, a longitude of 75° 41' E and an altitude of 245 m above mean sea level. Jalandhar is located in a region characterized by well-irrigated and high yield farmland, specifically between the Beas and Sutlej Rivers. It covers a large area of 2624 square kilometers, or 5.3% of the state's overall geographical area.

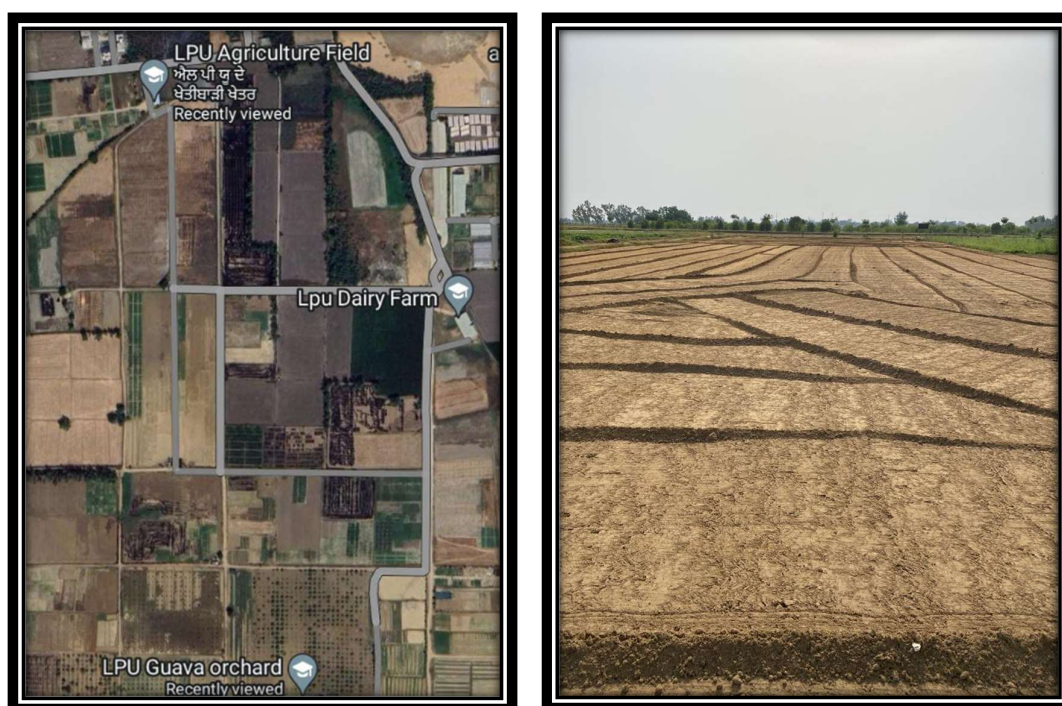


Plate 1 Experimental site and Location

3.2 Physico-Chemical Soil Analysis

3.2.1 Procedure for gathering soil samples for chemical analysis

Prior to the investigation, aggregated soil samples were obtained from randomly selected sites in a zigzag (or criss-cross) pattern within the experimental plots over two consecutive years of cropping. The soil samples were obtained from depths of 0 to 15 or 0 to 30 cm. The same procedure was repeated for the second-year trial as well. The experimental field soil was identified as having a sandy clay loam texture, characterized by a high organic carbon content, high levels of available phosphorus, moderate levels of nitrogen and potassium, slightly acidic to near-neutral pH and an electrical conductivity within the safe range. The collected samples were precisely desiccated in a shaded area, pulverized into fine particles, filtered through a 0.2 mm mesh and subsequently analyzed, as shown in Table 3.1, to estimate the following:

Table 3.1 Physico-chemical properties of the research field

Properties	Characterization			Method of analysis
	2023	2024	Pooled	
Soil pH	6.7	6.8	6.75	Glass electrode pH meter model 335 (Jackson, 1973)
Electrical conductivity (dSm ⁻¹)	0.37	0.33	0.35	Conductivity Bridge ELICO Model EM 88 (Jackson, 1973)
Organic Carbon (%/g)	1.60	1.70	1.65	Rapid titration method (Walkley, A. and Black, I.A., 1934)
Available Nitrogen (kg/ha)	439	460.30	449.65	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available Phosphorus (P ₂ O ₅) (kg/ha)	49.60	40.20	44.90	Olsen's method (Olsen, 1954)
Available Potassium (K ₂ O) (kg/ha)	146	180.70	163.35	Neutral normal Ammonium Acetate method using Flame Photometer (Muhr <i>et al.</i> , 1965).

3.2.2 Determination of pH

Soil pH can be measured using a potentiometer to measure the level of acidity or alkalinity in soils when they are combined with distilled water. Prior to analyzing samples, the potentiometer was calibrated using buffer solutions of known pH.

Reagents

- Commercially available pH buffers with values of 4.00, 7.00, and 9.2 were accessible.
- The combination electrode was filled with a saturated potassium chloride (KCl) solution. The reference electrode was filled with a saturated potassium chloride aqueous solution while utilizing separate glass and reference electrodes.
- Deionized or distilled water with a pH range of 6.5 to 7.5 was utilized to clean the probe between sample measurements.

pH Calibration Procedure

Every three hours of use, calibrate the pH/mV/ORP meter using a recognized buffer solution. The selected buffers must cover the pH range of the samples.

Procedure

In a 100 ml beaker, place dried 25 g of soil specimen and 50 ml of distilled water, stir with a glass rod every 15 to 20 minutes. Allow the samples to remain undisturbed for two to two and a half hours after stirring them three to four times. The buffer solutions with pH values of 4.0 and 7.0 for two-point calibration and 4.0, 7.0 and 9.2 for three-point calibration were used to calibrate the pH meter. After calibrating the pH meter, immerse the electrode into the soil sample solution, and the reading can be recorded. While measuring pH, it was important to ensure that the electrodes were kept from coming into contact with the beaker's surface and walls (Jakson, 1973).

3.2.3 Determination of Electrical conductivity

Reagents

Standard stock solution of KCl (0.1N), Distilled water, Glass beakers (100 ml), Conductivity meter.

Procedure

The addition of 50 ml of distilled water should be made to 25 g of the dried soil sample in a 100 ml beaker. The mixture should be stirred every fifteen to twenty minutes with a glass rod. Stir the samples three to four times, and then allow them to remain undisturbed for two to two and a half hours. Use a 0.1N solution of potassium chloride (7.46 g dried potassium chloride in one liter of distilled water) to calibrate the conductivity meter. After the instrument has been

calibrated, take a reading by dipping the conductivity cell into the filtrate solution, ensuring that the sample remains undisturbed. The recorded value was expressed as EC (dS/m⁻¹) (Jackson, 1973).

3.2.4 Soil organic carbon (SOC)

Reagents

- Standard potassium dichromate at a concentration of 1N: Dissolve 49.04 gram of K₂Cr₂O₇ in one litre of distilled water.
- Ferrous ammonium sulfate at a concentration of 0.5N: In a beaker containing 196.1 g of Fe(NH₄)₂(SO₄)₂·6H₂O, add 800 milliliters of double-distilled water. Slowly mix twenty milliliters of concentrated H₂SO₄ into it, and after cooling the solution, adjust the final volume of one liter.
- Concentrated H₂SO₄, diphenylamine indicator and ortho-phosphoric acid (85%): In 20 millilitres of distilled water, mix 0.5 g of diphenylamine indicator. Gently add 100 millilitres of concentrated H₂SO₄. Allow the reactant to cool, then pour it into a bottle for storage. It is recommended that the solution be prepared fresh.

Method

Weigh 2 gram of soil that has been filtered using a screen with a sieve size of 0.2 mm. Place the soil in a conical flask with a volume of 500 ml. Add ten milliliters of K₂Cr₂O₇ using a pipette, then gently shake the mixture. Carefully pour twenty millilitres of concentrated H₂SO₄ into the flask while gently swirling. Maintain the flask at an ambient temperature for a duration of thirty minutes. Additionally, prepare a soil-less blank sample. Once the mixture has reached room temperature, mix it with ten milliliters of 85% H₃PO₄ and two hundred milliliters of distilled water. After shaking the mixture, add ten drops of the diphenylamine indicator, which changes the solution to violet. Perform a titration using a 0.5N solution of Fe(NH₄)₂(SO₄)₂·6H₂O until the colour turns from violet to vivid green. Finally, record the volume of the Fe(NH₄)₂(SO₄)₂·6H₂O. The estimation of SOC was carried out by Walkley-Black titration method formula (1934).

Calculation

$$\text{Soil organic carbon (\%)} = \frac{(\text{B-S}) \times 0.03 \times \text{N} \times 100}{\text{W (g)}}$$

Where,

B = Volume taken for blank solution (ml)

S = Volume taken for soil sample (ml)

N = Normality of $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$

W = Weight of soil sample in grams

Note: one milliliter of $\text{K}_2\text{Cr}_2\text{O}_7$ is equal to 0.003 grams of soil organic carbon

3.2.5 Estimation of Available nitrogen in soil samples using kjeldahl method

The soil organic substances were oxidized by alkaline KMnO_4 in the presence of sodium hydroxide, liberating NH_4 during the oxidation process, which was absorbed in boric acid to form ammonium borate. The resulting ammonium borate was titrated with standard sulphuric acid to estimate the nitrogen content.

Reagents

- Potassium permanganate with a concentration of 0.32%: Dilute 3.2 grams of KMnO_4 in 750 milliliters of DW, then made the final volume to 1 litre.
- Sodium hydroxide pellets at a concentration of 2.5%: Dissolve 25 g of NaOH with 750 ml of DW and adjust the final volume to 1 litre.
- Standard sulphuric acid with a concentration of 0.01N: Mix 28 ml of concentrated H_2SO_4 (36N) in one litre of DW. The initial solution was approximately 1N H_2SO_4 , dilute it 100 times to obtain a 0.01N H_2SO_4 solution. Using methyl red as the indicator, titrate this solution with a 0.01N Na_2CO_3 solution to standardize it.
- Boric acid at a concentration of 2% with a mixed indicator: Dissolve 20 g of H_3BO_3 with 750 ml of DW, and 20 ml of mixed indicator and dilute to one Liter were added.
- Mixed indicator: Mix 1 gram of bromo-cresol green and 0.66 grams of methyl red in 1 L of 95% ethanol, maintain pH to 4-5 with HCl or NaOH for a bluish-purple colour, and store the mixture in cool conditions.

Procedure

- Add 8.0 grams of soil, 10 ml of DW, 40 ml of 2.5% NaOH and 40 ml of 0.32% KMnO_4 in to a flask, either using an instrument or by manually operating the distillation apparatus.
- Add approximately 10-20 ml of 2% of boric acid into the conical flask and initiate the process of distillation.
- Obtain approximately 100 ml of the substance, or set the timer for 6 minutes in the apparatus.
- Titrate the obtained solution using 0.01N H_2SO_4 till green colour changes to wine red/ pink red and estimate the volume as R ml and also run a blank without soil and record the reading.

Calculations

$$\text{Available N (kg/ha)} = \frac{(X-Y) \times T \times 14 \times 10^{-3} - 2.24 \times 10^6}{W_s}$$

Where,

X = Volume of standard H₂SO₄ used in soil sample (ml)

Y = Volume of standard H₂SO₄ used in blank (ml)

T = Normality of standard H₂SO₄

W_s = Weight of oven dried soil (g)

(Note* - taking weight of 0-15 cm surface as 2.24 million kg/ha)

3.2.6 Estimation of available phosphorus

Phosphorus in soils is present in different forms, such as Al-P, Ca-P, Fe-P, etc. Among them, Ca-P is the most abundant element in neutral and alkaline soils. A 0.5M NaHCO₃ solution with a pH of 8.5 was used in the extraction process to affect the solubility of CaCO₃ and regulate the ionic activity of calcium. The ascorbic acid-based method produces a more stable blue colour.

Reagents

- NaHCO₃ extraction precursor at a concentration of 0.5M: Add 42 grams of NaHCO₃ in approx. 900 milliliters of DW. The pH of the compound should be maintained to 8.5 using a 10% NaOH solution.
- Ammonium molybdate mixed reagent: In approximately 250 millilitres of distilled water, mix 20 grams of ammonium molybdate. Add 0.29 gram of antimony potassium tartrate to approximately 100 milliliters of distilled water and mix until it is completely diluted. Dissolve both of these solutions in approximately 1 litre of NH₂SO₄ and gently shake, then adjust the volume to two litres.
- Sulphuric acid at a concentration of 5N: Add 140 ml of concentrated sulphuric acid to approximately 800 milliliters of DW to adjust final volume to one litre.
- Ascorbic acid (freshly prepared): Add 0.528 grams of ascorbic acid to approximately 100 ml containing ammonium molybdate mixed reagent.
- p-Nitro phenol at a concentration of 0.5%: 0.5 g of the reagent to 100 ml of DW was added and gently shake the solution.

Extraction

- 2.5 g of soil specimen was added to a conical flask of 100 ml, followed by 0.5 g of Darco G-60 charcoal and 50 ml of extracting substance. Two blanks without a soil sample were also prepared.
- After 30 minutes of shaking the sample on an automated shaker, the specimen was filtered using Whatman No. 42 paper, and the filtrate was collected into a flask

Procedure

- Transfer 5 ml of the soil specimen into a volumetric flask with a capacity of 25 ml.
- One to two drops of p-nitrophenol were added, turning the sample's colour yellow.
- Add and carefully quantify 9–12 drops of 5N H₂SO₄ to remove the yellow colour, while stirring continuously to produce CO₂ effervescence. The colour disappears, resulting in the sample's pH being approximately 5. Add an equal number of drops to the other samples in order to decolorize them.
- Gently, place it over to allow the CO₂ to completely bubble out, or wait one hour with constant shaking.
- Combine 4 milliliters of the ascorbic acid reagent with approximately 10 milliliters of DW to prepare a volume of 25 milliliters.
- After calibrating the instrument using a standard curve, wait for ten minutes and observe the %T at 882 or 660 nm.

Calculation

$$\text{Available Phosphorus (kg/ha)} = \frac{\text{graph ppm} \times V_e \times \text{volume made (ml)} \times 2 \times 10^6 \times 2.29}{10^6 \times W_s \times V_a}$$

Where,

V_e = Volume of extractant in ml

W_s = Weight of soil in grams

V_a = Volume of aliquot (filtrate) taken in ml

3.2.7 Estimation of available potassium

Three persistent forms of potassium are found in soils: water-soluble, exchangeable and fixed. The first two types consist less than 1% of the potassium concentration. Both water-soluble and exchangeable forms of potassium can be easily identified in soils. When the available form of K is exhausted, the amount of K that can be exchanged is transferred to the site of exchange. Due to its similar size to potassium ions, the ammonium ion in NH₄OAc facilitates faster dissociation from the exchange complex compared to other cations.

Reagents

- Ammonium acetate at a concentration of 1N: Mix 77 grams of NH_4OAc in DW and adjust the solution to one litre.
- KCl at a concentration of 1000 ppm: To make the volume 1 litre, add 1.908 g of KCl (oven dried) to distilled water.

Procedure

- Add 5 g soil sample and 25 ml of NH_4OAc in a conical flask of 100 ml.
- Place the solution on an automated shaker and agitate for 5 minutes. Then filter it with Whatman No. 1 filter paper.
- After calibration, use a flame photometer to record the potassium content.

Calculation

$$\text{Available 'K' (kg/ha)} = \frac{P \times V_e \times 2.24}{W_s}$$

Where,

P = recorded volume of potassium (ppm)

V_e = extractant volume (ml)

W_s = Weight of soil (g)

$$\begin{aligned}\text{Available 'K' (kg/ha)} &= \frac{R \times 25 \times 2.24}{5} \\ &= R \times 11.2\end{aligned}$$

3.3 Climatic conditions

The experimental field of Lovely Professional University is located in the Central Zone (PB-3) of the state. Both the North-East and South-West monsoons provide precipitation to this region, characterized by a lower coefficient of variation and uniform distribution from June to September. The region has a sub-tropical climate, with summer temperatures varying from 23°C to 43°C and winter temperatures varying from 7°C and 19°C. The warmest months are typically from March to May, while the coldest months are December and January. The mean annual precipitation is 686 millimetres. Tables 3.2 and 3.3 represent the weather-related data during the cropping season of both years:

Table 3.2 Mean weekly meteorological data of agricultural farm in Phagwara during the cropping season (*Kharif* 2023).

SMW	Temperature (°C)		Relative humidity (%)		Windspeed (km/hr)	Rainfall (mm)	Evaporation (mm)	Sunshine (hrs)
	Maximum (°C)	Minimum (°C)	Morning RH (%)	Evening RH (%)				
23	37.57	22.14	79.43	34.57	5.29	3.37	5.77	11.34
24	36.29	23.71	84.43	45.86	3.57	5.89	4.94	9.56
25	37.86	27.57	80.86	51.57	2.57	2.31	6.20	5.86
26	35.71	27.00	82.71	56.14	2.57	0.34	4.74	4.71
27	33.57	25.29	86.71	65.57	3.00	21.89	2.55	4.57
28	33.57	25.86	88.43	66.14	7.00	1.63	3.89	2.50
29	34.57	27.43	86.43	70.00	5.71	7.17	3.36	2.01
30	33.57	27.00	90.86	72.71	4.29	8.57	1.79	3.27
31	35.43	27.59	90.86	68.71	5.57	8.66	2.21	5.91
32	34.29	26.86	90.29	73.00	4.29	0.83	3.23	4.21
33	34.71	27.29	90.57	72.14	5.57	0.47	4.06	5.79
34	34.71	26.86	92.00	70.00	4.43	0.31	2.67	5.01
35	33.57	26.48	91.71	64.29	5.16	1.60	3.16	8.91
36	34.92	24.71	92.00	60.86	5.20	0.00	4.63	10.27
37	34.24	25.99	91.00	70.00	4.28	0.57	2.81	3.01
38	31.65	23.93	92.00	71.08	3.96	2.44	2.63	3.07
39	33.76	21.21	93.00	60.23	4.37	0.34	3.44	9.30
40	33.79	17.79	92.51	48.48	5.76	0.14	0.63	9.83
41	32.33	18.70	91.89	53.21	4.47	1.00	3.16	8.39
42	28.19	15.46	92.01	52.20	4.94	0.60	2.90	8.44
43	30.27	13.71	92.59	47.06	5.40	0.06	2.87	7.96

(Source: LPU, Agro-meteorological department, 2023)

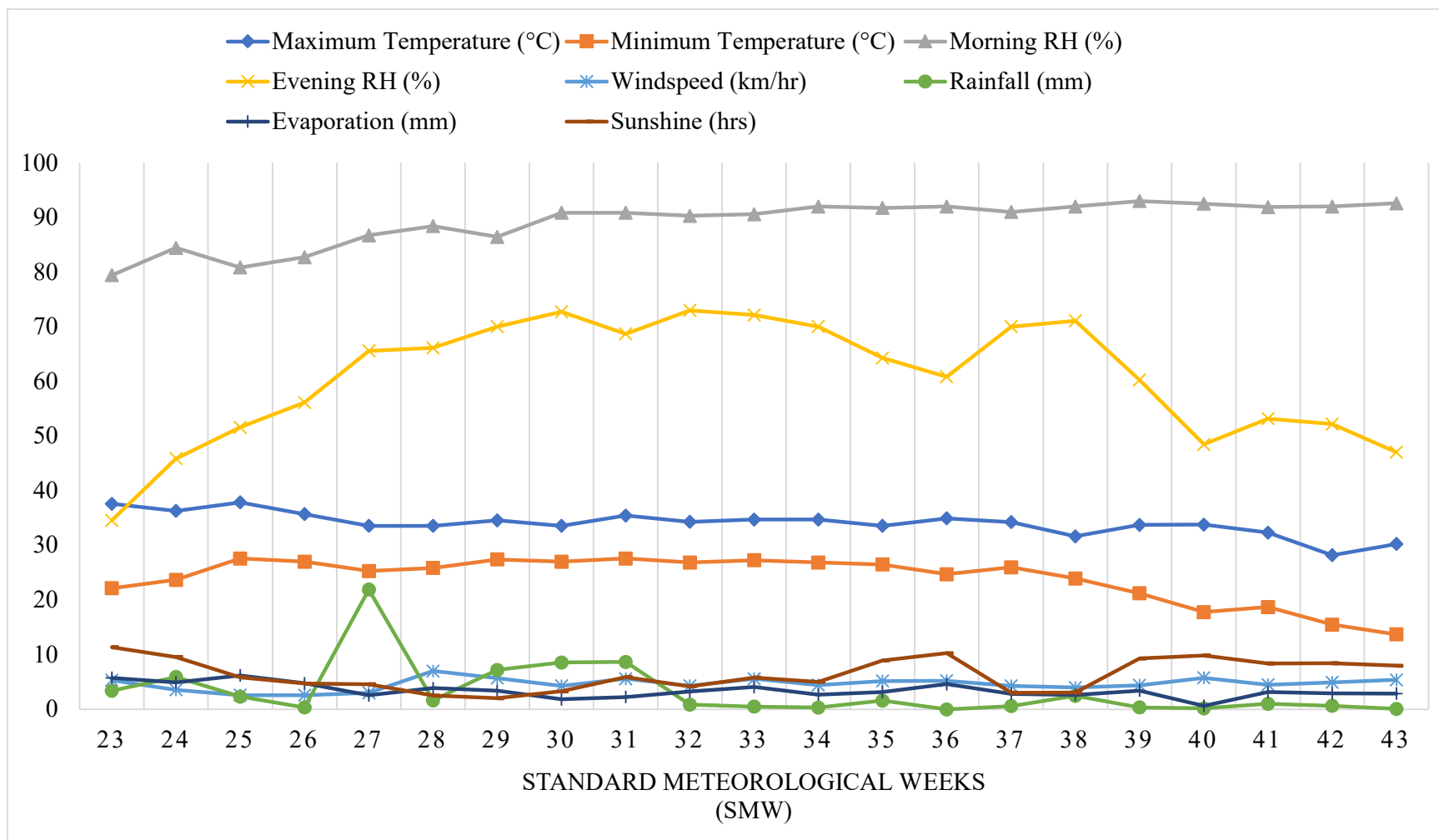


Fig. 3.1 Mean weekly meteorological data of agricultural farm in Phagwara during the cropping season (*Kharif* 2023).

Table 3.3 Mean weekly meteorological data of agricultural farm in Phagwara during the cropping season (*Kharif* 2024).

SMW	Temperature (°C)		Relative humidity (%)		Windspeed (km/hr)	Rain (mm)	Evaporation (mm)	Sunshine (hrs)
	Maximum (°C)	Minimum (°C)	Morning RH (%)	Evening RH (%)				
23	39.81	23.25	75.90	28.60	8.85	1.33	10.87	6.28
24	43.36	25.66	71.07	26.66	12.45	0.00	12.87	6.48
25	39.85	27.05	72.69	39.72	10.13	0.00	13.07	8.23
26	36.58	27.61	85.68	60.49	7.92	0.40	11.90	8.39
27	34.08	26.51	88.89	69.00	9.98	0.54	4.09	3.53
28	36.42	27.08	90.22	62.56	5.40	0.00	6.13	4.90
29	37.13	27.98	87.99	65.18	5.14	0.20	5.46	5.33
30	35.47	27.79	90.26	73.07	4.47	0.00	5.53	5.77
31	35.60	28.11	92.58	77.52	5.49	2.46	4.20	5.34
32	33.79	26.64	91.20	74.22	6.79	3.36	3.46	5.62
33	32.53	27.12	93.83	72.48	5.25	4.57	3.00	5.44
34	35.10	26.11	94.82	73.06	3.96	3.13	4.81	6.03
35	33.27	25.25	94.39	73.68	5.66	0.47	4.74	5.78
36	34.13	26.22	95.08	73.72	3.39	1.63	4.21	6.98
37	34.64	24.97	93.79	68.21	4.06	0.34	4.10	7.43
38	34.68	24.53	94.17	64.48	3.19	0.00	4.60	7.46
39	33.62	24.25	94.06	68.49	3.50	0.20	4.81	6.54
40	35.48	21.56	94.04	60.61	3.60	1.43	3.40	9.62
41	33.43	17.91	93.32	50.41	4.37	0.00	3.69	9.23
42	34.11	17.80	93.43	47.57	2.83	0.00	3.03	9.36
43	32.77	16.42	93.65	52.55	4.47	0.00	3.07	9.10

(Source: LPU, Agro-meteorological department, 2024)

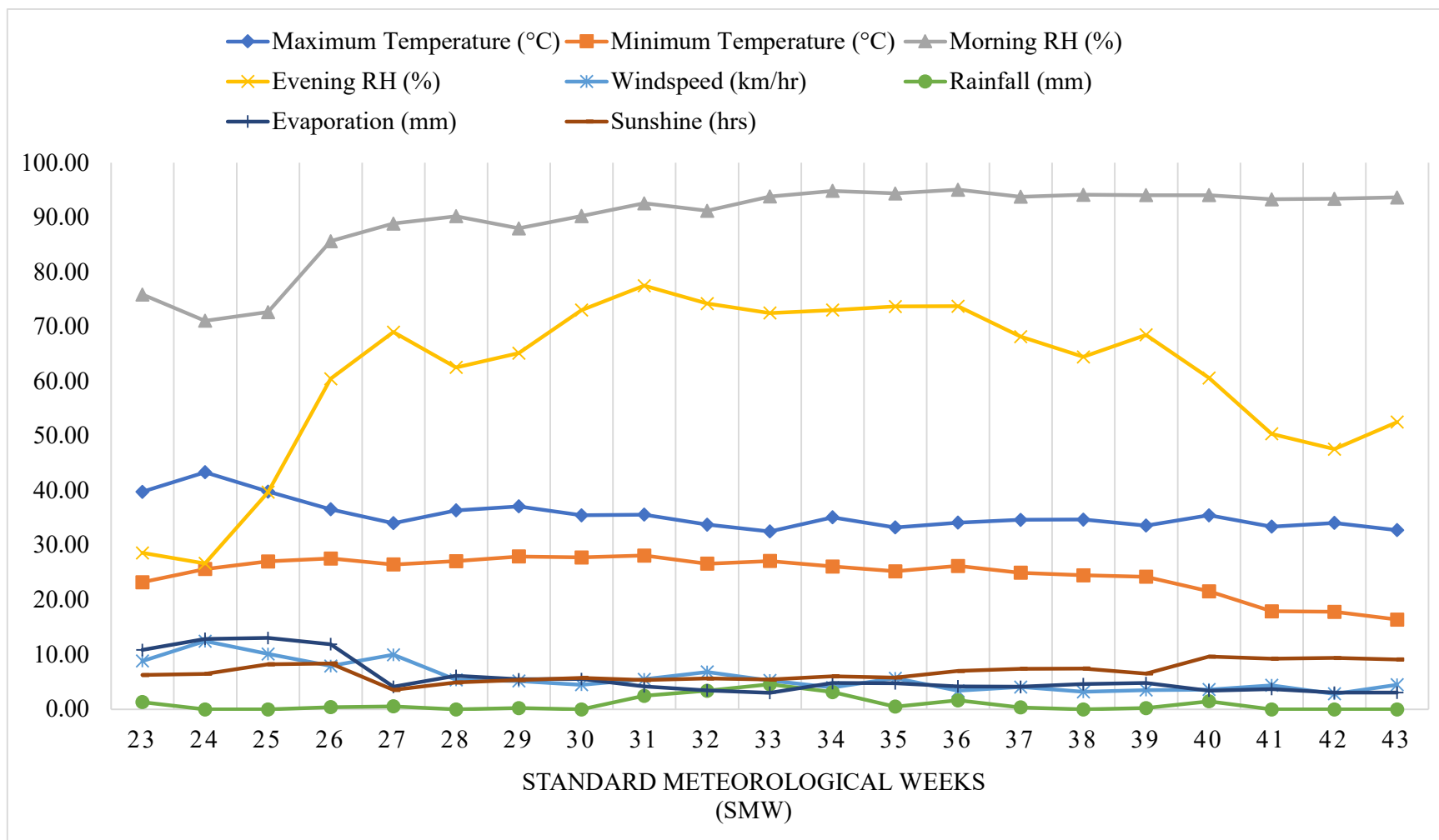


Fig. 3.2 Mean weekly meteorological data of agricultural farm in Phagwara during the cropping season (*Kharif* 2024).

3.4.1 Experimental Details

Title of the experiment: Residual studies of promising pesticides in Brinjal.

Name of the crop: Brinjal

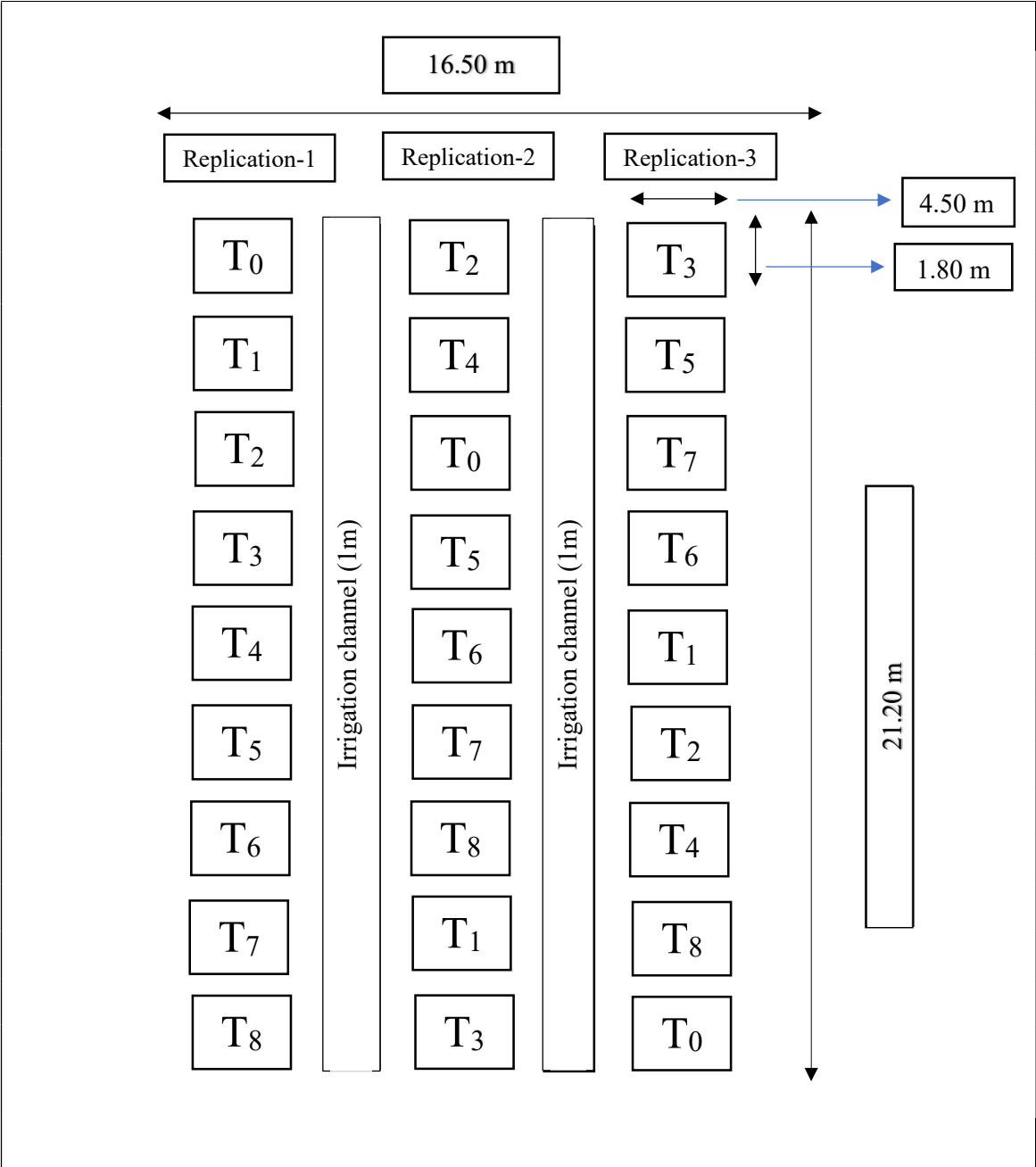
Name of the variety: Navkiran

General description of the variety Navkiran

- Navkiran variety belongs to the round fruit group in brinjal.
- Its fruit colour is bright purple.
- It yields 20-30 t/ha in normal soils conditions.
- It matures 60-65 days after transplantation.

Crop	:	Brinjal
Variety	:	Navkiran
Design	:	Randomized Block Design (RBD)
Replication	:	Three
Spacing	:	60 cm × 45 cm
Total length	:	21.20 m
Total width	:	16.50 m
Size of single plot	:	8.10 m ²
Length of single plot	:	1.80 m
Width of single plot	:	4.50 m
Total area	:	349.8 m ²
Net area	:	286.2 m ²
Total number of beds	:	30
Number of plants per plot	:	30
Number of treatments	:	Nine
Total number of plants	:	810
Season	:	<i>Kharif</i>
Recommended dose of fertilizers	:	FYM 25 t/ha + N:P:K @ 123.6:61.8:29.65 kg/ha

3.4.2 Layout of experimental area



3.4.3 Treatment details

	Treatment	a.i. (g/ha)	Recommended dose	References
T ₀	Control	Water-spray	Water-spray	-
T ₁	Chlorpyrifos 20% EC	200	2.0 ml/lit	Sakharam <i>et al.</i> , 2020
T ₂	Triazophos 40% EC	500	1.5 ml/lit	Kaur <i>et al.</i> , 2022a
T ₃	Karanj oil 1%	20	7.5 ml/lit	Abirami <i>et al.</i> , 2023
T ₄	Neem oil 1%	20	4.0 ml/lit	Abirami <i>et al.</i> , 2023
T ₅	Acetamiprid 20% SP	20	1.5 ml/lit	Jadhav <i>et al.</i> , 2018
T ₆	Deltamethrin 2.8% EC	15	1.0 ml/lit	Manna <i>et al.</i> , 2023
T ₇	Cartap hydrochloride 50% SP	500	0.75 g/lit	Chandan <i>et al.</i> , 2019
T ₈	Carbofuran 3% CG	2000	7 kg/ha	Rajasekar <i>et al.</i> , 2024

3.5 Agronomical operations

3.5.1 Raising of seedlings

Brinjal seedlings were grown in pro-trays (99 cells), and were covered with sterilized coco peat medium. The pro-trays were loaded with a combination of coco peat, vermiculite and vermicompost in a proportion of 2:1:1. Seeds were sown at a rate of one seed per cell, and the pro-trays were positioned above the greenhouse slab until germination began. Rose can was used to irrigate the trays consistently and mildly, depending on the weather conditions and moisture of growing media. The seedlings were regularly monitored. On the 20th day post-planting, a water-soluble fertilizer N:P:K (19:19:19) was applied at a rate of 3 g per Liter of water.

3.5.2 Preparation of field

Before transplanting the seedlings, two harrowings and one cross-cultivation with a tractor-drawn cultivator were carried out to achieve the optimum soil tilth for sowing. The field was subsequently arranged in beds and irrigation channels for the experiment according to the layout of the study.

3.5.3 Raising of crop

Brinjal (var. Navkiran) was cultivated using recommended agronomic practices (Anonymous, 2021). The brinjal seedlings were transplanted in June 2023 for the year-1 and in June 2024 for the year-2, with a plant spacing of 60 x 45 cm in an area of 349.8 m², carried out in a randomized block design. Before transplanting the seedlings to the main field, they were acclimatized by reducing irrigation and lowering shade.

3.5.4 Application of fertilizers

The proper use of manures and fertilizers is essential for optimal production of crops. As a prolonged-growth crop, brinjal necessitates an adequate quantity of fertilizers. Well-rotted farmyard manure (FYM) was precisely incorporated at a rate of 25 tons per hectare into the soil during land preparation prior to the last ploughing. The recommended fertilizer applications included 123.6 kg per hectare nitrogen, 61.8 kg per hectare phosphorus and 29.65 kg per hectare potassium, which were applied in the form of Urea (271.81 kg per hectare), SSP (383.01 kg per hectare) and MOP (49.42 kg per hectare), respectively. Following fertilization rates are generally recommended for cultivating brinjal under Punjab conditions. These rates can be used as a reference, and modifications may be required based on soil test results. A half dosage of nitrogenous fertilizers and a full dosage of P₂O₅ and potash were applied to the field as a basal application. After two harvests, apply a half dosage of nitrogen in the form of urea (135.85 kg/ha).

3.5.5 Intercultural operations

During the brinjal cropping season, the necessary intercultural operations were carried out as described below:

3.5.5.1 Gap filling of seedling

During transplantation, several seedlings were planted along the outer borders of the field trial for gap filling. After transplantation, a number of seedlings suffered damage, leading to their replacement with healthy seedlings earlier planted on the experimental plot's borders.

3.5.5.2 Weeding

The land of each experimental plot was maintained free from weeds. Four weeding operations were conducted manually at 20, 40, 60, and 80 days after transplantation (DAT) to maintain weed-free plots. The weeding was carried out using the hand weeding method.

3.5.5.3 Irrigation and drainage

Flood irrigation was applied to the experimental field immediately after the transplantation of seedlings. To promote the efficient development and growth of the seedlings, further irrigation was applied at three-day intervals. When the plants in the field trial showed wilted symptoms and the soil moisture level was critically low, the field was immediately irrigated on the same day until it was properly moistened. Stagnant water was efficiently removed during the time of excessive irrigation.

3.5.5.4 Application of insecticide

Insecticides were applied at the recommended dosages using a high-volume knapsack sprayer (capacity 16 L). During both years, the first spray was applied at the onset of pest infestation, followed by a second application 15 days later. The percentage of active ingredients (a.i.) in the pesticides was used to prepare the required amount of insecticidal solution. The spray solution was further diluted by adding 500 Litres of water per hectare for field application.

3.5.6 Sampling

From each plot, five healthy plants were randomly chosen and labelled to record observations as per proposed schedule for various parameters. For residual analysis, samples of brinjal fruits were randomly gathered from each treatment at 0 (2 hours after spray), first, third, fifth, seventh, tenth and fifteenth days after the second application of pesticide. Around one kilogram of marketable brinjal fruits was randomly collected from each treatment, placed in labelled polythene bags, and transported to the laboratory for analysis. The fruit samples were chopped, properly blended, and reduced to the required sample size through sequential sub-sampling.

3.5.7 Harvesting

Five healthy plants were randomly chosen and labelled within the net plot area for documenting observation. The Statistical analysis was performed on the average values of the observed data. Marketable brinjal fruits were randomly collected from selected plants for recording observation. The fruits from the experimental plot were harvested individually and weighed for recording yield. The brinjal fruits were harvested consistently at an interval of seven to ten days after the first picking. A total of five pickings were made.

3.6 Observations Recorded

Five randomly chosen healthy plants from each plot of various treatments, excluding the border rows, were tagged to record the observations on the morphological, yield and quality characteristics of brinjal. The mean values of these observations were calculated from recorded data. The detailed view of recorded observations was described below:

3.6.1 Growth characteristics

3.6.1.1 Plant height (cm)

Plant height was measured as the distance from the soil surface to the tip of the main stem. The plant height was obtained at final harvesting using a measuring scale in centimeters and the average values of each replication were analyzed statistically.

3.6.1.2 Shoot length (cm)

The plants were uprooted and rinsed with distilled water to eliminate sand particles. The shoot length of 5 randomly chosen plants from each replication was estimated at the final harvest in centimetres (cm) from the base to the tip of the shoot using a meter scale. The mean of each replication was calculated for statistical analysis.

3.6.1.3 Root length (cm)

The plants were uprooted and rinsed with distilled water to eliminate sand particles. The root length of 5 randomly chosen plants from each replication was estimated at the final harvest in centimetres (cm) from the base to the tip of the longest root using meter scale. The mean of each replication was calculated for statistical analysis.

3.6.1.4 Number of leaves

The total leaf count was determined by counting leaves on each tagged plant. Data were averaged from five randomly selected plants per replication across treatments at final harvest.

3.6.1.5 Number of branches

The data were collected by counting the branches at final harvesting from five tagged plants. The mean of each replication was statistically analyzed.

3.6.1.6 Stem diameter (cm)

Stem diameters of five tagged plants were taken using the vernier calliper at final harvesting. The average of each replication was statistically analyzed.

3.6.1.7 Days to flower initiation

Days to flower initiation were recorded for the number of days taken in each treatment showing its first flower emergence. It was recorded from the date of transplantation. The days until the first five plants flowered in each treatment were recorded, averaged and analyzed statistically.

3.6.1.8 Days to 50% flowering

For each treatment, the days to 50% flowering was observed by counting number of days from transplanting date to 50% flowering on five tagged plants, and the average was used for statistical analysis.

3.6.1.9 Number of flowers per plant

The observation was recorded by counting flowers count on five selected plants in each treatment after a full blooming stage and the mean values were statistically analyzed.

3.6.1.10 Days to fruit formation

Days to fruit formation was observed by counting days from the transplantation date to the formation of 50% fruits for each treatment among five tagged plants, and the average was statistically analyzed.

3.6.1.11 Days to harvesting

Fruits were harvested seventy to eighty days post-transplantation. The interval from the transplanting date to the first harvesting date was recorded in order to estimate the days to the first harvest. The days of harvesting for the randomly selected five plants in each treatment were recorded, averaged and analyzed statistically.

3.6.1.12 Leaf area (cm²)

It was determined by observing fresh leaf samples under a leaf area meter at the final harvest. The mean values for each replication were calculated for statistical analysis.

3.6.1.13 Leaf area index (LAI)

Five randomly chosen plants under each treatment were estimated at the final harvest using the following formula:

$$\text{LAI (Leaf Area Index)} = \frac{L_a (\text{cm}^2)}{G_a (\text{cm}^2)}$$

Where,

L_a = Total leaf area/plant

G_a = ground area covered by the plant

3.6.1.14 Number of shoot damage

The observation was recorded by counting the infested shoots of five selected plants and the average were calculated for statistical analysis.

3.6.1.15 Incidence of shoot borer (%)

The total number of damaged and healthy shoots on five tagged plants was counted, and the percent incidence of shoot borer on the plant was computed according to the formula described below:

$$\text{Incidence of shoot borer (\%)} = \frac{\text{Damaged shoots}}{\text{Total shoots (Infested + Healthy)}} \times 100$$

3.6.2 Yield characteristics

3.6.2.1 Number of fruits per plant

Observation was recorded by counting the fruits on five chosen plants and the average was computed.

3.6.2.2 Fruit length (cm)

The length of five tagged marketable-sized fruits was measured individually in centimetres, from the base of the calyx to the fruit tip, using a vernier calliper, and the mean fruit length was computed.

3.6.2.3 Fruit width (cm)

Five randomly picked fruits of marketable size were measured for girth in centimetres at their widest point using a vernier calliper. The average width of five fruits was determined for each treatment.

3.6.2.4 Fruit yield per plant (kg)

Fruits were harvested from the five selected plants and placed in separate polythene bags during each picking, after which the mean values of yield per plant for each treatment was determined. It was calculated by adding the fruit weights of five tagged plants at each picking and expressed in Kg/plant.

3.6.2.5 Fruit yield per plot (kg)

The total fruits picked from the plot were measured in kg per plot. The average fruit yield per plot was computed for each treatment and analyzed statistically.

3.6.2.6 Yield per hectare (t)

The fruits picked from each plot were continuously weighed in kilograms, and the total yield per plot was computed. Similarly, the fruit yield was estimated on a per-hectare basis and expressed in t/ha.

3.6.2.7 Yield increase over control per hectare (%)

The fruit yield produced from each treatment was converted to a per-hectare basis and analyzed statistically. The yield increase over control per hectare was determined using the following formula:

$$Y (\%) = \frac{T - C}{C} \times 100$$

Where,

T = Yield of insecticide treated plot (kg ha⁻¹)

C = Yield of untreated plot (kg ha⁻¹)

3.6.2.8 Incidence of fruit borer (%)

Incidence of fruit borer (%) on five tagged plants was calculated on number and weight basis. Percent damage of fruit borer (number basis and weight basis) was computed according to formula described below:

$$\text{Percent incidence (number basis)} = \frac{\text{Damaged fruits (count)}}{\text{Total fruit count}} \times 100$$

$$\text{Percent incidence (weight basis)} = \frac{\text{Damaged fruits (kg)}}{\text{Total fruit weight (kg)}} \times 100$$

3.6.3 Quality characteristics

3.6.3.1 Total soluble solids (°Brix)

A digital refractometer was used to measure the total soluble solids in the juice extracted from the fruit samples. The TSS of the observed samples was expressed in degrees Brix. The reading was obtained at 20° C and represented as a percentage of total soluble solids (TSS) in fresh fruit juice.

3.6.3.2 Titratable acidity (%)

It was estimated using the AOAC (2004) method, as discussed below:

Reagents

- 0.1N sodium hydroxide (NaOH): Dissolve 40.005 g pellets of NaOH in distilled water and dilute to 1 Liter in a volumetric flask. Standardize by titrating with a standard H₂SO₄ (sulphuric acid) solution (0.1N). To standardize H₂SO₄ against sodium carbonate (Na₂CO₃), heat analytical grade sodium carbonate at 105°C for 8 hours.
- 0.1N sodium carbonate (Na₂CO₃) solution: Transfer 25 milliliters of 0.1 N H₂SO₄ into a 250 milliliters conical flask by using a pipette. Dissolve approximately 100 milliliters of distilled water and some drops of bromophenol blue. Add the standard 0.1N sodium carbonate solution from the burette until a blue endpoint or pH 4.1 was achieved with a pH meter.
- 1% phenolphthalein solution: Dissolve 1 gram of phenolphthalein in 100 milliliters of ethanol.

Procedure

The juice collected from a 5-gram fruit sample was filtered using muslin cloth. The final volume of 25 ml was prepared using distilled water. The solution was subsequently titrated with standard 0.1N NaOH, adding 1% phenolphthalein solution as an indicator. The change in colour of the solution to pale pink was observed at the end point. Record the titre value and

compute the percentage of titratable acidity as the predominant acid. The final result was expressed as a percentage of acidity in the fruit.

Calculation

$$\% \text{ Acidity} = \frac{V_n \times T \times E_{wt.}}{V_s \times 1000} \times 100$$

Where,

V_n = Volume of sodium hydroxide used (ml)

T = Normality of sodium hydroxide (0.1N)

$E_{wt.}$ = Equivalent weight of predominant acid (64.04 g/mol for citric acid)

V_s = Volume of sample taken for estimation (ml)

3.6.3.3 Crude protein (%)

It was calculated by multiplication of nitrogen content (%) by a conversion factor of 6.25. It was estimated using the micro-Kjeldahl method (AOAC, 2001), as detailed below:

Reagents

- Concentrated H_2SO_4 (98%)
- Digestion mixture: Dissolve 35g of potassium sulphate (K_2SO_4) and 4g of copper sulphate ($CuSO_4$).
- 0.1N of standard hydrochloric acid (HCl): Dilute 4 milliliters of concentrated hydrochloric acid in 450 ml of DW. Standardize using 1.9% borax as specified below:
 - Measure 10 ml of 1.9% borax into a conical flask and mix 3 drops of methyl orange.
 - Dissolve 0.1N standard hydrochloric acid in the burette and titrate against the borax solution until a colour changes to pink.
 - Record the titre value in the burette.
- Boric acid solution (4%): 40 g of boric acid were added to an adequate amount of DW to maintain the final volume up to 100 ml.
- 4% H_3BO_3 (boric acid) solution: Dissolve 40 milligrams of boric acid in 900 ml of heated DW. After cooling, add 10 ml of bromocresol green and 7 ml of methyl red solution. Mix thoroughly, adjust the final volume to one litre with distilled water, and add a drop of 40% sodium hydroxide solution.
- NaOH (sodium hydroxide) solution (40%).

Procedure

Precisely measure one gram of the oven-dried powdered brinjal fruit sample into a digestion tube. Take 10 g of digestion mixture and 10 milliliters of concentrated Sulphuric acid. Gently heat the tube to around 350°C, then gradually raise the temperature to 450°C and boil the solution until it obtains a light green colour. While the tube is cooling, add about 35 ml of distilled water, allow it to cool again, then add 40 ml of Sodium hydroxide. Next, start the distillation process using a Kjeldahl distillation flask. NH₃ liberated is captured in 25 ml of 4% H₃BO₃ kept in a conical flask. Stop distillation when the solution volume in the flask reaches 150 ml, then titrate the solution with 0.1N hydrochloric acid until the green colour changes to pink. Record the burette reading. A blank was run immediately through each step to monitor any nitrogen added by the chemical.

Calculation

Crude protein content (%) was estimated by using the following method:

$$N (\%) = \frac{(T-C) \times S \times 14 \times 100}{W_s \times 1000}$$

Where,

T = sample titre reading (ml)

C = blank titre reading (ml)

S = normality of standard hydrochloric acid (0.1N)

W_s = weight of sample (g)

After Nitrogen (%) estimation,

Protein (%) = Nitrogen (%) x conversion factor (6.25)

3.6.3.4 Chlorophyll index of leaves (SPAD-502)

A Soil Plant Analysis Development (SPAD-502) chlorophyll meter was used to measure the chlorophyll index in the leaves. Fully developed and healthy leaves were chosen from the middle portion of the five randomly tagged plants. Observations from the leaves that were damaged, older, or located at the extreme top or bottom of the plant were avoided. To obtain an accurate estimate, a minimum of three readings per leaf was observed and the mean of these readings was computed.

3.6.4 Estimation of pesticides residues from brinjal fruit

3.6.4.1 Materials utilized during analysis

3.6.4.1.1 Solvents and chemicals

The analytical standards for various insecticides have been acquired from Sigma-Aldrich, Kolkata, India. Commercial insecticide formulations included chlorpyrifos 20% EC (Radar, Jivagro Ltd.), triazophos 40% EC (Cheminova India Ltd.), karanj oil 1% (Vijaya Agro Industries), neem oil 1% (Indore Biotech Inputs and Research Private Ltd.), acetamiprid 20% SP (Kingtech Bio Chem Pvt. Ltd.), deltamethrin 2.8% EC (Bayer Crop Science Ltd.), cartap hydrochloride 50% SP (Sumitomo Chemical India Ltd.), and carbofuran 3% CG (DCM Shriram Limited). HPLC-grade solvents were acquired from Loba Chemie Pvt. Ltd., Mumbai, India. Various solvents and reagents, including acetone (HPLC grade), hexane (AR grade), acetonitrile (AR and HPLC grade) and dichloromethane (AR grade), were utilized in the analysis of insecticide residues.

3.6.4.1.2 Other materials

Whatman filter paper No. 1, activated charcoal, microcentrifuge tubes, teepol, distilled water and anhydrous sodium sulphate (AR grade).

3.6.4.1.3 Glassware and plastic ware

The equipment includes beakers (50 and 100 ml), measuring cylinders (10, 50, 100 and 500 ml), volumetric flasks (25 milliliters), graduated test tubes with stoppers (5 ml), injection vials (1.5 ml), reagent bottles (125 and 250 ml), graduated vials (15 ml), plastic tube stands, separatory funnels, round bottom flasks, funnels, flasks, stands and glass columns.

3.6.4.1.4 Instruments

The instruments used included an electronic balance (Shimadzu), High-Performance Liquid Chromatography (HPLC Shimadzu), homogenizer, hot air oven, double distillation unit, blender, refrigerator, rotary vacuum evaporator and deep freezer.

3.6.4.2 Procedure of residual analysis

3.6.4.2.1 Glassware sterilization

The protocol provided by the EPA (1980) for glassware sanitization was implemented to remove all forms of impurities. The glassware was immersed in heated water and subsequently sterilized with an organic substance to eliminate impurities. Chromic acid at a concentration of 20 percent, consisting of 20 grams of potassium dichromate dissolved in 100 milliliters of Sulphuric acid (w/v), was used as a potent oxidizing agent to eliminate deposits of organic impurities. The glassware was immersed in an H_2CrO_4 solution for four to five hours and then

rinsed with tap water to eliminate traces of the H_2CrO_4 solution. The glassware was later disinfected with a detergent and normal water, sterilized with distilled water and ultimately treated with acetone to eliminate any remaining organic pollutants. The sanitized glassware was maintained at 100°C in an electric oven for two hours. Prior to use, it was subjected to cooling and rinsed with the identical solvent selected for the analysis.

3.6.4.2.2 Sampling

Marketable-sized brinjal fruit samples were obtained from the field trial conducted at the Main Agricultural Field of the Department of Vegetable Science during the Kharif seasons of 2023 and 2024 by harvesting the fruits using a knife and placing them into a polythene bag. Three replications were performed using nine treatments organized in a randomized block design, having a plot area of 8.10 m^2 . Samples from each replication were mixed in the laboratory prior to obtaining a representative sample of 15 g. Samples from the treated and untreated plots were taken at intervals of 0th (2 hours), first, third, fifth, seventh, tenth and fifteenth days after the initial spray.

3.6.4.2.3 Isolation and purification of residues

The separation and purification of samples for residual analysis were carried out by using the method described by Pandit *et al.*, 2016. Brinjal fruit samples (25 g) were blended with 100 ml of acetonitrile for two to 3 minutes, filtered through coarse filter paper using Buchner funnel and refrigerated overnight. The process was repeated with 50 ml acetonitrile, followed by filtration and the addition of 500 mg of DARCO G 60 activated charcoal, then agitated for 30 minutes on a rotary shaker. After filtration through Whatman No. 1 paper, the solution was concentrated to 5 millilitres using a rotary vacuum evaporator (RVE). It was then transferred to a separating funnel and mixed with 50 millilitres of hexane and 50 millilitres of saturated aqueous NaCl solution. After layer separation, the aqueous layer was extracted and partitioned three times with 50 mL of dichloromethane. The extract was collected over an anhydrous Na_2SO_4 bed, evaporated to dryness using an RVE, reconstituted in HPLC-grade acetonitrile up to a volume of 5 mL, and filtered through a $0.22\text{ }\mu\text{m}$ membrane.

3.6.4.3 HPLC residual analysis

The quantification of various insecticidal residues was done by utilizing RP HPLC (Shimadzu), fully equipped with a RI and PDA detector, along with an auto-sampler. Analytes separation was performed using a C_{18} end-capped column with an injection volume of $20\text{ }\mu\text{l}$. A digital microprocessor and user software operate the HPLC instrument, enabling computer data analysis to identify the peak area and retention time for each peak. The comparison was conducted using the peak area of the pesticide standards. The minimum interval between

injections was 1 to 2 minutes. Table 3.4 presents the operational parameters of the RP-HPLC utilized for residue determination.

3.6.4.3.1 Calculation of residues of insecticides

Residues of insecticides were calculated with the help of method given by Ahmed *et al.*, 2021 which was described below:

$$\text{Residue Level (mg kg}^{-1}\text{)} = \frac{A - B}{C}$$

Where,

A = Concentration extracted in injected volume (mg kg⁻¹)

B = final volume prepared (ml)

C = Sample weight (kg)

Table 3.4 Operational parameters of RP-HPLC.

Instrument		HPLC (Shimadzu)
Column		C ₁₈ , 150 mm × 4.6 mm, 5 μm particle size
Detector		Photodiode Array (PDA)
Flow rate		Isocratic, 1.0 ml/min
Volume injected		20
Mobile phase	Insecticides	Acetonitrile : Water (v/v)
	Chlorpyrifos	70 : 30
	Triazophos	60 : 40
	Karanj oil	60 : 40
	Neem oil	60 : 40
	Acetamiprid	70 : 30
	Deltamethrin	70 : 30
	Cartap hydrochloride	70 : 30
	Carbofuran	60 : 40
Wavelength of instrument		190-800 nm
End time		20 minutes
Retention time (min)	Insecticides	Time (minutes)
	Chlorpyrifos	8.10
	Triazophos	15.25
	Karanj oil	9.10
	Neem oil	9.55
	Acetamiprid	2.85
	Deltamethrin	8.60
	Cartap hydrochloride	10.46
	Carbofuran	8.50

3.6.4.3.2 Dissipation rate

The following mathematical method was used to determine the dissipation rate of different insecticidal treatments, as described by Mishra *et al.*, (2022):

$$\text{Dissipation rate (\%)} = 1 - \frac{\text{Initial concentration} - \text{Residual concentration}}{\text{Initial concentration}} \times 100$$

3.6.5 Seasonal Incidence of Shoot and fruit borer

Weekly observations were observed from the initial appearance of pest infestation until the last harvesting of the crop in order to monitor the overall infestation of shoots and fruits. From each plot, five healthy plants were randomly chosen and labelled for taking observations related to the *Leucinodes orbonalis*. The withered or drooping shoot indicated the onset of shoot infection. The infestation of shoots was evaluated by counting the total shoots and damaged shoots per plant, facilitating the calculation of the percentage of shoot infestation. Data related to fruit infestation was recorded during each picking of fruits. The fruits collected from each plot were analyzed for borer infestations, with those exhibiting holes obstructed by excreta categorized as infested. The infested and healthy fruits were subsequently separated and individually counted to ascertain the percentage of fruit infestation. Weekly weather data was obtained from the Department of Agro-meteorology at Lovely Professional University, Phagwara, Punjab, to analyze the correlation between the appearance of shoot and fruit borer with meteorological parameters.

3.6.6 Performance of insecticides against *Leucinodes orbonalis*

A field investigation was performed at the main agricultural research field of the School of Agriculture, Lovely Professional University, Punjab, with eight insecticidal and botanical treatments alongside an untreated control using a randomized block design with three replicates, during the years 2023 and 2024. The brinjal (var. Navkiran) was cultivated in a plot measuring 1.80 x 4.50 meters with spacing of 60 x 45 centimetres during the first week of June on both 2023 and 2024. Pesticides were sprayed using a Knapsack sprayer at the onset of *Leucinodes orbonalis* with a 15-day interval between application. Five plants from each plot were examined before spray and on the 1, 3, 5, 7, 10 and 14 days after each spray for fruit infestation. After each picking, the total weight of healthy and damaged fruits as well as the counting of healthy and damage fruits from each plot on an individual basis were performed to ascertain the percentage of fruit infestation.

3.6.7 Economics of Cultivation

After evaluating the variables, fixed inputs, and associated rates, the cost for each treatment was determined to identify the most cost-effective treatment for the profitable cultivation of various treatment combinations.

3.6.7.1 Total cost of cultivation (Rs/ha)

The overall agricultural expenditure was calculated by summing the expenses for each input, including irrigation, labour, and intercultural operations carried out during the growing seasons.

Operational expenditure = Total cost of variable inputs + Total cost of fixed inputs.

3.6.7.2 Gross return (Rs/ha)

Based on market price, crop production was converted into gross revenue.

Gross return = Market price of the produce (Rs/kg) x Total yield (kg).

3.6.7.3 Net return (Rs/ha)

The net return was computed by reducing the overall cultivation expenditures from the crop's gross revenue.

Net income = Gross revenue - Total cost of cultivation

3.6.7.4 Benefit cost ratio (B:C)

The B:C ratio was determined by dividing the net income by the corresponding cultivation cost using the following formula:

Benefit Cost ratio = Net income/Total cost of cultivation

3.7 Method of statistical analysis

SPSS (Version 25.0) statistical software was utilized to perform the statistical analysis of all recorded observations. The percent infestation data underwent an arcsine transformation prior to analysis. The average values were subjected to an analysis of variance and a critical difference (C.D.) test at a 5% probability level in a Randomized Block Design, as recommended by Gomez and Gomez (1984).



Plate 2. A view of well-prepared experimental field



Plate 3. Raising of seedlings in nursery



Plate 4. Application of fertilizer in the experimental field



Plate 5. A closer view of weeding operation in experimental field



Plate 6. A view of application of different insecticidal treatments



Plate 7. A view of experimental field after irrigating the crop



Plate 8. A closer view of tagging of randomly selected five plants



Plate 9. A view of harvesting of brinjal fruits



Plate 10. A view of observations recorded on growth parameters of brinjal

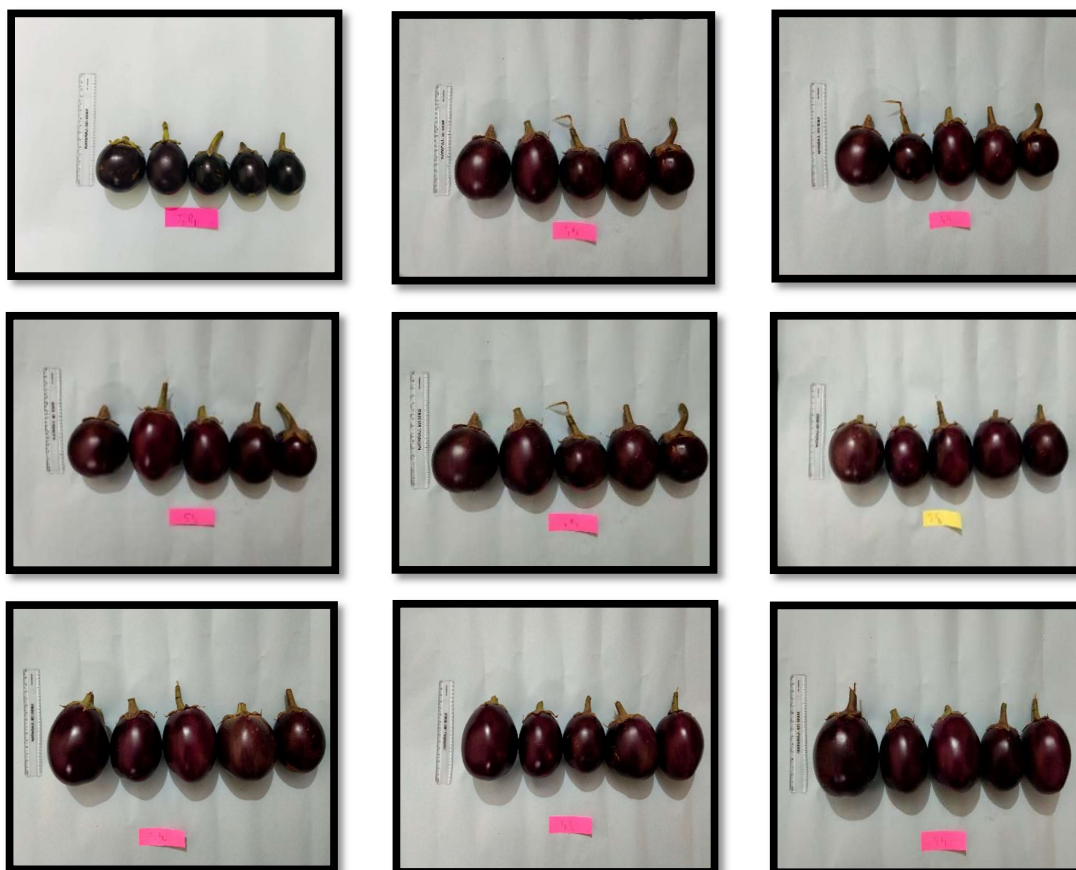


Plate 11. Harvested fruit from different plots of experimental field



Plate 12. A view of observations recorded on yield parameters of brinjal

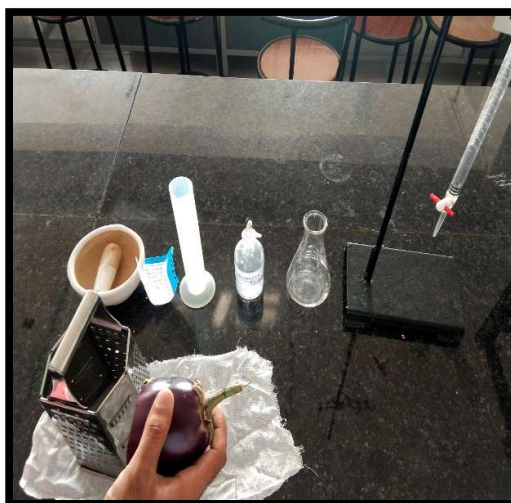


Plate 13. A view of observations recorded on quality parameters of brinjal

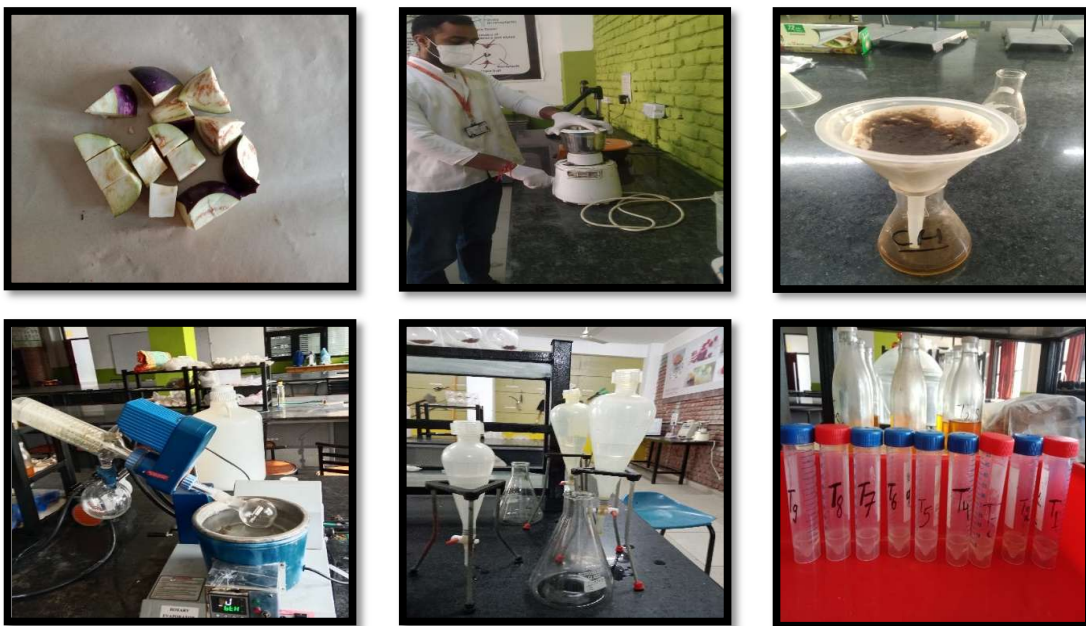


Plate 14. Extraction and clean-up of samples collected from experimental field



Plate 15. Estimation of different treatments residues in brinjal fruits using HPLC with RI and PDA detectors



Plate 16. A field view at Main Agricultural Field, Department of Horticulture, Lovely Professional University, Phagwara, Punjab, India

This chapter consists of data observed on “**Residual studies of promising pesticides in Brinjal**”. The investigation was performed during the *kharif* seasons of two consecutive years, 2023 and 2024, at the main agricultural farm, Lovely Professional University, Phagwara, Punjab, India. Data from two years and the pooled mean were statistically analyzed and the significance of the findings was confirmed. The findings related to growth, yield, quality, residual analysis, seasonal incidence, efficacy and benefit-cost ratio parameters, along with potential scientific justifications and supporting references from published literature are presented and discussed in this chapter. The findings are presented in tables, including graphical representations wherever required. The findings have been interpreted under the following subheadings:

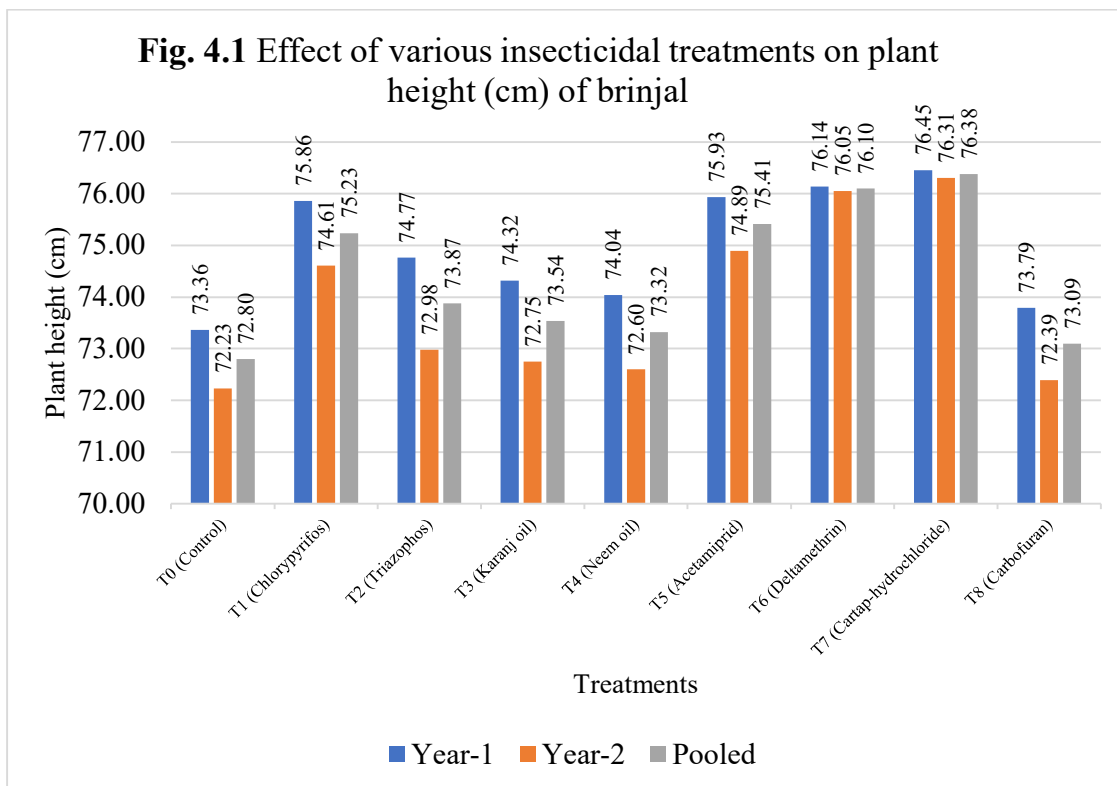
4.1 Growth characteristics

4.1.1 Plant height (cm)

The perusal of data on the plant height of brinjal revealed significant variation among the various treatments compared to the control. The mean data for the years 2023, 2024 and pooled analysis are illustrated in Table 4.1 and Fig. 4.1. Among the selected treatments, the maximum plant height (76.45 cm) during the first year of research was recorded in T₇ (Cartap hydrochloride 20% EC) which was *at par* with the treatment T₆ (76.14 cm), followed by the treatment T₅ (75.93 cm), while the minimum (73.36 cm) was observed in T₀ (Control) *at par* with treatment T₈ (73.79 cm). Similarly, during the second year, the highest plant height (76.31 cm) was also observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (76.05 cm), while the lowest (72.23 cm) was recorded in T₀ (Control). During the pooled analysis, the maximum plant height (76.38 cm) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (76.10 cm), while the minimum (72.80 cm) was found in T₀ (Control), respectively. A pesticide belonging to the nereistoxin analogue group, cartap hydrochloride effectively controls insects through contact and systemic action (Sonawane and Rayate, 2018) while ensuring long-lasting plant protection, which further leads to an indirect impact on crop growth. The aforementioned results were in line with the conclusions drawn by Rahman *et al.*, 2015, who suggested that synthetic pesticides resulted in increase of plant height of brinjal.

Table 4.1: Effect of various insecticidal treatments on plant height (cm) of brinjal

Treatments	Plant height (cm)		
	2023	2024	Pooled
T₀ (Control)	73.36 ^e ± 0.02	72.23 ⁱ ± 0.05	72.80 ^g ± 0.04
T₁ (Chlorpyrifos 20% EC)	75.86 ^b ± 0.04	74.61 ^d ± 0.03	75.23 ^c ± 0.01
T₂ (Triazophos 40% EC)	74.77 ^c ± 0.03	72.98 ^e ± 0.04	73.87 ^d ± 0.04
T₃ (Karanj oil 1%)	74.32 ^{cd} ± 0.54	72.75 ^f ± 0.11	73.54 ^e ± 0.23
T₄ (Neem oil 1%)	74.04 ^d ± 0.52	72.60 ^g ± 0.04	73.32 ^{ef} ± 0.27
T₅ (Acetamiprid 20% SP)	75.93 ^{ab} ± 0.04	74.89 ^c ± 0.06	75.41 ^c ± 0.05
T₆ (Deltamethrin 2.8% EC)	76.14 ^{ab} ± 0.06	76.05 ^b ± 0.08	76.10 ^b ± 0.07
T₇ (Cartap hydrochloride 50% SP)	76.45 ^a ± 0.15	76.31 ^a ± 0.04	76.38 ^a ± 0.07
T₈ (Carbofuran 3% CG)	73.79 ^{de} ± 0.53	72.39 ^h ± 0.06	73.09 ^f ± 0.25
CD (P=0.05)	0.56	0.05	0.27
SE_m (±)	0.18	0.02	0.09
CV (per cent)	0.43	0.04	0.21

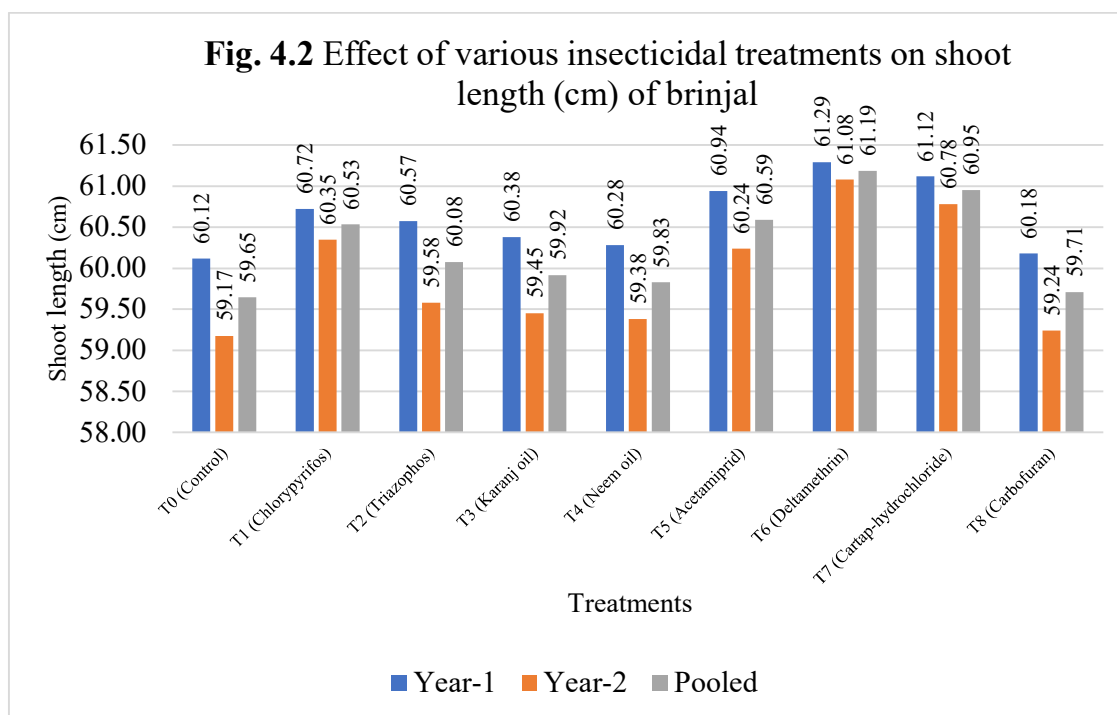


4.1.2 Shoot length (cm)

The observations recorded on shoot length of brinjal influenced by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.2 and Fig. 4.2. It is evident that there was a significant variation in shoot length with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the highest shoot length of 61.29 cm was recorded in treatment T₆ (Deltamethrin 2.8% EC), *at par* with treatment T₇ (61.12 cm), followed by T₅ (60.94 cm) during 2023. The lowest shoot length of 60.12 cm was recorded in treatment T₀ (Control), *at par* with T₈ (60.18 cm), T₄ (60.28 cm) and T₃ (60.38 cm) during 2023. During 2024 and in the pooled analysis, the highest shoot lengths of 61.08 and 61.19 cm were recorded in treatment T₆ (Deltamethrin 2.8% EC), followed by T₇ (60.78 and 60.95 cm) and T₅ (60.24 and 60.59 cm). The lowest shoot lengths of 59.17 and 59.65 cm were observed in treatment T₀ (Control), which was *at par* with T₈ (59.24 and 59.71 cm) and T₄ (59.38 and 59.83 cm), followed by T₃ (59.45 and 59.92 cm) during 2024 and in the pooled analysis. Due to deltamethrin's rapid inhibitory effect on feeding insects, there is optimism that it could be effective in controlling "non-persistent" virus vectors, which are capable of spreading within minutes after the vector begins feeding on the plant. Among synthetic pyrethroids, deltamethrin has been identified as the most effective due to its extremely broad spectrum of action (Bhardwaj *et al.*, 2020). The present findings were in close agreement with the results suggested by Singh *et al.*, 2018a, who found that synthetic insecticides at optimal dosages increased the shoot length of brinjal.

Table 4.2: Effect of various insecticidal treatments on shoot length (cm) of brinjal

Treatments	Shoot length (cm)		
	2023	2024	Pooled
T ₀ (Control)	60.12 ^f ± 0.07	59.17 ^f ± 0.12	59.65 ^f ± 0.04
T ₁ (Chlorpyrifos 20% EC)	60.72 ^{cd} ± 0.11	60.35 ^c ± 0.13	60.53 ^c ± 0.10
T ₂ (Triazophos 40% EC)	60.57 ^{de} ± 0.51	59.58 ^d ± 0.09	60.08 ^d ± 0.22
T ₃ (Karanj oil 1%)	60.38 ^{def} ± 0.10	59.45 ^{de} ± 0.08	59.92 ^{de} ± 0.08
T ₄ (Neem oil 1%)	60.28 ^{ef} ± 0.08	59.38 ^{def} ± 0.19	59.83 ^{ef} ± 0.12
T ₅ (Acetamiprid 20% SP)	60.94 ^{bc} ± 0.11	60.24 ^c ± 0.05	60.59 ^c ± 0.06
T ₆ (Deltamethrin 2.8% EC)	61.29 ^a ± 0.05	61.08 ^a ± 0.09	61.19 ^a ± 0.07
T ₇ (Cartap hydrochloride 50% SP)	61.12 ^{ab} ± 0.04	60.78 ^b ± 0.09	60.95 ^b ± 0.06
T ₈ (Carbofuran 3% CG)	60.18 ^f ± 0.05	59.24 ^{ef} ± 0.16	59.71 ^f ± 0.06
CD (P=0.05)	0.32	0.21	0.20
SE _m (±)	0.11	0.07	0.07
CV (per cent)	0.31	0.20	0.19

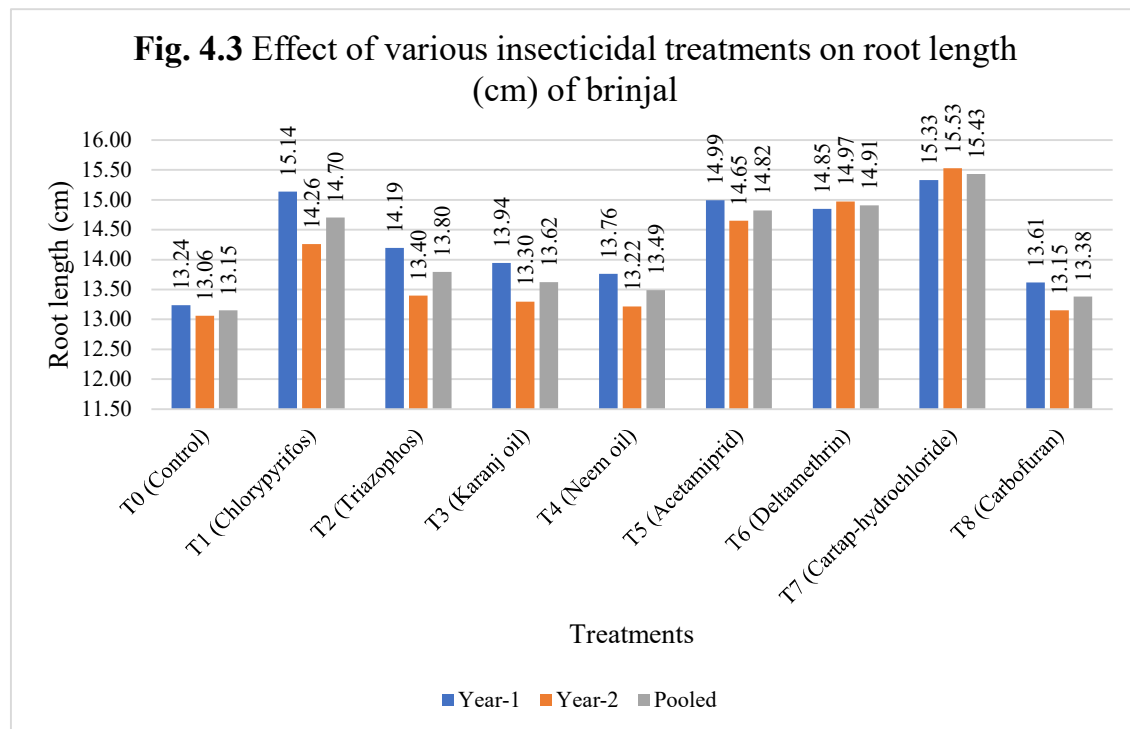


4.1.3 Root length (cm)

The data pertaining to the influence of several insecticidal applications on root length of brinjal during 2023, 2024 and the pooled analysis are shown in Table 4.3 and illustrated in Fig. 4.3. The findings demonstrated that root length varied significantly due to the impact of various insecticidal treatments. Among the selected insecticides, the highest root length of 15.33 cm was observed in treatment T₇ (Cartap hydrochloride 20% EC), which was *at par* with treatments T₁ (15.14 cm), T₅ (14.99 cm) and T₆ (14.85 cm), followed by T₂ (14.19 cm) during 2023. The lowest root length of 13.24 cm was obtained in treatment T₀ (Control), *at par* with T₈ (13.61 cm) and T₄ (13.76 cm) during 2023. During 2024 and in the pooled analysis, the highest root lengths of 15.53 and 15.43 cm were recorded in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (14.97 and 14.91 cm). The lowest root lengths of 13.06 and 13.15 cm were observed in treatment T₀ (Control), which was *at par* with T₈ (13.15 and 13.38 cm) during 2024 and in the pooled analysis. This may be attributed to the ability of synthetic insecticides to effectively reduce pest density, thereby preventing damage caused by sap-feeding insects. They also help in maintaining the plant physiology and essential natural processes, such as nutrient uptake, photosynthesis, and the stimulation of vegetative and root growth (Farhan *et al.*, 2022). The recent findings are in close conformity with the suggestions of Singh *et al.*, 2018a, who reported that synthetic insecticides at optimal dosages increased the root length of brinjal.

Table 4.3: Effect of various insecticidal treatments on root length (cm) of brinjal

Treatments	Root Length (cm)		
	2023	2024	Pooled
T₀ (Control)	13.24 ^c ± 0.05	13.06 ^f ± 0.16	13.15 ^e ± 0.05
T₁ (Chlorpyrifos 20% EC)	15.14 ^a ± 0.14	14.26 ^d ± 0.15	14.70 ^b ± 0.10
T₂ (Triazophos 40% EC)	14.19 ^b ± 0.48	13.40 ^e ± 0.11	13.80 ^e ± 0.19
T₃ (Karanj oil 1%)	13.94 ^b ± 0.54	13.30 ^e ± 0.03	13.62 ^{cd} ± 0.26
T₄ (Neem oil 1%)	13.76 ^{bc} ± 0.50	13.22 ^{ef} ± 0.18	13.49 ^d ± 0.16
T₅ (Acetamiprid 20% SP)	14.99 ^a ± 0.12	14.65 ^c ± 0.11	14.82 ^b ± 0.10
T₆ (Deltamethrin 2.8% EC)	14.85 ^a ± 0.01	14.97 ^b ± 0.09	14.91 ^b ± 0.04
T₇ (Cartap hydrochloride 50% SP)	15.33 ^a ± 0.16	15.53 ^a ± 0.07	15.43 ^a ± 0.06
T₈ (Carbofuran 3% CG)	13.61 ^{bc} ± 0.56	13.15 ^f ± 0.21	13.38 ^{de} ± 0.19
CD (P=0.05)	0.63	0.22	0.27
SE_m (±)	0.21	0.07	0.09
CV (per cent)	2.53	0.92	1.08

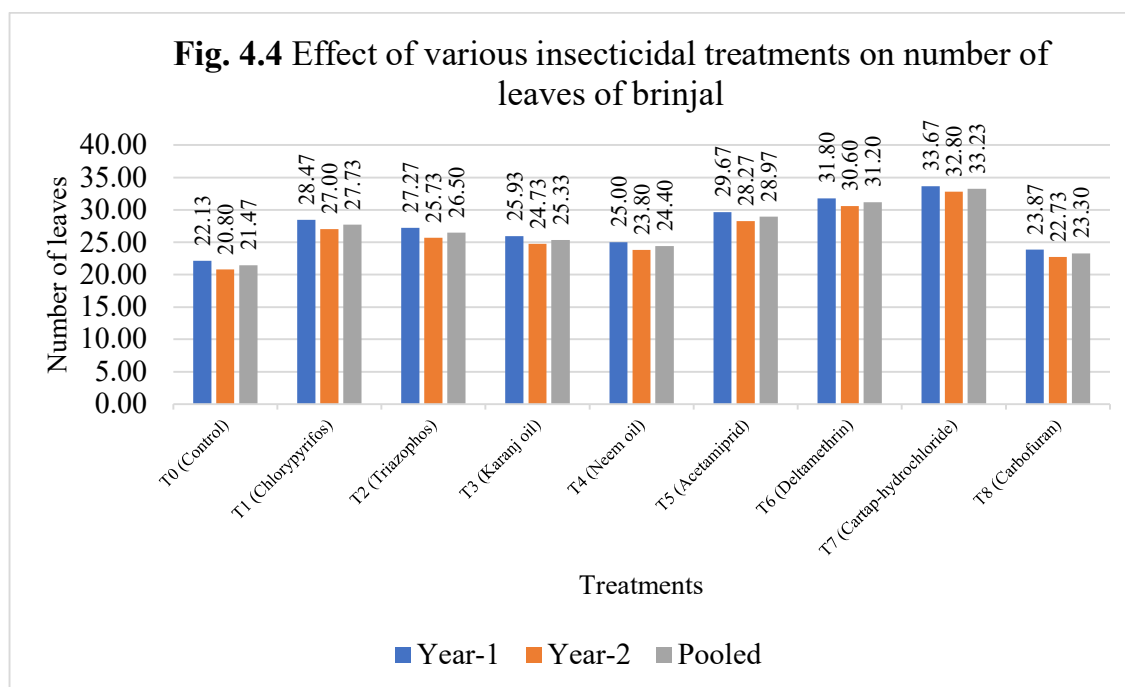


4.1.4 Number of leaves

The data related to the number of leaves showed significant variation under the influence of different insecticidal treatments compared to the control in brinjal. The data recorded on number of leaves of brinjal for the years 2023, 2024 and the pooled analysis are depicted in Table 4.4 and Fig. 4.4. The maximum number of leaves (33.67, 32.80 and 33.23) were observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by the treatment T₆ (31.80, 30.60 and 31.20) whereas minimum number of leaves (22.13, 20.80 and 21.47) were recorded in treatment T₀ (Control), followed by the treatment T₈ (23.87, 22.73 and 23.30) during 2023, 2024 and pooled analysis. The improved effectiveness of pesticides implies a stronger effect on targeted pests while causing minimal harm to plants, resulting in healthier plant growth (Yadav *et al.*, 2024). The aforementioned results were in line with the conclusions drawn by Priyanka (2015) in brinjal. The above findings were also supported by Yadav *et al.*, 2024, who suggested that spraying of insecticides increased the number of leaves in cucumber crop.

Table 4.4: Effect of various insecticidal treatments on number of leaves of brinjal

Treatments	Number of leaves		
	2023	2024	Pooled
T₀ (Control)	22.13 ^h ± 0.83	20.80 ^h ± 0.87	21.47 ⁱ ± 0.85
T₁ (Chlorpyrifos 20% EC)	28.47 ^d ± 0.64	27.00 ^d ± 0.20	27.73 ^d ± 0.40
T₂ (Triazophos 40% EC)	27.27 ^e ± 0.50	25.73 ^e ± 0.31	26.50 ^e ± 0.36
T₃ (Karanj oil 1%)	25.93 ^f ± 0.81	24.73 ^f ± 0.50	25.33 ^f ± 0.42
T₄ (Neem oil 1%)	25.00 ^f ± 0.20	23.80 ^f ± 0.20	24.40 ^g ± 0.20
T₅ (Acetamiprid 20% SP)	29.67 ^c ± 0.50	28.27 ^c ± 0.50	28.97 ^c ± 0.50
T₆ (Deltamethrin 2.8% EC)	31.80 ^b ± 0.20	30.60 ^b ± 0.87	31.20 ^b ± 0.53
T₇ (Cartap hydrochloride 50% SP)	33.67 ^a ± 0.81	32.80 ^a ± 0.80	33.23 ^a ± 0.45
T₈ (Carbofuran 3% CG)	23.87 ^g ± 0.31	22.73 ^g ± 0.90	23.30 ^h ± 0.60
CD (P=0.05)	0.94	0.97	0.73
SE_m (±)	0.31	0.32	0.24
CV (per cent)	1.96	2.12	1.55



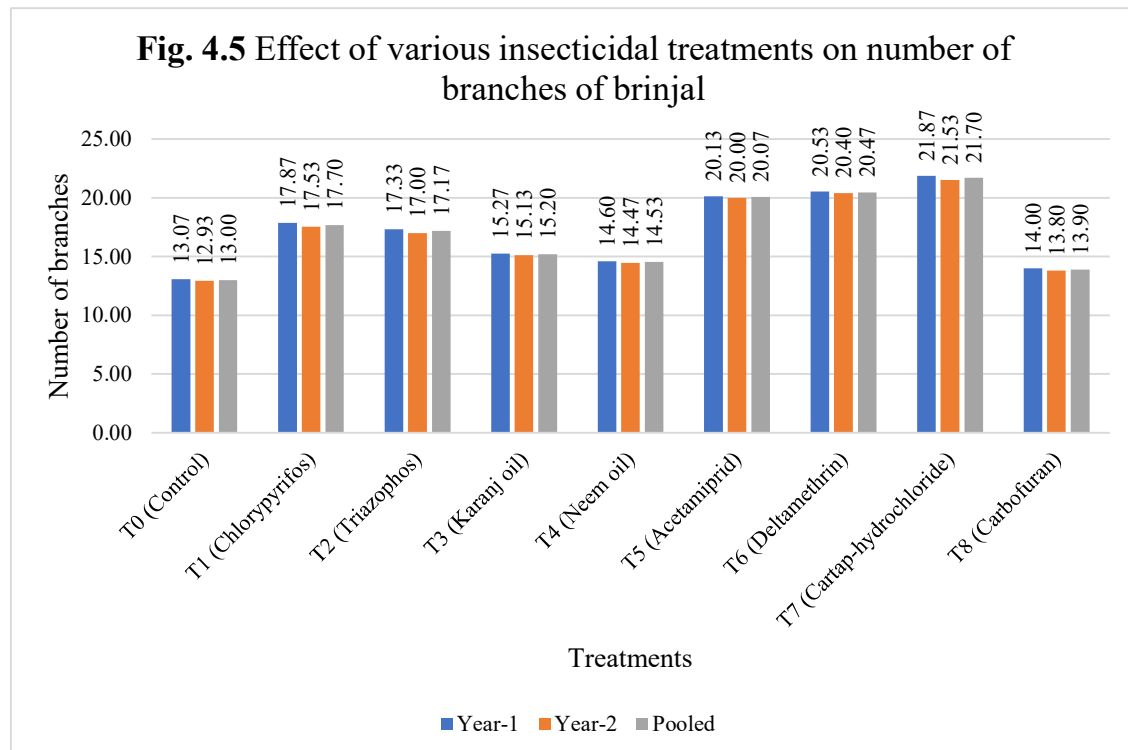
4.1.5 Number of branches

The perusal of data on the number of branches of brinjal revealed significant variation among the various treatments compared to the control. The mean data for the years 2023, 2024 and pooled analysis are illustrated in Table 4.5 and Fig. 4.5. Among the selected treatments, the maximum number of branches (21.87 cm) during the first year of research were recorded in T₇ (Cartap hydrochloride 20% EC) followed by the treatment T₆ (20.53 cm) and T₅ (20.13 cm), while minimum (13.07 cm) was observed in T₀ (Control) followed by the treatment T₈ (14.00 cm). In the second year, the maximum number of branches (21.53 cm) were also observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (20.40 cm) while the lowest (12.93 cm) was observed in T₀ (Control). During the pooled analysis, the maximum number of branches (21.70 cm) were observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (20.47 cm), while the minimum (13.00 cm) was found in T₀ (Control), respectively. Multiple factors, including the influence of pesticides, may contribute to variations in number of branches. Shoot branching is influenced by the crop's genotype, growth stage and meteorological conditions. A network of interrelated hormonal signals is likely responsible for integrating these factors. Insecticides can alter hormone formation and concentration in plants (Dhungana *et al.*, 2020). The process of shoot branching is primarily regulated by different hormones such as auxin, strigolactone and cytokinin. Optimal hormonal regulation is essential for hormone formation and signaling, which ultimately enhances plant growth and development. The significant increase in number of branches may be attributed to

enhanced plant growth. The above findings were closely agreed by the findings reported by Begum *et al.*, 2024 who suggested that synthetic insecticides significantly increased the number of branches in brinjal.

Table 4.5: Effect of various insecticidal treatments on number of branches of brinjal

Treatments	Number of branches		
	2023	2024	Pooled
T₀ (Control)	13.07 ^f ± 0.12	12.93 ^f ± 0.12	13.00 ^f ± 0.10
T₁ (Chlorpyrifos 20% EC)	17.87 ^c ± 0.12	17.53 ^c ± 0.12	17.70 ^c ± 0.10
T₂ (Triazophos 40% EC)	17.33 ^c ± 0.12	17.00 ^c ± 0.20	17.17 ^c ± 0.15
T₃ (Karanj oil 1%)	15.27 ^d ± 0.12	15.13 ^d ± 0.12	15.20 ^d ± 0.10
T₄ (Neem oil 1%)	14.60 ^{de} ± 0.20	14.47 ^{de} ± 0.23	14.53 ^{de} ± 0.21
T₅ (Acetamiprid 20% SP)	20.13 ^b ± 0.23	20.00 ^b ± 0.20	20.07 ^b ± 0.21
T₆ (Deltamethrin 2.8% EC)	20.53 ^b ± 0.23	20.40 ^b ± 0.20	20.47 ^b ± 0.21
T₇ (Cartap hydrochloride 50% SP)	21.87 ^a ± 1.29	21.53 ^a ± 1.22	21.70 ^a ± 1.22
T₈ (Carbofuran 3% CG)	14.00 ^e ± 0.20	13.80 ^e ± 0.20	13.90 ^e ± 0.20
CD (P=0.05)	0.83	0.79	0.79
SE_m (±)	0.27	0.26	0.26
CV (per cent)	2.76	2.68	2.64

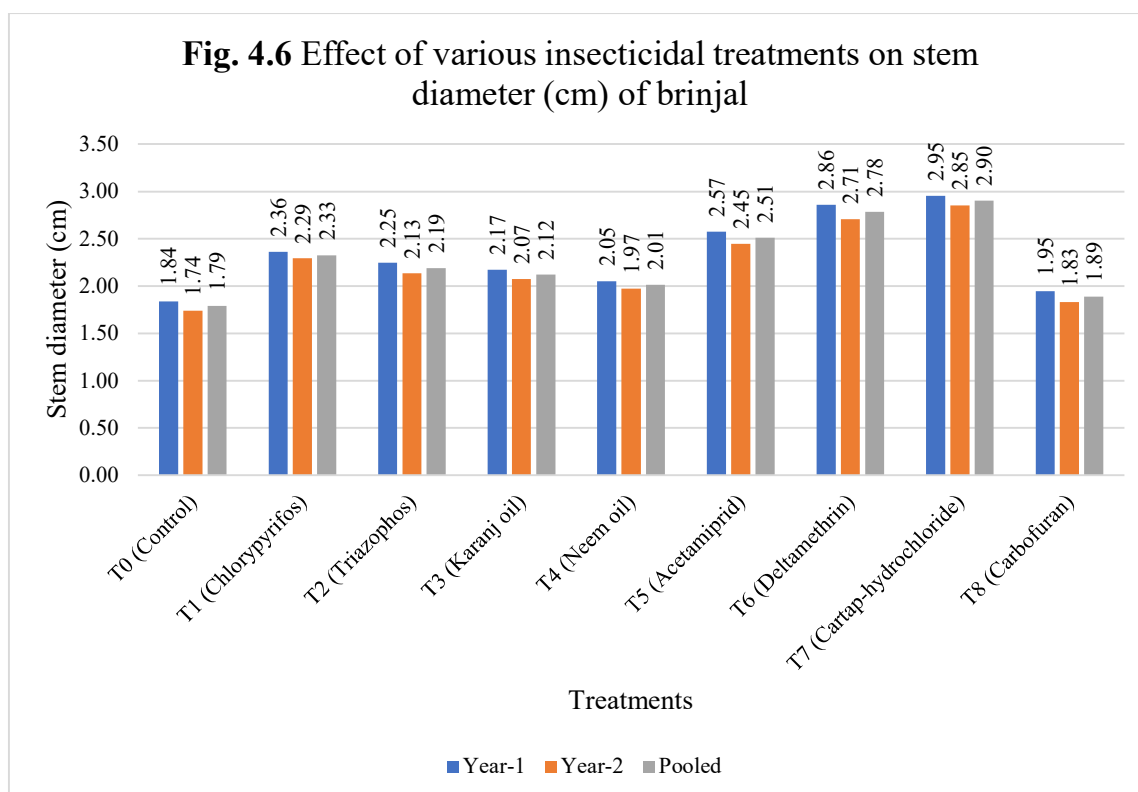


4.1.6 Stem diameter (cm)

The observations recorded on the stem diameter of brinjal influenced by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.6 and Fig. 4.6. It is evident that there was a significant variation on stem diameter with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the largest stem diameter (2.95, 2.85 and 2.90 cm) was recorded in treatment T₇ (Cartap hydrochloride 20% EC) followed by T₆ (2.86, 2.71 and 2.78 cm) during 2023, 2024 and the pooled analysis. The smallest stem diameter (1.84, 1.74 and 1.79 cm) was observed in treatment T₀ (Control) followed by treatment T₈ (1.95, 1.83 and 1.89 cm) during 2023, 2024 and the pooled analysis, respectively. Various factors, including the influence of pesticides, may contribute to variations in stem diameter. It may also be influenced by the crop's genotype, growth stage and prevailing meteorological conditions (Dhungana *et al.*, 2020). A significant increase in stem diameter is likely directly related to enhanced plant growth and overall health. The above findings were closely agreed by the findings reported by Sammaiah *et al.*, 2011 who suggested that applying synthetic insecticides at optimal concentrations significantly increased the stem diameter of brinjal.

Table no. 4.6: Effect of various insecticidal treatments on stem diameter (cm) of brinjal

Treatments	Stem diameter (cm)		
	2023	2024	Pooled
T ₀ (Control)	1.84 ⁱ ± 0.04	1.74 ⁱ ± 0.02	1.79 ⁱ ± 0.03
T ₁ (Chlorpyrifos 20% EC)	2.36 ^d ± 0.05	2.29 ^d ± 0.03	2.33 ^d ± 0.04
T ₂ (Triazophos 40% EC)	2.25 ^c ± 0.03	2.13 ^c ± 0.03	2.19 ^c ± 0.03
T ₃ (Karanj oil 1%)	2.17 ^f ± 0.03	2.07 ^f ± 0.03	2.12 ^f ± 0.02
T ₄ (Neem oil 1%)	2.05 ^g ± 0.03	1.97 ^g ± 0.03	2.01 ^g ± 0.03
T ₅ (Acetamiprid 20% SP)	2.57 ^c ± 0.05	2.45 ^c ± 0.03	2.51 ^c ± 0.02
T ₆ (Deltamethrin 2.8% EC)	2.86 ^b ± 0.04	2.71 ^b ± 0.05	2.78 ^b ± 0.04
T ₇ (Cartap hydrochloride 50% SP)	2.95 ^a ± 0.03	2.85 ^a ± 0.04	2.90 ^a ± 0.03
T ₈ (Carbofuran 3% CG)	1.95 ^h ± 0.03	1.83 ^h ± 0.03	1.89 ^h ± 0.03
CD (P=0.05)	0.07	0.05	0.05
SE _m (±)	0.02	0.02	0.02
CV (per cent)	1.60	1.36	1.17

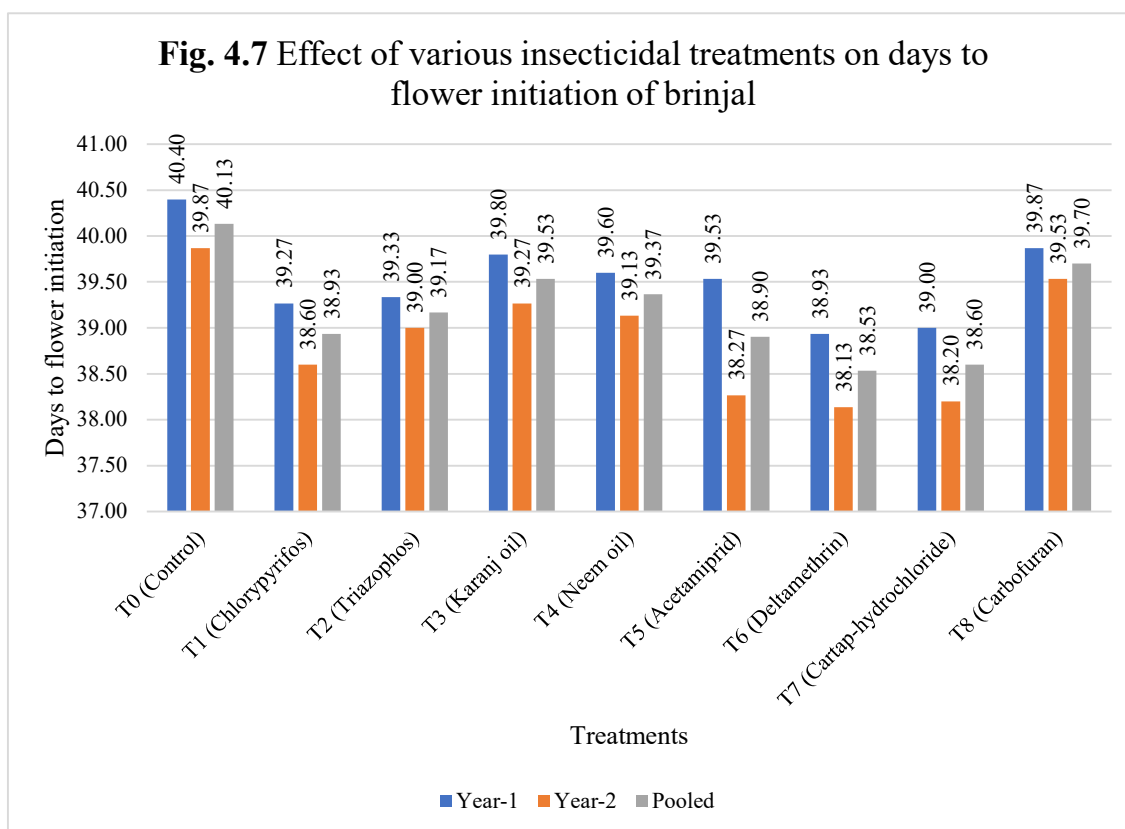


4.1.7 Days to flower initiation

The observations recorded on the days to flower initiation of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.7 and Fig. 4.7. It is evident that there was no significant variation in the days to flower initiation with respect to various insecticidal treatments in brinjal. Among the various insecticidal treatments, the minimum days to flower initiation (38.93, 38.13 and 38.53) were recorded in treatment T₆ (Deltamethrin 2.8% EC) during 2023, 2024 and the pooled analysis. The maximum days to flower initiation (40.40, 39.87 and 40.13) were observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively. The improved effectiveness of pesticides implies a stronger effect on targeted pests while causing minimal harm to plants, resulting in healthier plant growth (Yadav *et al.*, 2024). The above findings were closely supported by the findings reported by Khatun *et al.*, 2015, who suggested synthetic insecticides applied at recommended doses have non-significant effect on the days to flower initiation of chickpea.

Table no. 4.7: Effect of various insecticidal treatments on days to flower initiation of brinjal

Treatments	Days to flower initiation		
	2023	2024	Pooled
T₀ (Control)	40.40 ^a ± 0.87	39.87 ^a ± 0.61	40.13 ^a ± 0.71
T₁ (Chlorpyrifos 20% EC)	39.27 ^a ± 0.12	38.60 ^{ab} ± 0.69	38.93 ^{ab} ± 0.40
T₂ (Triazophos 40% EC)	39.33 ^a ± 1.90	39.00 ^{ab} ± 0.53	39.17 ^{ab} ± 1.17
T₃ (Karanj oil 1%)	39.80 ^a ± 0.69	39.27 ^{ab} ± 0.46	39.53 ^{ab} ± 0.50
T₄ (Neem oil 1%)	39.60 ^a ± 0.53	39.13 ^{ab} ± 0.12	39.37 ^{ab} ± 0.31
T₅ (Acetamiprid 20% SP)	39.53 ^a ± 0.58	38.27 ^b ± 0.12	38.90 ^{ab} ± 0.26
T₆ (Deltamethrin 2.8% EC)	38.93 ^a ± 1.10	38.13 ^b ± 2.00	38.53 ^b ± 1.50
T₇ (Cartap hydrochloride 50% SP)	39.00 ^a ± 1.64	38.20 ^b ± 0.20	38.60 ^b ± 0.75
T₈ (Carbofuran 3% CG)	39.87 ^a ± 1.15	39.53 ^{ab} ± 0.58	39.70 ^{ab} ± 0.87
CD (P=0.05)	NS	NS	NS
SE_m (±)	0.60	0.43	0.44
CV (per cent)	2.61	1.92	1.92

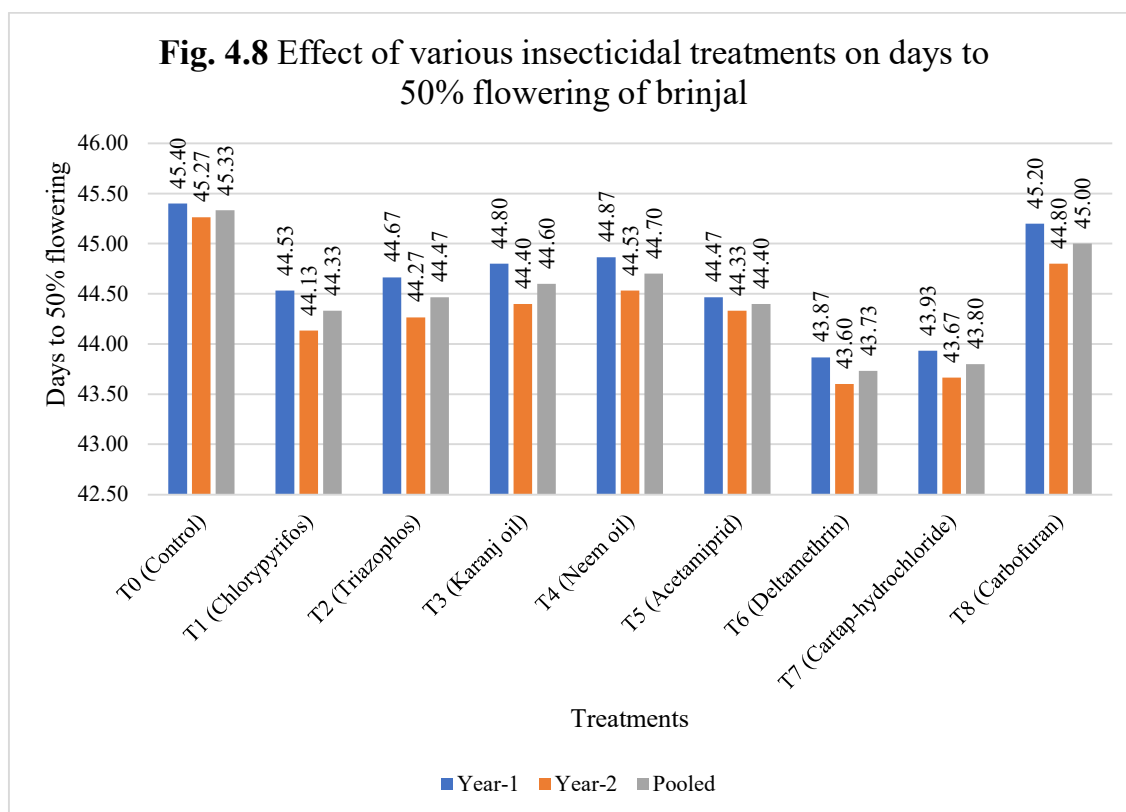


4.1.8 Days to 50% flowering

The observations recorded on the days to 50% flowering of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.8 and Fig. 4.8. It is evident that there was no significant variation in the days to 50% flowering with respect to various insecticidal treatments in brinjal. Among the various insecticidal treatments, the minimum days to 50% flowering (43.87, 43.60 and 43.73) were recorded in treatment T₆ (Deltamethrin 2.8% EC) during 2023, 2024 and the pooled analysis. The maximum days to 50% flowering (45.40, 45.27 and 45.33) were observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively. The above findings were closely supported by the findings reported by Khatun *et al.*, 2015 who suggested synthetic insecticides applied at recommended doses have non-significant effect on the days to 50% flowering of chickpea. Similarly, Bukar *et al.*, 2023 reported that insecticidal treatments have non-significant impact on the days to 50% flowering of watermelon.

Table no. 4.8: Effect of various insecticidal treatments on days to 50% flowering of brinjal

Treatments	Days to 50% flowering		
	2023	2024	Pooled
T₀ (Control)	45.40 ^a ± 0.87	45.27 ^a ± 0.90	45.33 ^a ± 0.87
T₁ (Chlorpyrifos 20% EC)	44.53 ^a ± 0.23	44.13 ^a ± 0.11	44.33 ^a ± 0.15
T₂ (Triazophos 40% EC)	44.67 ^a ± 2.20	44.27 ^a ± 2.00	44.47 ^a ± 2.10
T₃ (Karanj oil 1%)	44.80 ^a ± 0.69	44.40 ^a ± 1.04	44.60 ^a ± 0.87
T₄ (Neem oil 1%)	44.87 ^a ± 0.50	44.53 ^a ± 0.61	44.70 ^a ± 0.56
T₅ (Acetamiprid 20% SP)	44.47 ^a ± 0.64	44.33 ^a ± 0.58	44.40 ^a ± 0.61
T₆ (Deltamethrin 2.8% EC)	43.87 ^a ± 0.99	43.60 ^a ± 0.87	43.73 ^a ± 0.93
T₇ (Cartap hydrochloride 50% SP)	43.93 ^a ± 1.62	43.67 ^a ± 1.53	43.80 ^a ± 1.57
T₈ (Carbofuran 3% CG)	45.20 ^a ± 1.39	44.80 ^a ± 1.22	45.00 ^a ± 1.30
CD (P=0.05)	NS	NS	NS
SE_m (±)	0.64	0.60	0.61
CV (per cent)	2.47	2.34	2.39

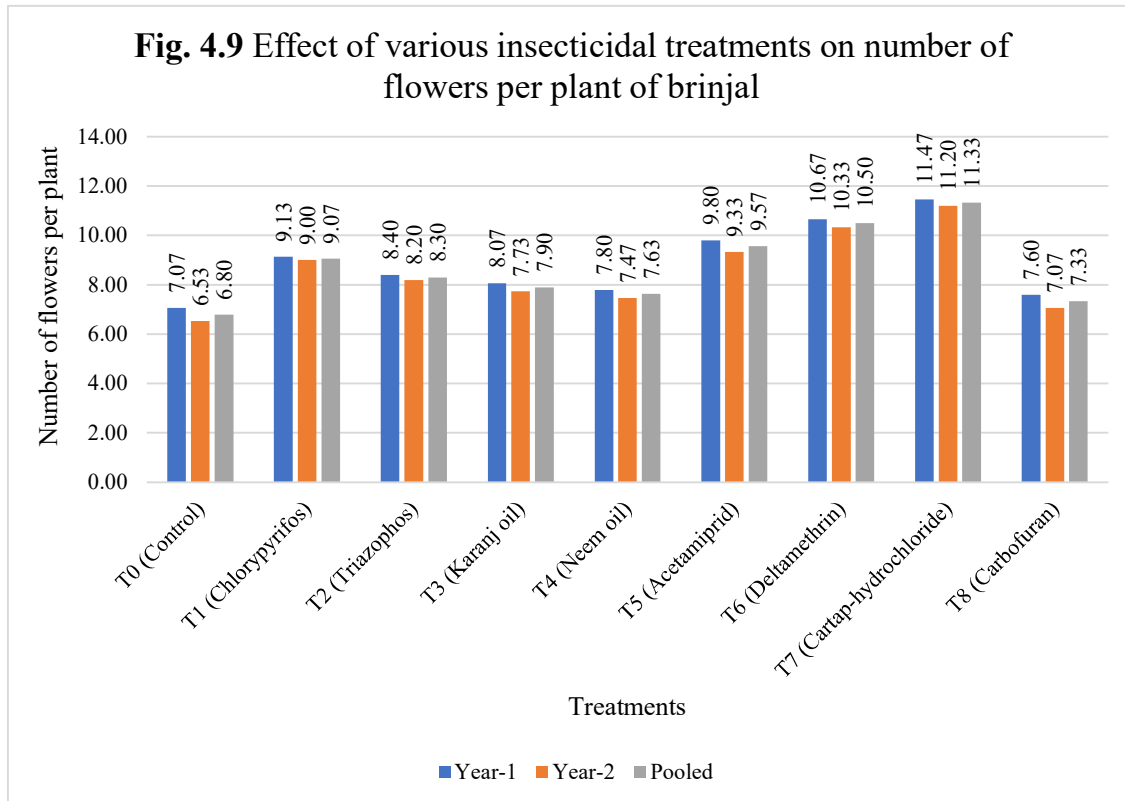


4.1.9 Number of flowers per plant

The data pertaining to the influence of various insecticidal applications on number of flowers per plant in brinjal during 2023, 2024 and the pooled analysis are shown in Table 4.9 and illustrated in Fig. 4.9. The findings indicated that the number of flowers per plant varied significantly due to the impact of various insecticidal treatments. Among the selected insecticides, the maximum number of flowers per plant (11.47, 11.20 and 11.33) were recorded in T₇ (Cartap hydrochloride 20% EC), followed by T₆ (10.67, 10.33 and 10.50), which were not statistically identical and performed better than the other insecticides during 2023, 2024 and the pooled analysis. The minimum number of flowers per plant (7.07, 6.53 and 6.80) were observed in treatment T₀ (Control), followed by T₈ (7.60, 7.07 and 7.33) during 2023, 2024 and the pooled analysis. This is because synthetic insecticides have been shown to effectively reduce pest density, preventing damage caused by plant-feeding insects (Shah *et al.*, 2019). This reduction in pest pressure decreases plant stress and enhances growth, thereby significantly increasing flower production. The above findings were in close agreement with the results of Ullah *et al.*, 2022, who suggested that synthetic insecticides at optimal dosages significantly increased the number of flowers per plant in brinjal.

Table no. 4.9: Effect of various insecticidal treatments on number of flowers per plant of brinjal

Treatments	Number of flowers per plant		
	2023	2024	Pooled
T₀ (Control)	7.07 ^g ± 0.23	6.53 ^g ± 0.23	6.80 ^h ± 0.20
T₁ (Chlorpyrifos 20% EC)	9.13 ^d ± 0.12	9.00 ^c ± 0.35	9.07 ^d ± 0.12
T₂ (Triazophos 40% EC)	8.40 ^e ± 0.20	8.20 ^d ± 0.53	8.30 ^e ± 0.35
T₃ (Karanj oil 1%)	8.07 ^{ef} ± 0.12	7.73 ^{de} ± 0.12	7.90 ^{ef} ± 0.10
T₄ (Neem oil 1%)	7.80 ^f ± 0.20	7.47 ^{ef} ± 0.31	7.63 ^{fg} ± 0.25
T₅ (Acetamiprid 20% SP)	9.80 ^c ± 0.20	9.33 ^c ± 0.12	9.57 ^c ± 0.15
T₆ (Deltamethrin 2.8% EC)	10.67 ^b ± 0.61	10.33 ^b ± 0.61	10.50 ^b ± 0.60
T₇ (Cartap hydrochloride 50% SP)	11.47 ^a ± 0.31	11.20 ^a ± 0.20	11.33 ^a ± 0.25
T₈ (Carbofuran 3% CG)	7.60 ^f ± 0.20	7.07 ^f ± 0.12	7.33 ^g ± 0.12
CD (P=0.05)	0.47	0.53	0.45
SE_m (±)	0.16	0.18	0.15
CV (per cent)	3.04	3.58	2.95

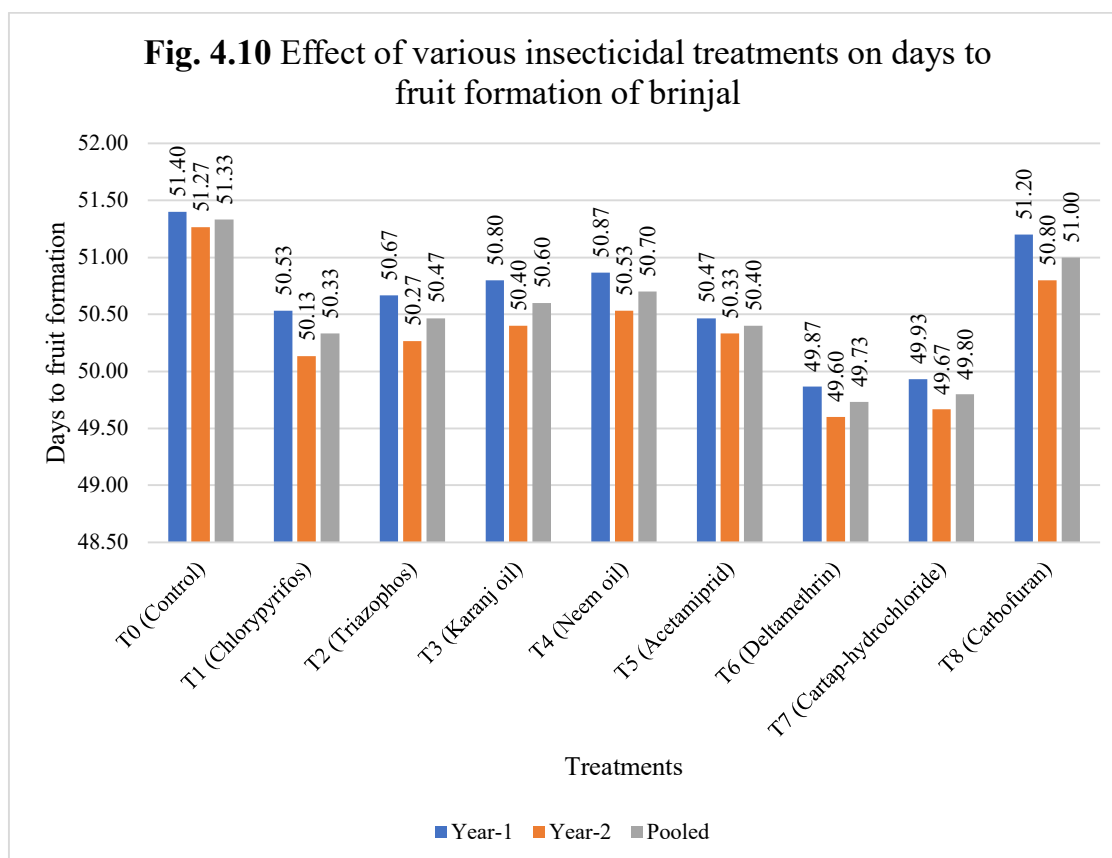


4.1.10 Days to fruit formation

The observations recorded on the days to fruit formation of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.10 and Fig. 4.10. It is evident that there was no significant variation in the days to fruit formation with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the minimum days to fruit formation (49.87, 49.60 and 49.73) were recorded in treatment T₆ (Deltamethrin 2.8% EC) during 2023, 2024 and the pooled analysis. The maximum days to fruit formation (51.40, 51.27 and 51.33) were observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively. By mitigating the detrimental effects of insect damage on plant growth, pesticides contribute positively to overall plant productivity and health. The above findings are closely supported by the findings reported by Bukar *et al.*, 2023 who suggested that insecticidal treatments have a non-significant effect on the days to fruit formation in watermelon.

Table no. 4.10: Effect of various insecticidal treatments on days to fruit formation of brinjal

Treatments	Days to fruit formation		
	2023	2024	Pooled
T ₀ (Control)	51.40 ^a ± 0.87	51.27 ^a ± 0.90	51.33 ^a ± 0.87
T ₁ (Chlorpyrifos 20% EC)	50.53 ^a ± 0.23	50.13 ^a ± 0.12	50.33 ^a ± 0.15
T ₂ (Triazophos 40% EC)	50.67 ^a ± 2.20	50.27 ^a ± 2.00	50.47 ^a ± 2.10
T ₃ (Karanj oil 1%)	50.80 ^a ± 0.69	50.40 ^a ± 1.03	50.60 ^a ± 0.87
T ₄ (Neem oil 1%)	50.87 ^a ± 0.50	50.53 ^a ± 0.61	50.70 ^a ± 0.56
T ₅ (Acetamiprid 20% SP)	50.47 ^a ± 0.64	50.33 ^a ± 0.58	50.40 ^a ± 0.61
T ₆ (Deltamethrin 2.8% EC)	49.87 ^a ± 0.99	49.60 ^a ± 0.87	49.73 ^a ± 0.93
T ₇ (Cartap hydrochloride 50% SP)	49.93 ^a ± 1.62	49.67 ^a ± 1.53	49.80 ^a ± 1.57
T ₈ (Carbofuran 3% CG)	51.20 ^a ± 1.39	50.80 ^a ± 1.22	51.00 ^a ± 1.30
CD (P=0.05)	NS	NS	NS
SE _m (±)	0.64	0.60	0.61
CV (per cent)	2.18	2.06	2.11

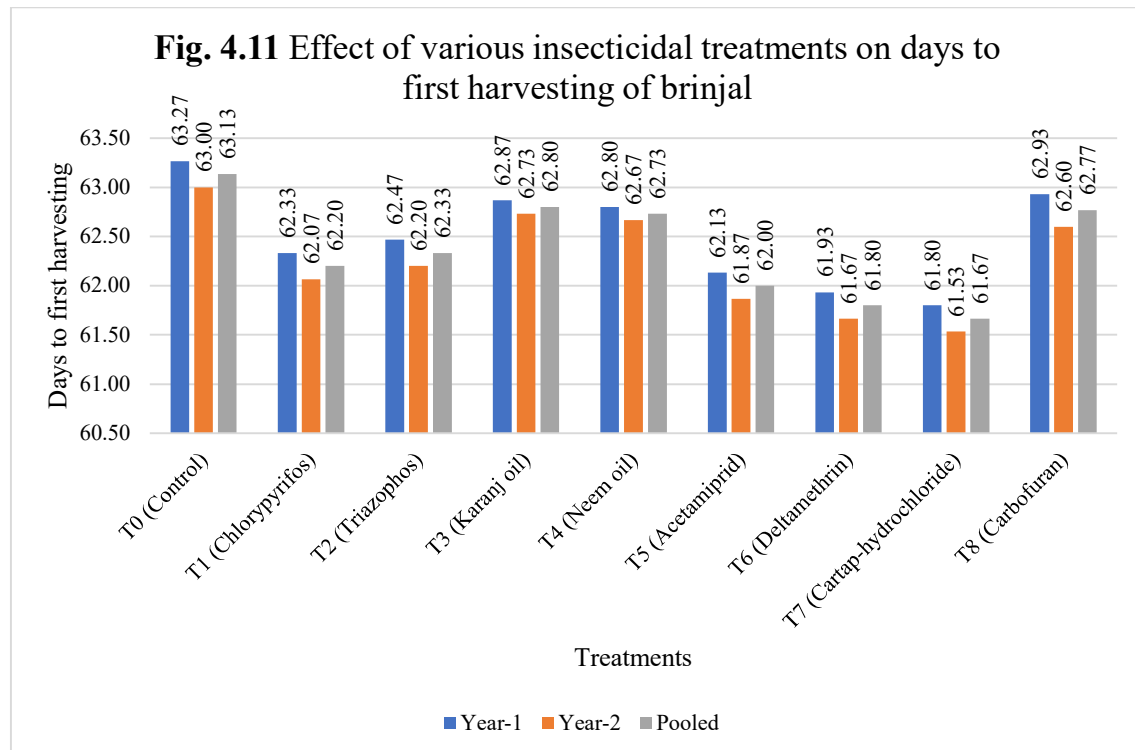


4.1.11 Days to first harvesting

The observations recorded on the days to first harvesting of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis has been depicted in Table 4.11 and Fig. 4.11. It is evident that there was no significant variation in the days to first harvesting with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the minimum days to first harvesting (61.80, 61.53 and 61.67) were recorded in treatment T₇ (Cartap hydrochloride 20% EC) during 2023, 2024 and the pooled analysis. The maximum days to first harvesting (63.27, 63.00 and 63.13) were observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively. By mitigating the detrimental effects of insect damage on plant growth, pesticides contribute positively to overall plant productivity and health. The above findings were closely supported by the findings reported by Khatun *et al.*, 2015 who suggested synthetic insecticides applied at recommended doses have non-significant effect on the days to first harvesting of chickpea.

Table no. 4.11: Effect of various insecticidal treatments on days to first harvesting of brinjal

Treatments	Days to first harvesting		
	2023	2024	Pooled
T₀ (Control)	63.27 ^a ± 1.03	63.00 ^a ± 0.92	63.13 ^a ± 0.97
T₁ (Chlorpyrifos 20% EC)	62.33 ^a ± 0.12	62.07 ^a ± 0.12	62.20 ^a ± 0.10
T₂ (Triazophos 40% EC)	62.47 ^a ± 1.92	62.20 ^a ± 1.91	62.33 ^a ± 1.91
T₃ (Karanj oil 1%)	62.87 ^a ± 0.83	62.73 ^a ± 0.46	62.80 ^a ± 0.60
T₄ (Neem oil 1%)	62.80 ^a ± 0.69	62.67 ^a ± 0.83	62.73 ^a ± 0.61
T₅ (Acetamiprid 20% SP)	62.13 ^a ± 0.12	61.87 ^a ± 0.12	62.00 ^a ± 0.10
T₆ (Deltamethrin 2.8% EC)	61.93 ^a ± 1.62	61.67 ^a ± 1.30	61.80 ^a ± 1.45
T₇ (Cartap hydrochloride 50% SP)	61.80 ^a ± 1.04	61.53 ^a ± 1.10	61.67 ^a ± 1.07
T₈ (Carbofuran 3% CG)	62.93 ^a ± 1.27	62.60 ^a ± 1.22	62.77 ^a ± 1.24
CD (P=0.05)	NS	NS	NS
SE_m (±)	0.60	0.57	0.57
CV (per cent)	1.64	1.58	1.59

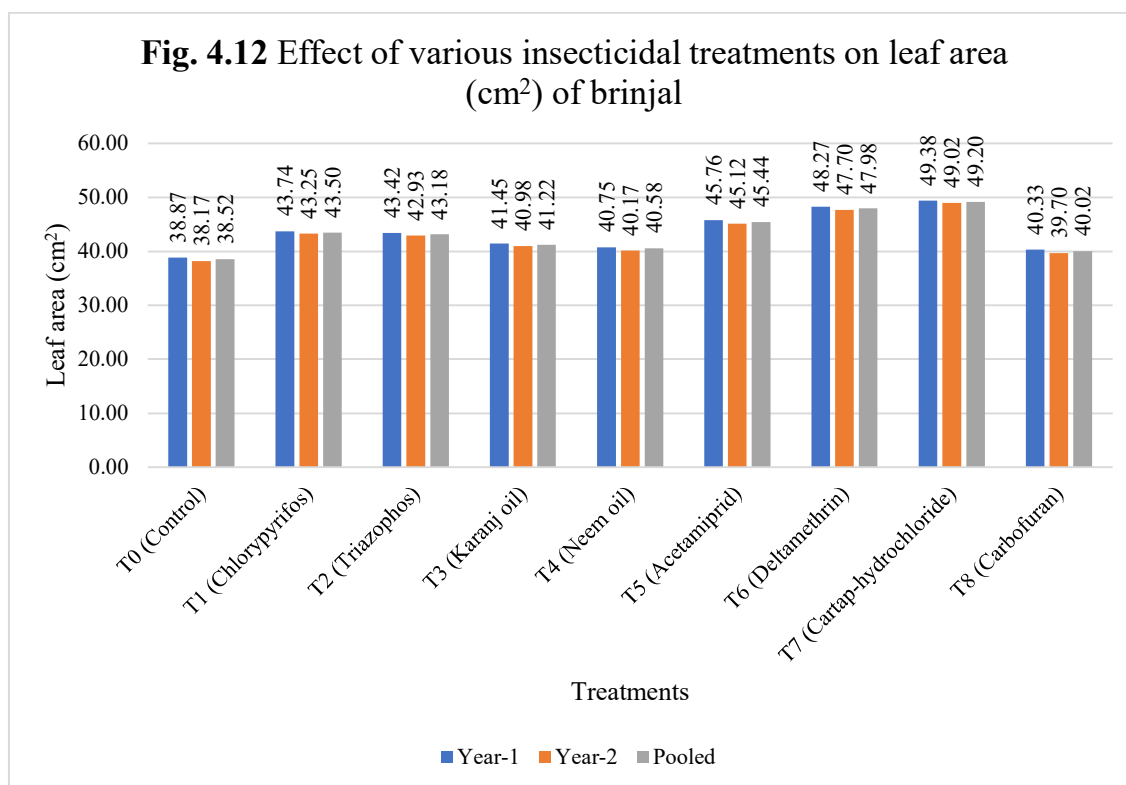


4.1.12 Leaf area (cm²)

The perusal of data on the leaf area of brinjal revealed significant variation among the various treatments compared to the control. The mean data for the years 2023, 2024 and pooled analysis are presented in Table 4.12 and Fig. 4.12. The maximum leaf area (49.38, 49.02 and 49.20 cm²) was recorded in T₇ (Cartap hydrochloride 20% EC) followed by T₆ (48.27, 47.70 and 47.98 cm²), which were not statistically similar and performed better than the other insecticides during 2023, 2024 and the pooled analysis. The minimum leaf area (38.87, 38.17 and 38.52 cm²) was observed in treatment T₀ (Control) followed by T₈ (40.33, 39.70 and 40.02 cm²) during 2023, 2024 and the pooled analysis. The application of insecticides during the crop's developmental stages contributes to maintaining pest populations below the Economic Threshold Level (ETL), thereby promoting improved growth and production characteristics (Meena *et al.*, 2023). The present results were in close conformity with the findings of Singh *et al.*, 2018a, who reported that chemical insecticides at lower concentrations significantly increased the leaf area of brinjal.

Table no. 4.12: Effect of various insecticidal treatments on leaf area (cm²) of brinjal

Treatments	Leaf area (cm ²)		
	2023	2024	Pooled
T₀ (Control)	38.87 ^g ± 0.55	38.17 ^g ± 0.61	38.52 ^g ± 0.13
T₁ (Chlorpyrifos 20% EC)	43.74 ^d ± 0.32	43.25 ^d ± 0.79	43.50 ^d ± 0.55
T₂ (Triazophos 40% EC)	43.42 ^d ± 0.20	42.93 ^d ± 0.31	43.18 ^d ± 0.07
T₃ (Karanj oil 1%)	41.45 ^e ± 0.41	40.98 ^e ± 0.50	41.22 ^e ± 0.33
T₄ (Neem oil 1%)	40.75 ^{ef} ± 0.43	40.17 ^{ef} ± 0.06	40.58 ^{ef} ± 0.20
T₅ (Acetamiprid 20% SP)	45.76 ^c ± 0.71	45.12 ^c ± 1.02	45.44 ^c ± 0.81
T₆ (Deltamethrin 2.8% EC)	48.27 ^b ± 0.25	47.70 ^b ± 0.51	47.98 ^b ± 0.35
T₇ (Cartap hydrochloride 50% SP)	49.38 ^a ± 0.23	49.02 ^a ± 0.71	49.20 ^a ± 0.45
T₈ (Carbofuran 3% CG)	40.33 ^f ± 0.28	39.70 ^f ± 0.48	40.02 ^f ± 0.23
CD (P=0.05)	0.72	0.98	0.69
SE_m (±)	0.24	0.32	0.23
CV (per cent)	0.95	1.30	0.91

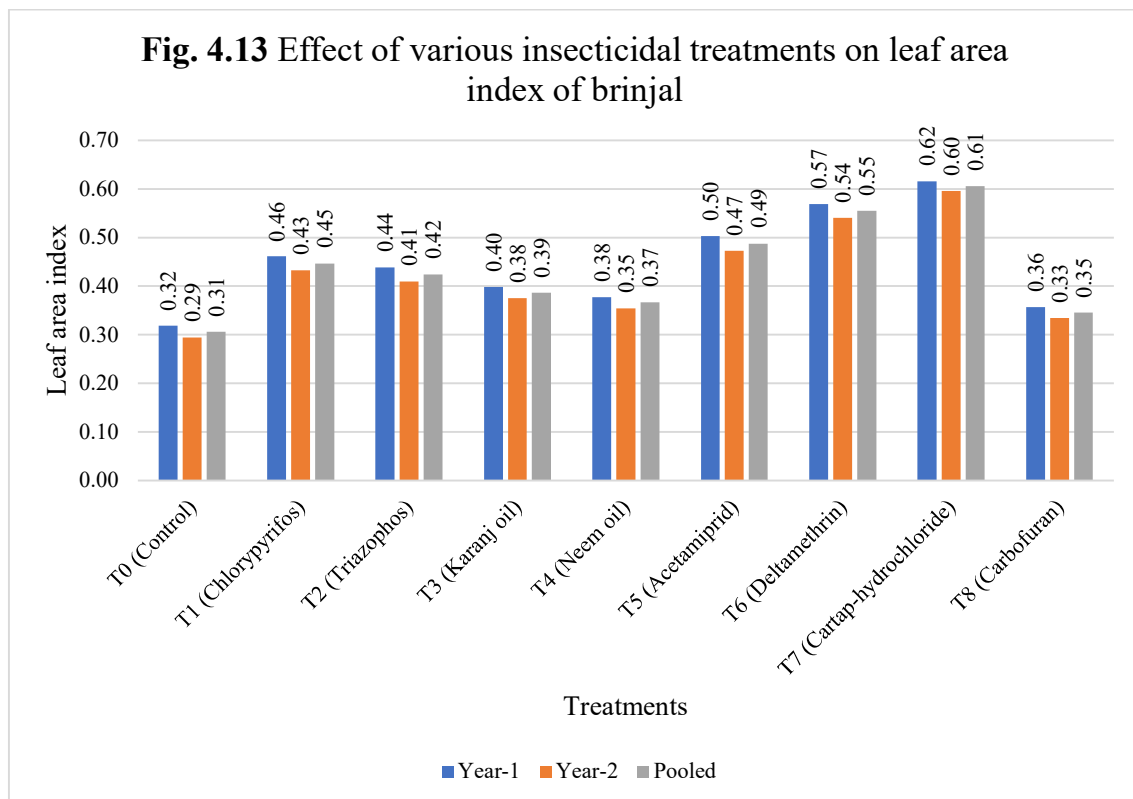


4.1.13 Leaf area index (LAI)

The data pertaining to the influence of various insecticidal treatments on leaf area index of brinjal during 2023, 2024 and the pooled analysis are presented in Table 4.13 and illustrated in Fig. 4.13. The findings indicated that the leaf area index was varied significantly by the impact of various insecticidal treatments. Among the selected insecticides, the highest leaf area index (0.62, 0.60 and 0.61) was recorded in T₇ (Cartap hydrochloride 20% EC) followed by T₆ (0.57, 0.54 and 0.55), which were not statistically similar and performed better than the other insecticides during 2023, 2024 and the pooled analysis. The lowest leaf area index (0.32, 0.29 and 0.31) was observed in treatment T₀ (Control) followed by T₈ (0.36, 0.33 and 0.35) during 2023, 2024 and the pooled analysis. The physiological functions of plants, including transpiration, respiration, stomatal conductance, and leaf photosynthesis, can be affected by insecticides. As a result, plant growth and development may be influenced, ultimately affecting their ability to reproduce (Chaudhary *et al.*, 2020). The aforementioned results were in line with the conclusions drawn by Gaikwad and Jirali, 2016, who suggested that insecticide treatments applied at lower dosages had a significant effect on leaf area index of brinjal.

Table no. 4.13: Effect of various insecticidal treatments on leaf area index (LAI) of brinjal

Treatments	Leaf area index (LAI)		
	2023	2024	Pooled
T₀ (Control)	0.32 ⁱ ± 0.02	0.29 ^h ± 0.02	0.31 ⁱ ± 0.02
T₁ (Chlorpyrifos 20% EC)	0.46 ^d ± 0.01	0.43 ^d ± 0.01	0.45 ^d ± 0.01
T₂ (Triazophos 40% EC)	0.44 ^c ± 0.01	0.41 ^c ± 0.01	0.42 ^c ± 0.01
T₃ (Karanj oil 1%)	0.40 ^f ± 0.01	0.38 ^f ± 0.01	0.39 ^f ± 0.01
T₄ (Neem oil 1%)	0.38 ^g ± 0.01	0.35 ^{fg} ± 0.01	0.37 ^g ± 0.01
T₅ (Acetamiprid 20% SP)	0.50 ^c ± 0.02	0.47 ^c ± 0.02	0.49 ^c ± 0.02
T₆ (Deltamethrin 2.8% EC)	0.57 ^b ± 0.01	0.54 ^b ± 0.02	0.55 ^b ± 0.02
T₇ (Cartap hydrochloride 50% SP)	0.62 ^a ± 0.02	0.60 ^a ± 0.02	0.61 ^a ± 0.01
T₈ (Carbofuran 3% CG)	0.36 ^h ± 0.01	0.33 ^g ± 0.02	0.35 ^h ± 0.02
CD (P=0.05)	0.02	0.02	0.02
SE_m (±)	0.01	0.01	0.01
CV (per cent)	2.37	2.80	2.00

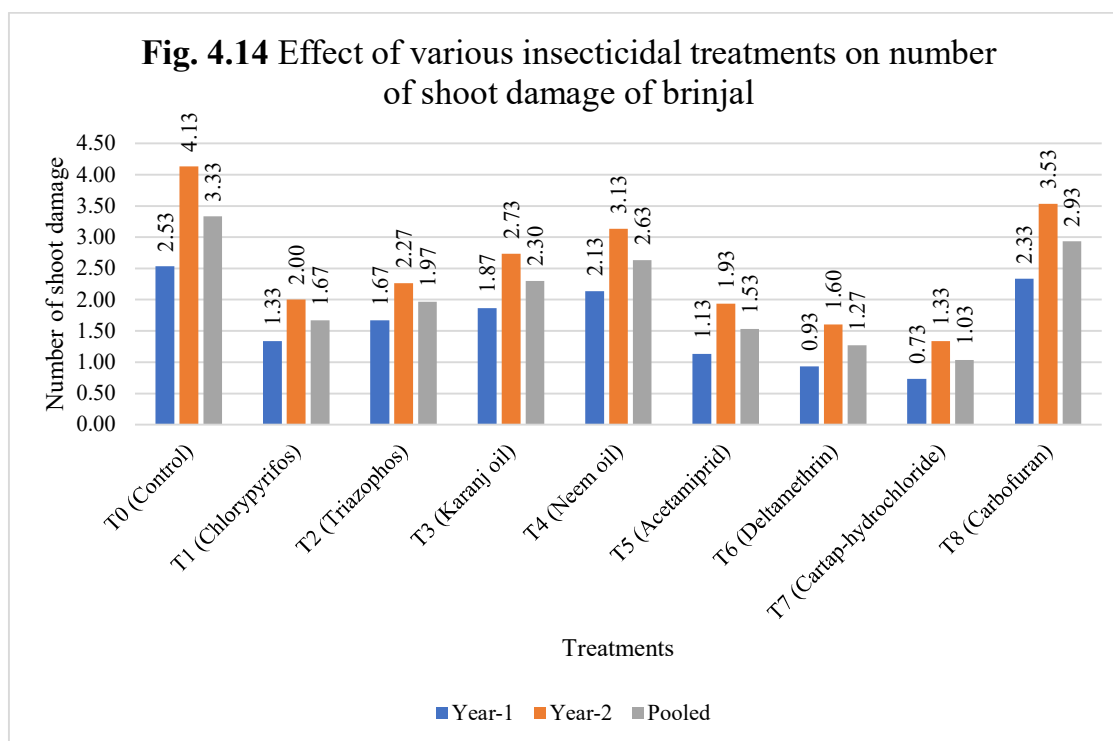


4.1.14 Number of shoot damage

The data pertaining to the influence of various insecticidal treatments on number of shoot damage in brinjal during 2023, 2024 and the pooled analysis is shown in Table 4.14 and illustrated in Fig. 4.14. The findings indicated that the number of shoot damage varied significantly due to the impact of various insecticidal treatments. Among the selected insecticides, the lowest number of shoot damage (0.73, 1.33 and 1.03) was recorded in T₇ (Cartap hydrochloride 20% EC), followed by T₆ (0.93, 1.60 and 1.27), which were not statistically similar and performed better than the other insecticides during 2023, 2024 and the pooled analysis. The highest number of shoot damage (2.53, 4.13 and 3.33) was observed in treatment T₀ (Control), followed by T₈ (2.33, 3.53 and 2.93) during 2023, 2024 and the pooled analysis. Insecticides were reported to kill both larvae and adults of *Leucinodes orbonalis* in the field, thereby reducing its population and the associated shoot damage (Latif *et al.*, 2010). Cartap hydrochloride, a pesticide classified under the nereistoxin analogue group, acts through both contact and systemic mechanisms (Sonawane and Rayate, 2018). This combined mechanism of action prevents larvae from boring into the shoots, thereby effectively minimizing shoot damage. These results align with the conclusions drawn by Thakur *et al.*, 2024, who suggested that cartap hydrochloride, when applied at the recommended dosage, is effective in reducing shoot damage in brinjal.

Table no. 4.14: Effect of various insecticidal treatments on number of shoot damage of brinjal

Treatments	Number of shoot damage		
	2023	2024	Pooled
T₀ (Control)	2.53 ^a ± 0.12	4.13 ^a ± 0.12	3.33 ^a ± 0.12
T₁ (Chlorpyrifos 20% EC)	1.33 ^f ± 0.12	2.00 ^f ± 0.20	1.67 ^f ± 0.15
T₂ (Triazophos 40% EC)	1.67 ^e ± 0.12	2.27 ^e ± 0.23	1.97 ^e ± 0.06
T₃ (Karanj oil 1%)	1.87 ^d ± 0.12	2.73 ^d ± 0.12	2.30 ^d ± 0.10
T₄ (Neem oil 1%)	2.13 ^c ± 0.12	3.13 ^c ± 0.12	2.63 ^c ± 0.12
T₅ (Acetamiprid 20% SP)	1.13 ^g ± 0.12	1.93 ^f ± 0.12	1.53 ^g ± 0.12
T₆ (Deltamethrin 2.8% EC)	0.93 ^h ± 0.12	1.60 ^g ± 0.20	1.27 ^h ± 0.15
T₇ (Cartap hydrochloride 50% SP)	0.73 ⁱ ± 0.12	1.33 ^h ± 0.23	1.03 ⁱ ± 0.06
T₈ (Carbofuran 3% CG)	2.33 ^b ± 0.12	3.53 ^b ± 0.12	2.93 ^b ± 0.12
CD (P=0.05)	0.15	0.23	0.13
SE_m (±)	0.05	0.08	0.04
CV (per cent)	5.15	5.17	3.54



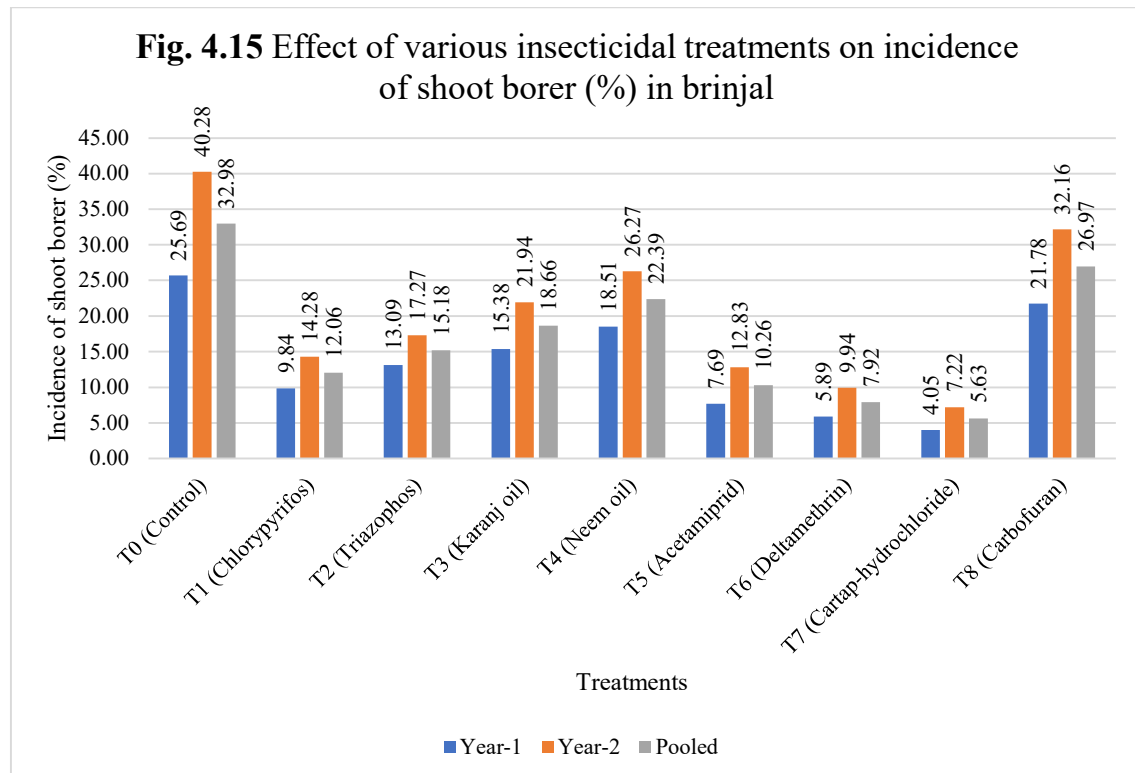
4.1.15 Incidence of shoot borer (%)

The data pertaining to the influence of various insecticidal treatments on the incidence of shoot borer in brinjal during 2023, 2024 and the pooled analysis is depicted in Table 4.15 and illustrated in Fig. 4.15. The findings indicated that the incidence of shoot borer varied significantly due to the impact of various insecticidal treatments. Among the selected insecticides, the minimum incidence of shoot borer (4.05, 7.22 and 5.63%) was recorded in T₇ (Cartap hydrochloride 20% EC) followed by T₆ (5.89, 9.94 and 7.92%), which were not statistically similar and performed better than the other insecticides during 2023, 2024 and the pooled analysis. The maximum incidence of shoot borer (25.69, 40.28 and 32.98%) was observed in treatment T₀ (Control) followed by T₈ (21.78, 32.16 and 26.97%) during 2023, 2024 and the pooled analysis. A pesticide belonging to the nereistoxin analogue group, cartap hydrochloride effectively controls insects through contact and systemic action (Sonawane and Rayate, 2018) while ensuring long-lasting plant protection, which further leads to an indirect impact on crop growth. The aforementioned results align with the conclusions drawn by Thakur *et al.*, 2024, who suggested that cartap hydrochloride, when applied at the recommended dosage, is effective in reducing the incidence of shoot borer in brinjal. Similarly, Samota and Jat (2014) reported moderate efficacy of cartap hydrochloride in reducing the incidence of shoot borer in brinjal. The difference in results could be attributed to ecological factors and

other variables such as spraying technique, sprayer pressure, frequency of spraying, and the interval between sprays (Latif *et al.*, 2010).

Table no. 4.15: Effect of various insecticidal treatments on incidence of shoot borer (%) in brinjal

Treatments	Incidence of shoot borer (%)		
	2023	2024	Pooled
T₀ (Control)	25.69 ^a ± 0.78	40.28 ^a ± 1.77	32.98 ^a ± 1.16
T₁ (Chlorpyrifos 20% EC)	9.84 ^f ± 0.55	14.28 ^f ± 1.33	12.06 ^f ± 0.90
T₂ (Triazophos 40% EC)	13.09 ^c ± 0.89	17.27 ^c ± 1.88	15.18 ^c ± 0.61
T₃ (Karanj oil 1%)	15.38 ^d ± 0.34	21.94 ^d ± 0.69	18.66 ^d ± 0.21
T₄ (Neem oil 1%)	18.51 ^c ± 1.06	26.27 ^c ± 1.16	22.39 ^c ± 1.10
T₅ (Acetamiprid 20% SP)	7.69 ^g ± 0.76	12.83 ^f ± 0.68	10.26 ^g ± 0.71
T₆ (Deltamethrin 2.8% EC)	5.89 ^h ± 0.83	9.94 ^g ± 1.48	7.92 ^h ± 1.12
T₇ (Cartap hydrochloride 50% SP)	4.05 ⁱ ± 0.65	7.22 ^h ± 1.21	5.63 ⁱ ± 0.29
T₈ (Carbofuran 3% CG)	21.78 ^b ± 1.53	32.16 ^b ± 1.58	26.97 ^b ± 1.54
CD (P=0.05)	1.30	2.01	1.23
SE_m (±)	0.43	0.67	0.41
CV (per cent)	5.51	5.70	4.15



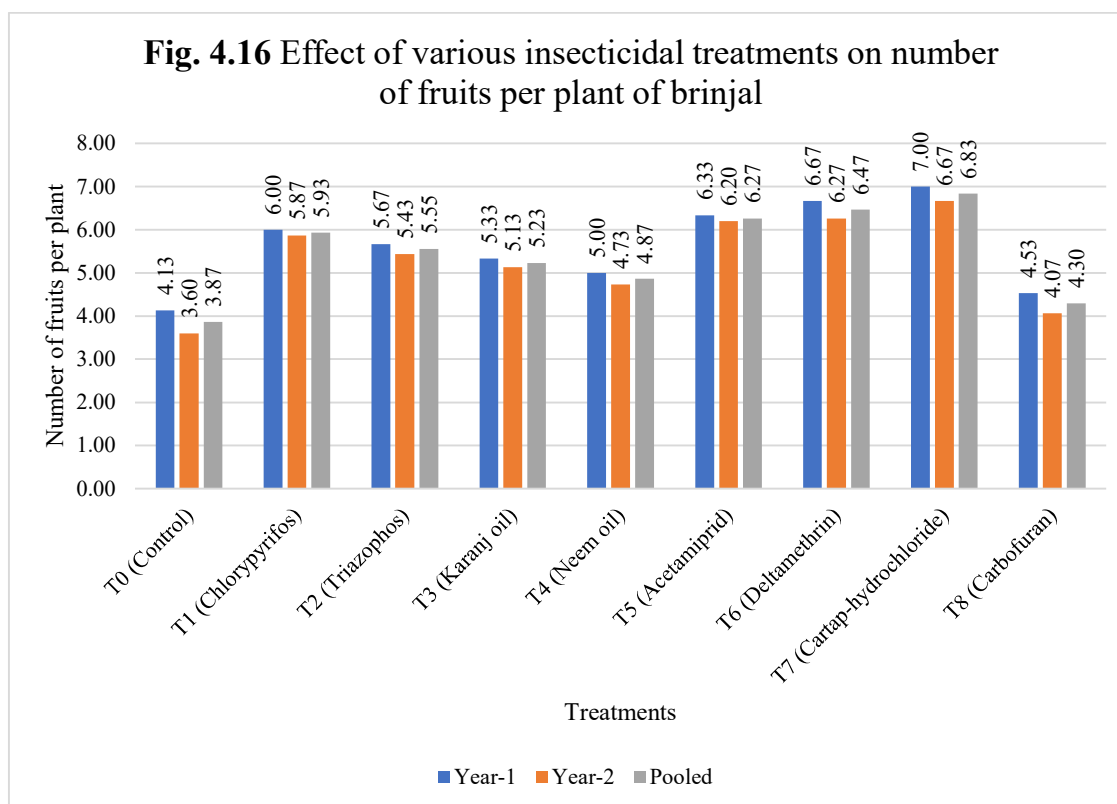
4.2 Yield parameters

4.2.1 Number of fruits per plant

The data pertaining to the influence of various insecticidal treatments on the number of fruits per plant of brinjal during 2023, 2024 and the pooled analysis are shown in Table 4.16 and illustrated in Fig. 4.16. The findings indicated that the number of fruits per plant varied significantly with respect to various insecticidal treatments. Among the selected insecticides, the maximum number of fruits per plant (7.00, 6.67 and 6.83) was recorded in T₇ (Cartap hydrochloride 20% EC), followed by T₆ (6.67, 6.27 and 6.47) during 2023, 2024 and the pooled analysis. The minimum number of fruits per plant (4.13, 3.60 and 3.87) was observed in treatment T₀ (Control) followed by T₈ (4.53, 4.07 and 4.30) during 2023, 2024 and the pooled analysis. The lower yield characters in the untreated control plots may have been influenced by the comparatively higher incidence of insect infestation. Therefore, in addition to reduced defoliation, the considerable decrease in insect populations observed in the insecticide-treated plots may have contributed to the significantly increased yield characteristics in the treated plots (Aetiba and Osekre, 2015). The above findings were closely supported by the findings reported by (Begum *et al.*, 2024; Visnupriya and Muthukrishnan, 2017) who suggested that insecticidal treatments significantly increased the number of fruits per plant in brinjal. Similarly, Natividad *et al.*, 2014 suggested that spraying of cartap hydrochloride recorded the highest number of fruits per plant in tomato.

Table no. 4.16: Effect of various insecticidal treatments on number of fruits per plant of brinjal

Treatments	Number of fruits per plant		
	2023	2024	Pooled
T₀ (Control)	4.13 ⁱ ± 0.23	3.60 ^g ± 0.20	3.87 ^g ± 0.15
T₁ (Chlorpyrifos 20% EC)	6.00 ^d ± 0.20	5.87 ^c ± 0.12	5.93 ^c ± 0.15
T₂ (Triazophos 40% EC)	5.67 ^e ± 0.12	5.43 ^d ± 0.15	5.55 ^d ± 0.13
T₃ (Karanj oil 1%)	5.33 ^f ± 0.31	5.13 ^d ± 0.12	5.23 ^d ± 0.21
T₄ (Neem oil 1%)	5.00 ^g ± 0.35	4.73 ^e ± 0.46	4.87 ^e ± 0.40
T₅ (Acetamiprid 20% SP)	6.33 ^c ± 0.31	6.20 ^{bc} ± 0.20	6.27 ^b ± 0.21
T₆ (Deltamethrin 2.8% EC)	6.67 ^b ± 0.23	6.27 ^b ± 0.12	6.47 ^b ± 0.21
T₇ (Cartap hydrochloride 50% SP)	7.00 ^a ± 0.20	6.67 ^a ± 0.31	6.83 ^a ± 0.29
T₈ (Carbofuran 3% CG)	4.53 ^h ± 0.12	4.07 ^f ± 0.12	4.30 ^f ± 0.10
CD (P=0.05)	0.33	0.35	0.29
SE_m (±)	0.11	0.11	0.10
CV (per cent)	3.32	3.70	3.01

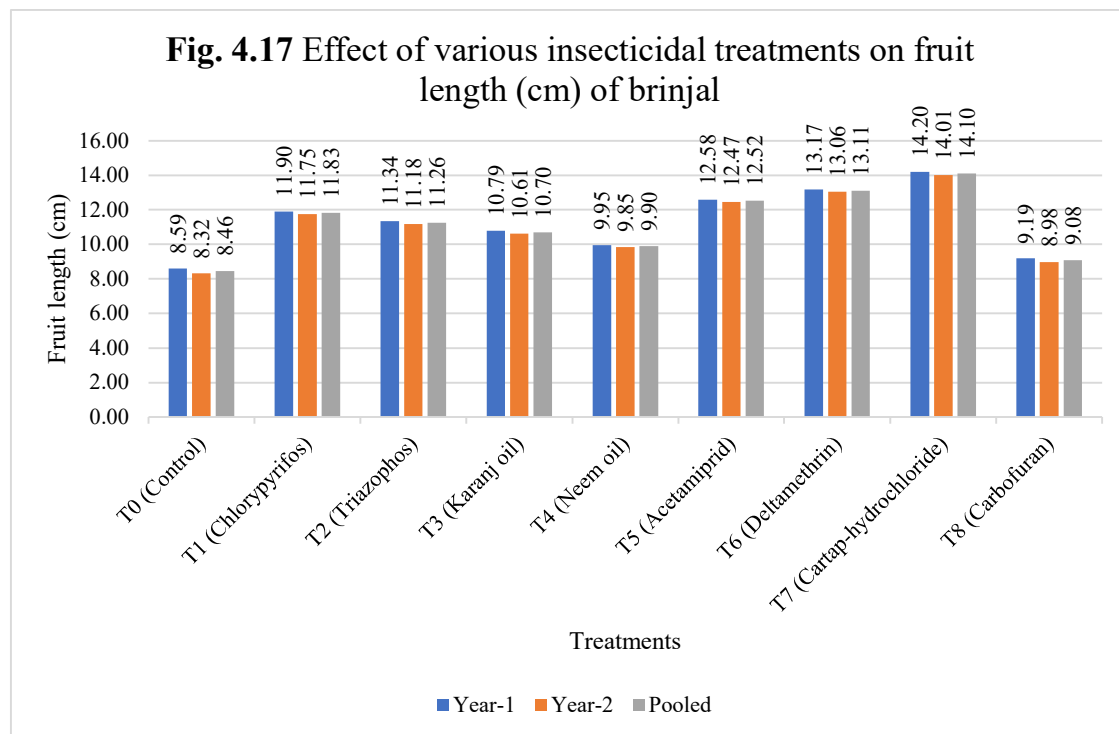


4.2.2 Fruit length (cm)

The data pertaining to the influence of various insecticidal treatments on the fruit length of brinjal during 2023, 2024 and the pooled analysis are shown in Table 4.17 and illustrated in Fig. 4.17. The findings indicated that the fruit length varied significantly due to the impact of various insecticidal treatments. Among the selected insecticides, the maximum fruit length (14.20, 14.01 and 14.10 cm) was recorded in T₇ (Cartap hydrochloride 20% EC) followed by T₆ (13.17, 13.06 and 13.11 cm), which were not statistically similar and performed better than the other insecticidal treatments during 2023, 2024 and the pooled analysis. The minimum fruit length (8.59, 8.32 and 8.46 cm) was observed in treatment T₀ (Control) followed by T₈ (9.19, 8.98 and 9.08 cm) during 2023, 2024 and the pooled analysis. Insect infestation causes fruit deformation and internal deterioration, making them unfit for consumption (Sharma *et al.*, 2024). The use of insecticides to protect crops from pests has significantly reduced losses and increased crop yields (Mbatchou *et al.*, 2024). Deshmukh and Bhamare (2006) found cartap hydrochloride most effective in increasing yield attributes of brinjal which agreed with the results of present investigation. The above findings were closely supported by the findings reported by (Begum *et al.*, 2024; Rahman *et al.*, 2015; Sammaiah *et al.*, 2011) who suggested that insecticidal treatments significantly increased the fruit length in brinjal.

Table no. 4.17: Effect of various insecticidal treatments on fruit length (cm) of brinjal

Treatments	Fruit length (cm)		
	2023	2024	Pooled
T₀ (Control)	8.59 ⁱ ± 0.62	8.32 ^g ± 0.70	8.46 ^h ± 0.66
T₁ (Chlorpyrifos 20% EC)	11.90 ^d ± 0.56	11.75 ^c ± 0.53	11.83 ^d ± 0.53
T₂ (Triazophos 40% EC)	11.34 ^e ± 0.21	11.18 ^{cd} ± 0.22	11.26 ^{de} ± 0.21
T₃ (Karanj oil 1%)	10.79 ^f ± 0.22	10.61 ^d ± 0.36	10.70 ^e ± 0.29
T₄ (Neem oil 1%)	9.95 ^g ± 0.28	9.85 ^e ± 0.30	9.90 ^f ± 0.29
T₅ (Acetamiprid 20% SP)	12.58 ^c ± 0.55	12.47 ^b ± 0.58	12.52 ^c ± 0.57
T₆ (Deltamethrin 2.8% EC)	13.17 ^b ± 0.18	13.06 ^b ± 0.05	13.11 ^b ± 0.11
T₇ (Cartap hydrochloride 50% SP)	14.20 ^a ± 0.60	14.01 ^a ± 0.72	14.10 ^a ± 0.66
T₈ (Carbofuran 3% CG)	9.19 ^h ± 0.34	8.98 ^f ± 0.42	9.08 ^g ± 0.38
CD (P=0.05)	0.54	0.64	0.58
SE_m (±)	0.18	0.21	0.19
CV (per cent)	2.75	3.30	2.97

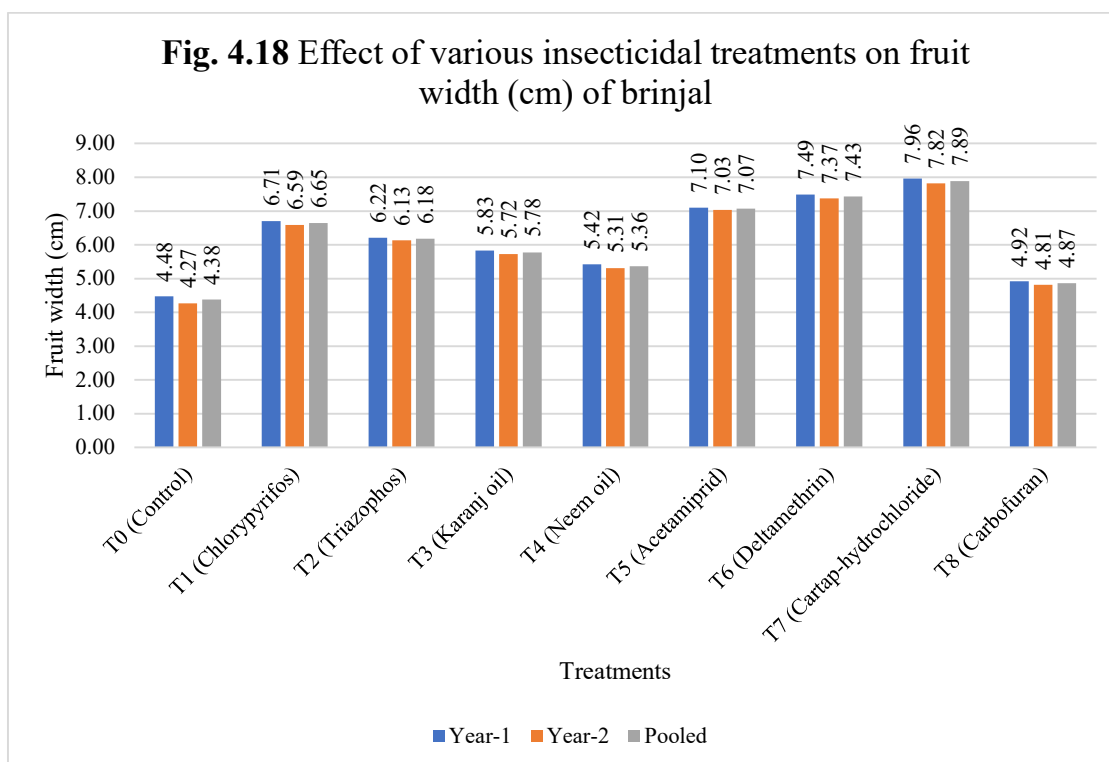


4.2.3 Fruit width (cm)

The data related to the fruit width showed significant variation under the influence of different insecticidal treatments compared to the control in brinjal. The data recorded on the fruit width for the years 2023, 2024 and the pooled analysis are depicted in Table 4.18 and Fig. 4.18. The maximum fruit width (7.96, 7.82 and 7.89 cm) was observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by the treatment T₆ (7.49, 7.37 and 7.43 cm) whereas minimum fruit width (4.48, 4.27 and 4.38 cm) was recorded in treatment T₀ (Control) followed by the treatment T₈ (4.92, 4.81 and 4.87 cm) during 2023, 2024 and the pooled analysis. Larvae feeding inside shoots result in wilting of young shoots. Wilted shoots are a sign that this insect has damaged the brinjal crop. Eventually, the injured shoots wilt and fall off, resulting in fewer and smaller fruits (Anwar *et al.*, 2015). The use of synthetic insecticides significantly reduced pest abundance and the damage caused by insects. The above findings were closely supported by the findings reported by (Begum *et al.*, 2024; Rahman *et al.*, 2015; Sammaiah *et al.*, 2011) who suggested that insecticidal treatments significantly increased the fruit width in brinjal.

Table no. 4.18: Effect of various insecticidal treatments on fruit width (cm) of brinjal

Treatments	Fruit width (cm)		
	2023	2024	Pooled
T₀ (Control)	4.48 ⁱ ± 0.14	4.27 ^h ± 0.06	4.38 ^h ± 0.10
T₁ (Chlorpyrifos 20% EC)	6.71 ^d ± 0.37	6.59 ^c ± 0.41	6.65 ^c ± 0.39
T₂ (Triazophos 40% EC)	6.22 ^e ± 0.15	6.13 ^d ± 0.14	6.18 ^d ± 0.15
T₃ (Karanj oil 1%)	5.83 ^f ± 0.225	5.72 ^e ± 0.26	5.78 ^e ± 0.25
T₄ (Neem oil 1%)	5.42 ^g ± 0.07	5.31 ^f ± 0.08	5.36 ^f ± 0.07
T₅ (Acetamiprid 20% SP)	7.10 ^c ± 0.20	7.03 ^b ± 0.20	7.07 ^b ± 0.20
T₆ (Deltamethrin 2.8% EC)	7.49 ^b ± 0.17	7.37 ^b ± 0.18	7.43 ^b ± 0.17
T₇ (Cartap hydrochloride 50% SP)	7.96 ^a ± 0.31	7.82 ^a ± 0.31	7.89 ^a ± 0.31
T₈ (Carbofuran 3% CG)	4.92 ^h ± 0.11	4.81 ^g ± 0.11	4.87 ^g ± 0.11
CD (P=0.05)	0.37	0.38	0.37
SE_m (±)	0.12	0.13	0.12
CV (per cent)	3.37	3.57	3.42

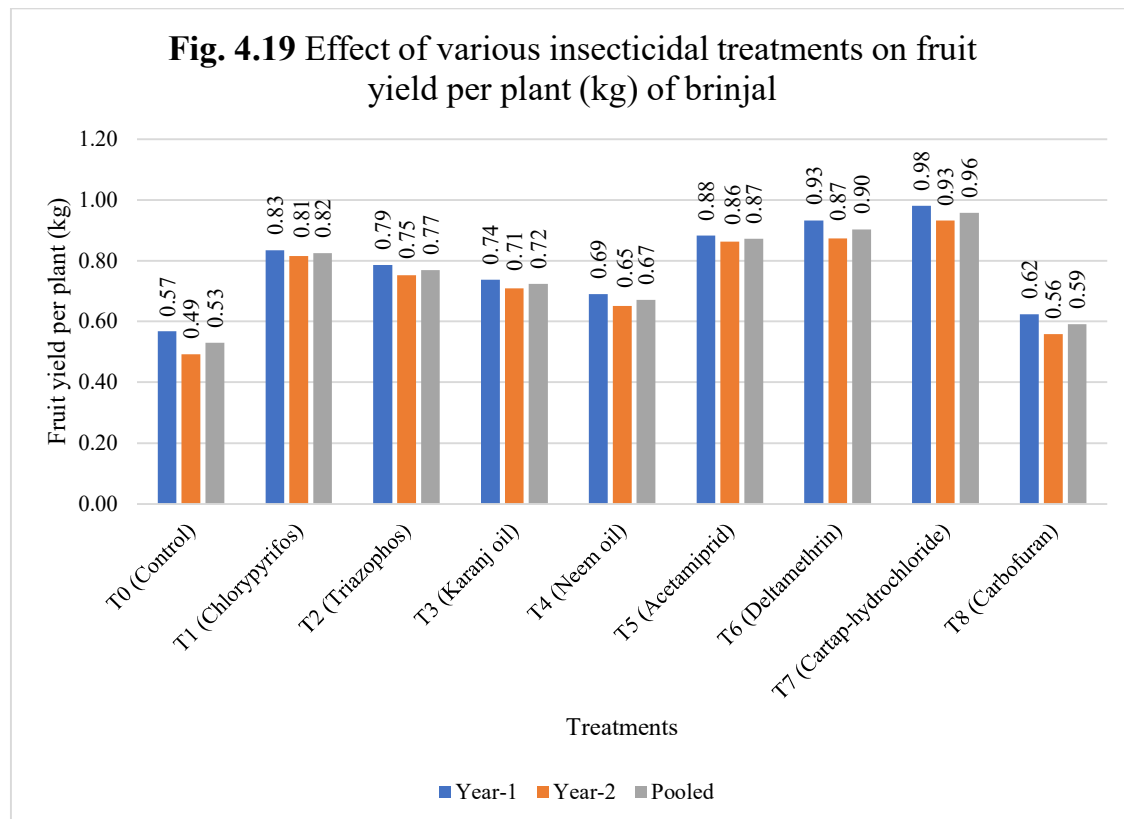


4.2.4 Fruit yield per plant (kg)

The perusal of data on the fruit yield per plant of brinjal revealed significant variation among the various treatments compared to the control. The mean data for the years 2023, 2024 and pooled analysis are presented in Table 4.19 and Fig. 4.19. Among the selected treatments, the maximum fruit yield per plant (0.98 kg) during the first year of research was recorded in T₇ (Cartap hydrochloride 20% EC), followed by the treatment T₆ (0.93 kg), while the minimum fruit yield per plant (0.57 kg) was observed in T₀ (Control) followed by the treatment T₈ (0.62 kg), respectively. Similarly, during the second year, the maximum fruit yield per plant (0.93 kg) was also observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (0.87 kg) while the minimum (0.49 kg) was observed in T₀ (Control). During the pooled analysis, the maximum fruit yield per plant (0.96 kg) was observed in treatment T₇ (Cartap hydrochloride 20% EC), followed by treatment T₆ (0.90 kg), while the minimum (0.53 kg) was found in T₀ (Control), respectively. The use of insecticides to protect crops from pests has significantly reduced losses and increased crop yields (Mbatchou *et al.*, 2024). These findings are consistent with those of Gaikwad *et al.*, 2017, who reported that synthetic insecticides significantly increased the fruit yield per plant in brinjal.

Table no. 4.19: Effect of various insecticidal treatments on fruit yield per plant (kg) of brinjal

Treatments	Fruit yield per plant (kg)		
	2023	2024	Pooled
T₀ (Control)	0.57 ⁱ ± 0.03	0.49 ^g ± 0.03	0.53 ^h ± 0.02
T₁ (Chlorpyrifos 20% EC)	0.83 ^d ± 0.03	0.81 ^c ± 0.01	0.82 ^c ± 0.02
T₂ (Triazophos 40% EC)	0.79 ^e ± 0.02	0.75 ^d ± 0.03	0.77 ^d ± 0.02
T₃ (Karanj oil 1%)	0.74 ^f ± 0.05	0.71 ^d ± 0.02	0.72 ^e ± 0.03
T₄ (Neem oil 1%)	0.69 ^g ± 0.05	0.65 ^c ± 0.06	0.67 ^f ± 0.05
T₅ (Acetamiprid 20% SP)	0.88 ^c ± 0.04	0.86 ^{bc} ± 0.03	0.87 ^b ± 0.03
T₆ (Deltamethrin 2.8% EC)	0.93 ^b ± 0.03	0.87 ^b ± 0.02	0.90 ^b ± 0.02
T₇ (Cartap hydrochloride 50% SP)	0.98 ^a ± 0.03	0.93 ^a ± 0.04	0.96 ^a ± 0.03
T₈ (Carbofuran 3% CG)	0.62 ^h ± 0.01	0.56 ^f ± 0.02	0.59 ^g ± 0.01
CD (P=0.05)	0.05	0.05	0.04
SE_m (±)	0.02	0.02	0.01
CV (per cent)	3.31	3.66	2.90

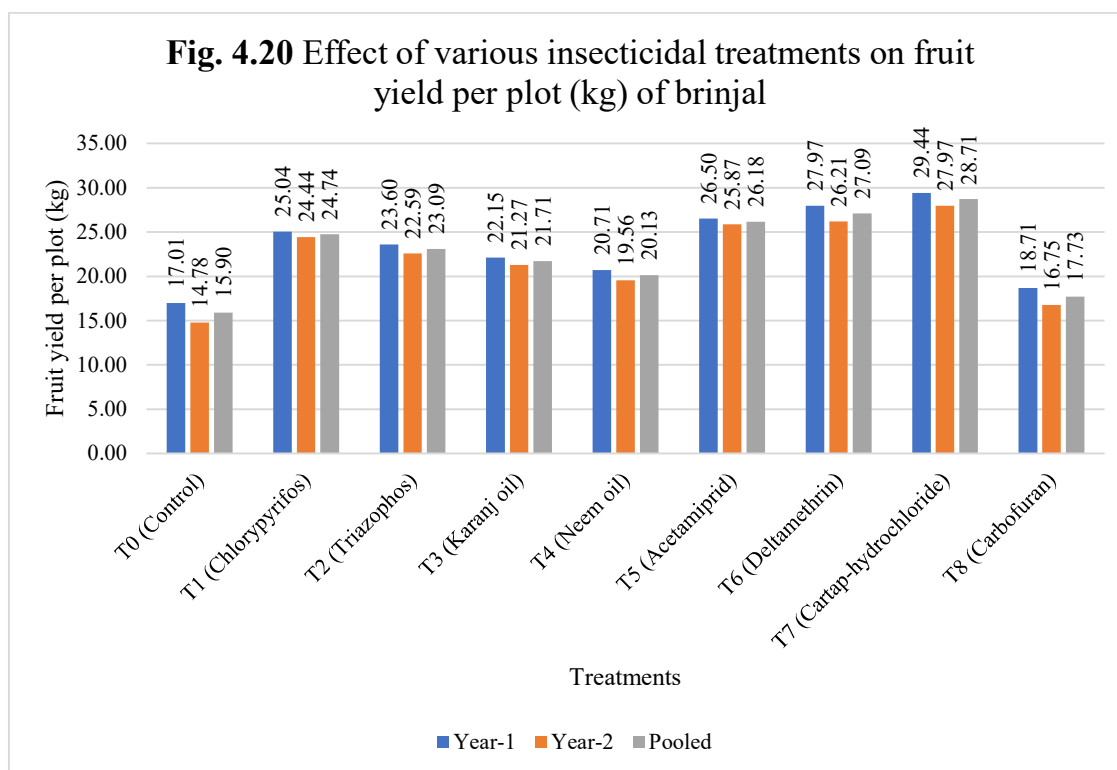


4.2.5 Fruit yield per plot (kg)

The observations recorded on the fruit yield per plot of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.20 and Fig. 4.20. It is evident that there was a significant variation in the fruit yield per plot with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the highest fruit yield per plot (29.44, 27.97 and 28.71 kg) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), followed by T₆ (27.97, 26.21 and 27.09 kg) during 2023, 2024 and the pooled analysis. The lowest fruit yield per plot (17.01, 14.78 and 15.90 kg) was observed in treatment T₀ (Control) followed by treatment T₈ (18.71, 16.75 and 17.73 kg) during 2023, 2024 and the pooled analysis, respectively. According to (Emeasor and Uwalaka, 2018), synthetic pesticides remain one of the most efficient methods for managing pests. They are highly effective, beneficial, adaptable to various situations, dependable for immediate action, and their application typically reduces pest infestation while significantly increasing yield. The aforementioned results align with the conclusions drawn by Amin *et al.*, 2014, who suggested that synthetic insecticides significantly increased the fruit yield per plot in brinjal.

Table no. 4.20: Effect of various insecticidal treatments on fruit yield per plot (kg) of brinjal

Treatments	Fruit yield per plot (kg)		
	2023	2024	Pooled
T ₀ (Control)	17.01 ⁱ ± 0.98	14.78 ^g ± 0.83	15.90 ^h ± 0.64
T ₁ (Chlorpyrifos 20% EC)	25.04 ^d ± 0.82	24.44 ^c ± 0.44	24.74 ^c ± 0.61
T ₂ (Triazophos 40% EC)	23.60 ^e ± 0.51	22.59 ^d ± 0.66	23.09 ^d ± 0.58
T ₃ (Karanj oil 1%)	22.15 ^f ± 1.30	21.27 ^d ± 0.52	21.71 ^e ± 0.90
T ₄ (Neem oil 1%)	20.71 ^g ± 1.45	19.56 ^e ± 1.92	20.13 ^f ± 1.68
T ₅ (Acetamiprid 20% SP)	26.50 ^c ± 1.30	25.87 ^b ± 0.86	26.18 ^b ± 0.89
T ₆ (Deltamethrin 2.8% EC)	27.97 ^b ± 0.98	26.21 ^b ± 0.51	27.09 ^b ± 0.66
T ₇ (Cartap hydrochloride 50% SP)	29.44 ^a ± 0.82	27.97 ^a ± 1.28	28.71 ^a ± 1.05
T ₈ (Carbofuran 3% CG)	18.71 ^h ± 0.45	16.75 ^f ± 0.47	17.73 ^g ± 0.39
CD (P=0.05)	1.35	1.42	1.19
SE _m (±)	0.45	0.47	0.39
CV (per cent)	3.31	3.67	2.99

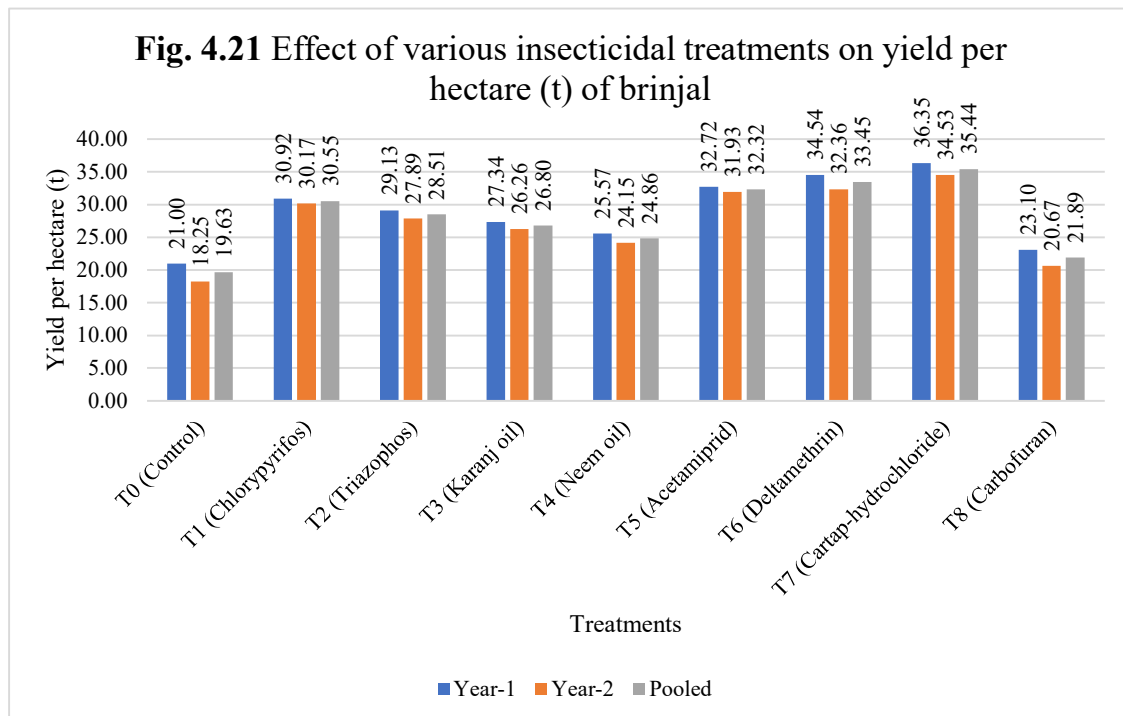


4.2.6 Yield per hectare (t)

The observations recorded on the yield per hectare of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.21 and Fig. 4.21. It is evident that there was a significant variation in yield per hectare with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the highest yield per hectare (36.35, 34.53 and 35.44 t) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), followed by T₆ (34.54, 32.36 and 33.45 t) during 2023, 2024 and the pooled analysis, respectively. The lowest yield per hectare (21.00, 18.25 and 19.63 t) was observed in treatment T₀ (Control), followed by treatment T₈ (23.10, 20.67 and 21.89 t) during 2023, 2024 and the pooled analysis, respectively. According to Gautam *et al.*, 2019, the application of synthetic insecticides effectively reduced the infestation of shoot and fruit borer in brinjal, which eventually led to an increase in the yield attributes of brinjal. The aforementioned results align with the conclusions drawn by Tamang *et al.*, 2025, who suggested that synthetic insecticides significantly increased the yield per hectare in brinjal. Similarly, (Senapati, 2006) reported that cartap hydrochloride was the most effective insecticidal treatment in decreasing shoot and fruit borer infestation and increasing the yield per hectare in brinjal.

Table no. 4.21: Effect of various insecticidal treatments on yield per hectare (t) of brinjal

Treatments	Yield per hectare (t)		
	2023	2024	Pooled
T₀ (Control)	21.00 ⁱ ± 1.20	18.25 ^g ± 1.01	19.63 ^h ± 0.80
T₁ (Chlorpyrifos 20% EC)	30.92 ^d ± 1.01	30.17 ^c ± 0.54	30.55 ^c ± 0.75
T₂ (Triazophos 40% EC)	29.13 ^e ± 0.63	27.89 ^d ± 0.81	28.51 ^d ± 0.71
T₃ (Karanj oil 1%)	27.34 ^f ± 1.61	26.26 ^d ± 0.64	26.80 ^e ± 1.11
T₄ (Neem oil 1%)	25.57 ^g ± 1.78	24.15 ^e ± 2.38	24.86 ^f ± 2.08
T₅ (Acetamiprid 20% SP)	32.72 ^c ± 1.60	31.93 ^b ± 1.06	32.32 ^b ± 1.10
T₆ (Deltamethrin 2.8% EC)	34.54 ^b ± 1.21	32.36 ^b ± 0.64	33.45 ^b ± 0.82
T₇ (Cartap hydrochloride 50% SP)	36.35 ^a ± 1.02	34.53 ^a ± 1.59	35.44 ^a ± 1.29
T₈ (Carbofuran 3% CG)	23.10 ^h ± 0.56	20.67 ^f ± 0.57	21.89 ^g ± 0.49
CD (P=0.05)	1.67	1.76	1.47
SE_m (±)	0.55	0.58	0.49
CV (per cent)	3.30	3.67	2.98

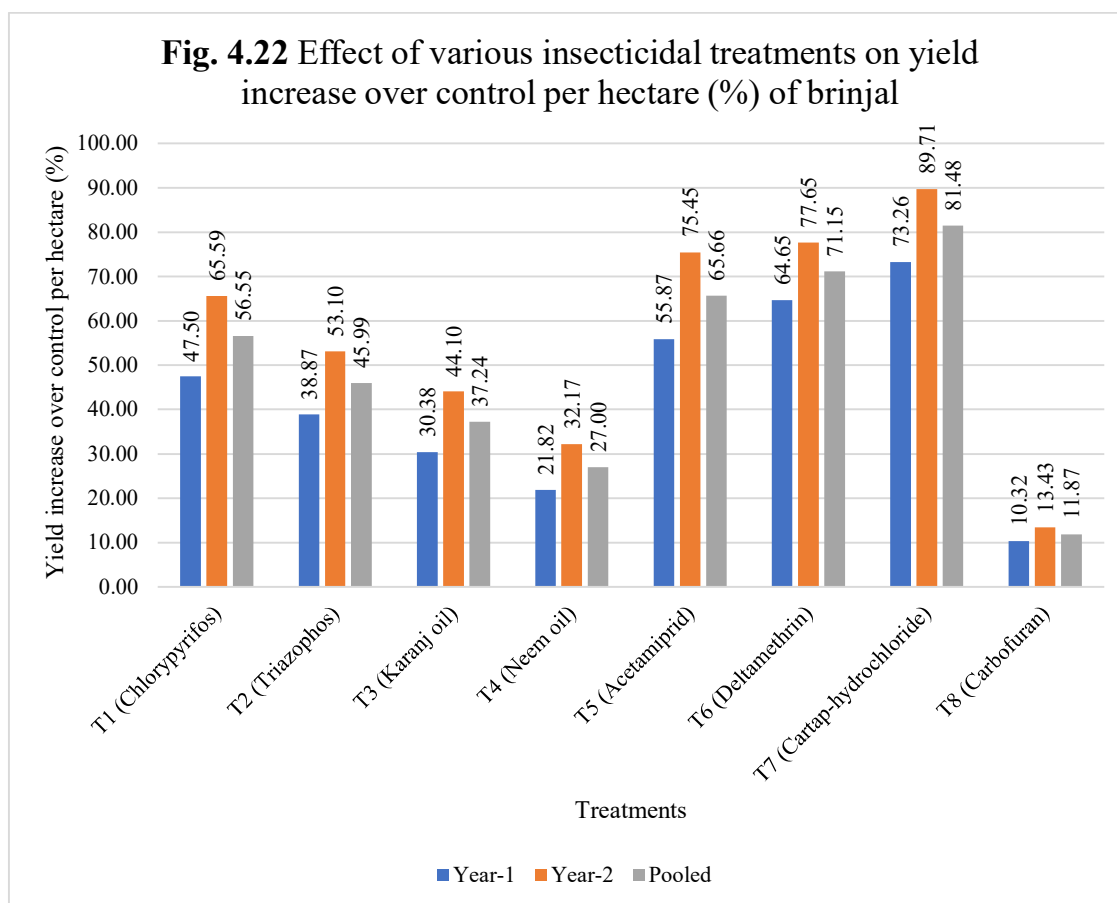


4.2.7 Yield increase over control per hectare (%)

The observations recorded on the yield increase over control per hectare of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.22 and Fig. 4.22. It is evident that there was a significant variation in yield increase over control per hectare with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the maximum yield increase over control per hectare (73.26, 89.71 and 81.48%) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), followed by T₆ (64.65, 77.65 and 71.15%) during 2023, 2024 and the pooled analysis, respectively. The minimum yield increase over control per hectare (10.32, 13.43 and 11.87%) was observed in treatment T₈ (Carbofuran 3% CG) during 2023, 2024 and the pooled analysis, respectively. According to Gautam *et al.*, 2019, the application of synthetic insecticides effectively reduced the infestation of shoot and fruit borer in brinjal, which eventually led to an increase in the yield attributes of brinjal. The aforementioned results align with the conclusions drawn by Tamang *et al.*, 2025, who suggested that synthetic insecticides recorded highest yield increase over control per hectare in brinjal.

Table no. 4.22: Effect of various insecticidal treatments on yield increase over control per hectare (%) of brinjal

Treatments	Yield increase over control per hectare (%)		
	2023	2024	Pooled
T₀ (Control)	0.00 ⁱ ± 0.00	0.00 ^g ± 0.00	0.00 ^h ± 0.00
T₁ (Chlorpyrifos 20% EC)	47.50 ^d ± 9.44	65.59 ^c ± 6.93	56.55 ^c ± 5.05
T₂ (Triazophos 40% EC)	38.87 ^e ± 4.79	53.10 ^d ± 8.08	45.99 ^d ± 3.67
T₃ (Karanj oil 1%)	30.38 ^f ± 9.65	44.10 ^d ± 5.04	37.24 ^e ± 2.64
T₄ (Neem oil 1%)	21.82 ^g ± 7.89	32.17 ^e ± 7.83	27.00 ^f ± 6.11
T₅ (Acetamiprid 20% SP)	55.87 ^c ± 5.81	75.45 ^{bc} ± 13.21	65.66 ^b ± 3.80
T₆ (Deltamethrin 2.8% EC)	64.65 ^b ± 7.97	77.65 ^b ± 10.11	71.15 ^b ± 2.83
T₇ (Cartap hydrochloride 50% SP)	73.26 ^a ± 5.96	89.71 ^a ± 14.81	81.48 ^a ± 7.61
T₈ (Carbofuran 3% CG)	10.32 ^h ± 8.69	13.43 ^f ± 3.96	11.87 ^g ± 5.53
CD (P=0.05)	8.10	11.38	7.90
SE_m (±)	2.68	3.76	2.61
CV (per cent)	12.19	13.00	10.26



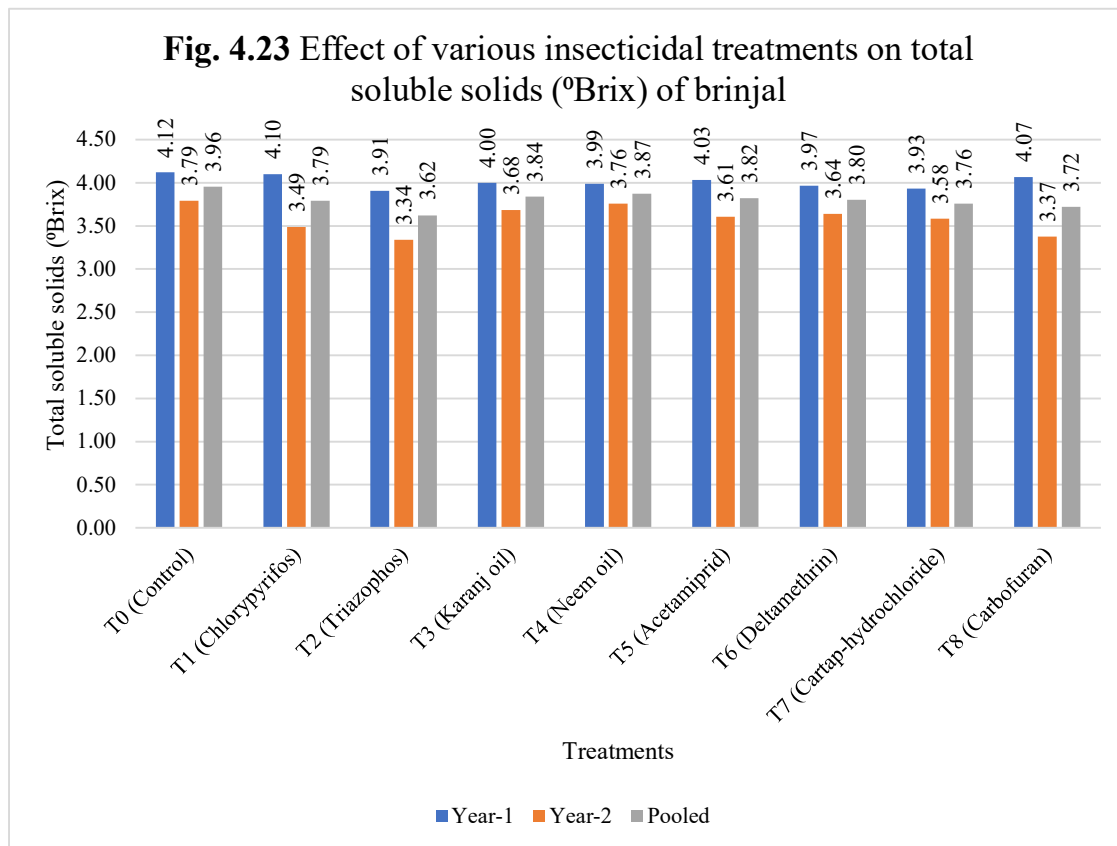
4.3 Quality parameters

4.3.1 Total soluble solids (°Brix)

The data presented in Table 4.23 and depicted in Fig. 4.23 indicate the influence of various insecticides on the qualitative characteristics of brinjal. The results showed no statistically significant ($p < 0.05$) differences in the overall change in TSS content between the T₀ (control) treatment and the insecticide-treated samples. Among the selected insecticides, the maximum total soluble solids (4.12, 3.79 and 3.96 °Brix) were recorded in treatment T₀ (Control), while the minimum total soluble solids (3.91, 3.34 and 3.62 °Brix) were observed in treatment T₂ (Triazophos 40% EC) during 2023, 2024 and the pooled analysis, respectively. Essam *et al.*, 2022, suggested that pesticides interfere with the physiological and biochemical functions of plants, leading to reduced fruit quality and alterations in the chemical composition and key quality attributes of brinjal. These findings are in agreement with those of Abdelfatah *et al.*, 2024, who observed that the total soluble solids (TSS) content and other fruit quality characteristics were minimally affected by the application of insecticides at the optimal dosage in brinjal.

Table no. 4.23: Effect of various insecticidal treatments on total soluble solids (°Brix) of brinjal

Treatments	Total soluble solids (°Brix)		
	2023	2024	Pooled
T ₀ (Control)	4.12 ^a ± 0.02	3.79 ^a ± 0.01	3.96 ^a ± 0.01
T ₁ (Chlorpyrifos 20% EC)	4.10 ^{ab} ± 0.10	3.49 ^{abc} ± 0.26	3.79 ^{abc} ± 0.16
T ₂ (Triazophos 40% EC)	3.91 ^b ± 0.10	3.34 ^c ± 0.39	3.62 ^c ± 0.24
T ₃ (Karanj oil 1%)	4.00 ^{ab} ± 0.17	3.68 ^{ab} ± 0.08	3.84 ^{abc} ± 0.13
T ₄ (Neem oil 1%)	3.99 ^{ab} ± 0.10	3.76 ^a ± 0.02	3.87 ^{ab} ± 0.05
T ₅ (Acetamiprid 20% SP)	4.03 ^{ab} ± 0.06	3.61 ^{abc} ± 0.01	3.82 ^{abc} ± 0.03
T ₆ (Deltamethrin 2.8% EC)	3.97 ^{ab} ± 0.06	3.64 ^{abc} ± 0.03	3.80 ^{abc} ± 0.04
T ₇ (Cartap hydrochloride 50% SP)	3.93 ^{ab} ± 0.06	3.58 ^{abc} ± 0.13	3.76 ^{abc} ± 0.04
T ₈ (Carbofuran 3% CG)	4.07 ^{ab} ± 0.21	3.37 ^{bc} ± 0.22	3.72 ^{bc} ± 0.21
CD (P=0.05)	NS	NS	NS
SE _m (±)	0.06	0.10	0.07
CV (per cent)	2.60	4.80	3.12

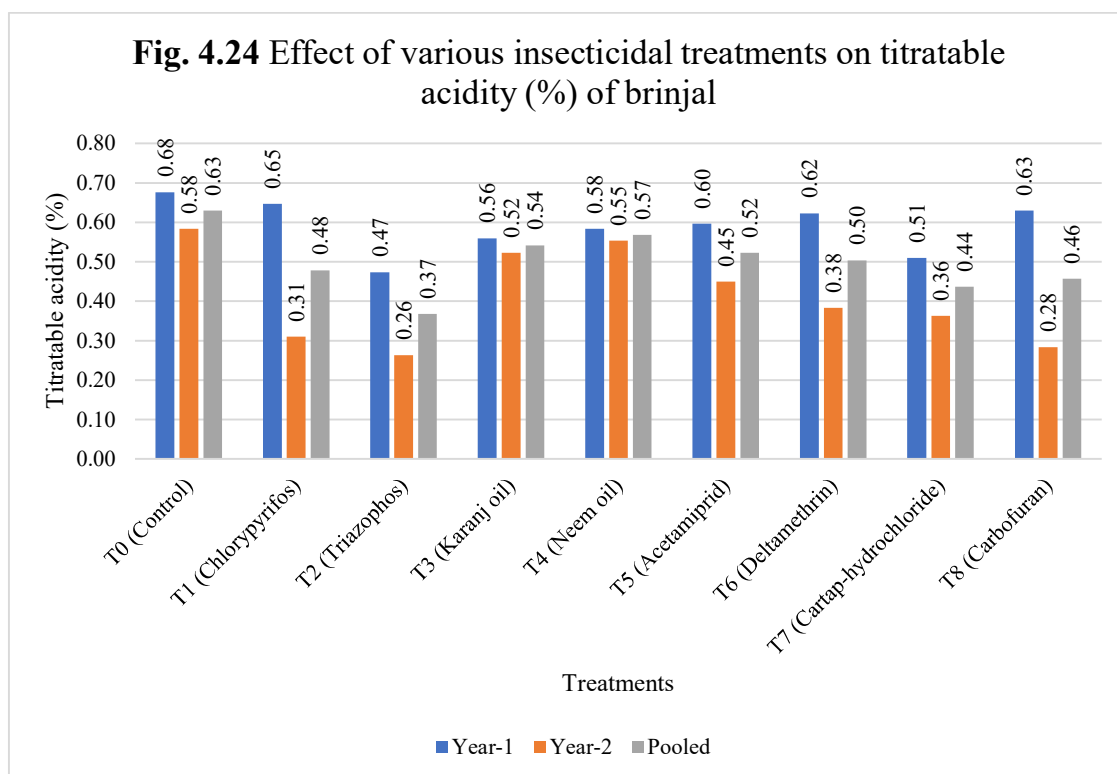


4.3.2 Titratable acidity (%)

The data presented in Table 4.24 and depicted in Fig. 4.24 indicate the influence of various insecticides on the qualitative characteristics of brinjal. The results showed no statistically significant ($p < 0.05$) differences in the overall change in titratable acidity between the T_0 (control) treatment and the insecticide-treated samples. Among the selected insecticides, the highest titratable acidity (0.68, 0.58 and 0.63%) was recorded in treatment T_0 (Control), while the lowest titratable acidity (0.47, 0.26 and 0.37%) was observed in treatment T_2 (Triazophos 40% EC) during 2023, 2024 and the pooled analysis, respectively. Insecticides control pests on plants and animals but may disrupt their biochemical processes. Pesticides can hinder photosynthesis, mitosis, cell division, protein and chlorophyll production, root development, enzyme activity, and cell membrane integrity (Abrokwah *et al.*, 2019). These findings are consistent with those of Abdelfatah *et al.*, 2024, who reported that the percentage of titratable acidity was minimally influenced by the application of synthetic insecticides at the optimal dosage in brinjal.

Table no. 4.24: Effect of various insecticidal treatments on titratable acidity (%) of brinjal

Treatments	Titratable acidity (%)		
	2023	2024	Pooled
T_0 (Control)	0.68 ^a ± 0.03	0.58 ^a ± 0.08	0.63 ^a ± 0.05
T_1 (Chlorpyrifos 20% EC)	0.65 ^{ab} ± 0.07	0.31 ^{bcd} ± 0.15	0.48 ^{abc} ± 0.07
T_2 (Triazophos 40% EC)	0.47 ^c ± 0.12	0.26 ^d ± 0.16	0.37 ^c ± 0.14
T_3 (Karanj oil 1%)	0.56 ^{abc} ± 0.05	0.52 ^{abc} ± 0.13	0.54 ^{abc} ± 0.06
T_4 (Neem oil 1%)	0.58 ^{abc} ± 0.04	0.55 ^{ab} ± 0.08	0.57 ^{ab} ± 0.06
T_5 (Acetamiprid 20% SP)	0.60 ^{abc} ± 0.01	0.45 ^{abcd} ± 0.05	0.52 ^{abc} ± 0.03
T_6 (Deltamethrin 2.8% EC)	0.62 ^{ab} ± 0.02	0.38 ^{abcd} ± 0.03	0.50 ^{abc} ± 0.02
T_7 (Cartap hydrochloride 50% SP)	0.51 ^{bc} ± 0.12	0.36 ^{abcd} ± 0.24	0.44 ^{bc} ± 0.18
T_8 (Carbofuran 3% CG)	0.63 ^{ab} ± 0.08	0.28 ^{cd} ± 0.13	0.46 ^{abc} ± 0.08
CD (P=0.05)	NS	NS	NS
SE_m (±)	0.04	0.08	0.05
CV (per cent)	12.23	31.47	17.95

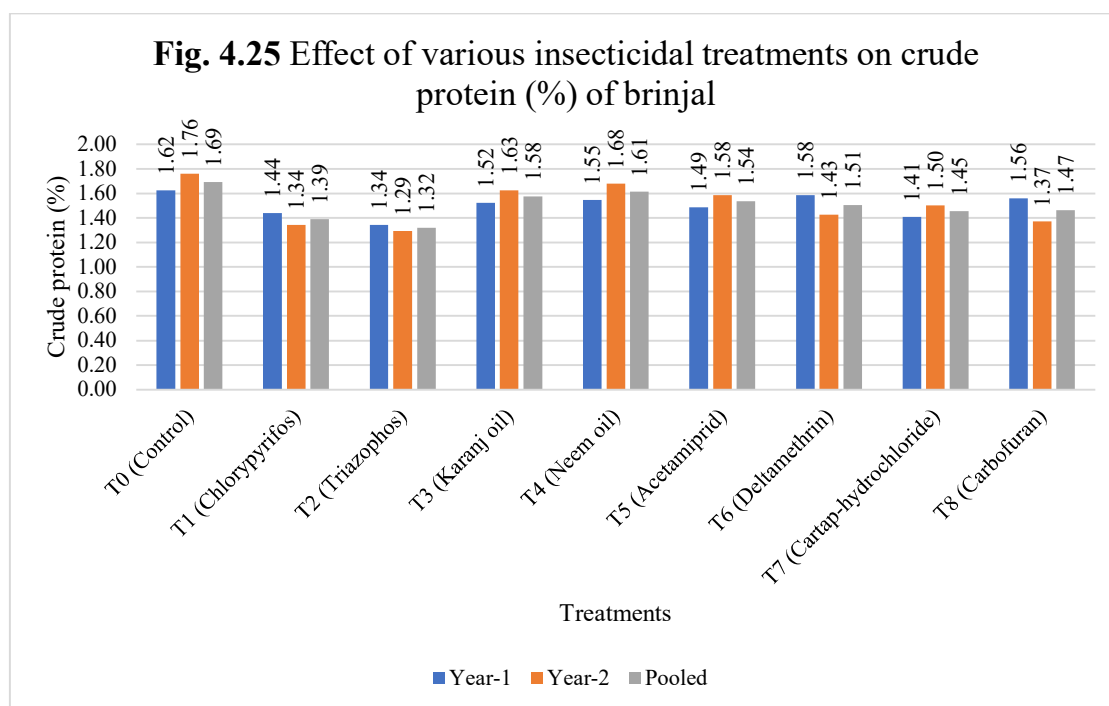


4.3.3 Crude protein (%)

The observation recorded on crude protein of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.25 and Fig. 4.25. It is evident that there was no significant variation in crude protein with respect to various insecticidal treatments in brinjal. Among the selected insecticides, the highest crude protein (1.62, 1.76 and 1.69%) was recorded in treatment T₀ (Control), while the minimum crude protein (1.34, 1.29 and 1.32%) was observed in treatment T₂ (Triazophos 40% EC) during 2023, 2024 and the pooled analysis, respectively. Crude protein levels may vary only slightly due to the insecticide's weak effects on the plant's nitrogen metabolism and protein synthesis pathways (Zhang *et al.*, 2022). The systemic effects of insecticides, which penetrate deeper into the fruit and impact the biochemical system, could be responsible for the biochemical changes observed in eggplant fruits treated with these pesticides (Abdelfatah *et al.*, 2024). These findings are consistent with the results reported by (Thakur *et al.*, 2024; Goswami *et al.*, 2018), who stated that optimal application of synthetic insecticides had a non-significant impact on the quality of brinjal.

Table no. 4.25: Effect of various insecticidal treatments on crude protein (%) of brinjal

Treatments	Crude protein (%)		
	2023	2024	Pooled
T₀ (Control)	1.62 ^a ± 0.01	1.76 ^a ± 0.10	1.69 ^a ± 0.05
T₁ (Chlorpyrifos 20% EC)	1.44 ^{ab} ± 0.18	1.34 ^b ± 0.30	1.39 ^{ab} ± 0.24
T₂ (Triazophos 40% EC)	1.34 ^{ab} ± 0.04	1.29 ^b ± 0.30	1.32 ^b ± 0.16
T₃ (Karanj oil 1%)	1.52 ^{ab} ± 0.17	1.63 ^{ab} ± 0.22	1.58 ^{ab} ± 0.19
T₄ (Neem oil 1%)	1.55 ^{ab} ± 0.13	1.68 ^{ab} ± 0.06	1.61 ^{ab} ± 0.08
T₅ (Acetamiprid 20% SP)	1.49 ^{ab} ± 0.12	1.58 ^{ab} ± 0.13	1.54 ^{ab} ± 0.12
T₆ (Deltamethrin 2.8% EC)	1.58 ^{ab} ± 0.06	1.43 ^{ab} ± 0.14	1.51 ^{ab} ± 0.10
T₇ (Cartap hydrochloride 50% SP)	1.41 ^b ± 0.21	1.50 ^{ab} ± 0.10	1.45 ^{ab} ± 0.14
T₈ (Carbofuran 3% CG)	1.56 ^{ab} ± 0.10	1.37 ^b ± 0.18	1.47 ^{ab} ± 0.13
CD (P=0.05)	NS	NS	NS
SE_m (±)	0.08	0.12	0.09
CV (per cent)	8.68	13.17	9.84



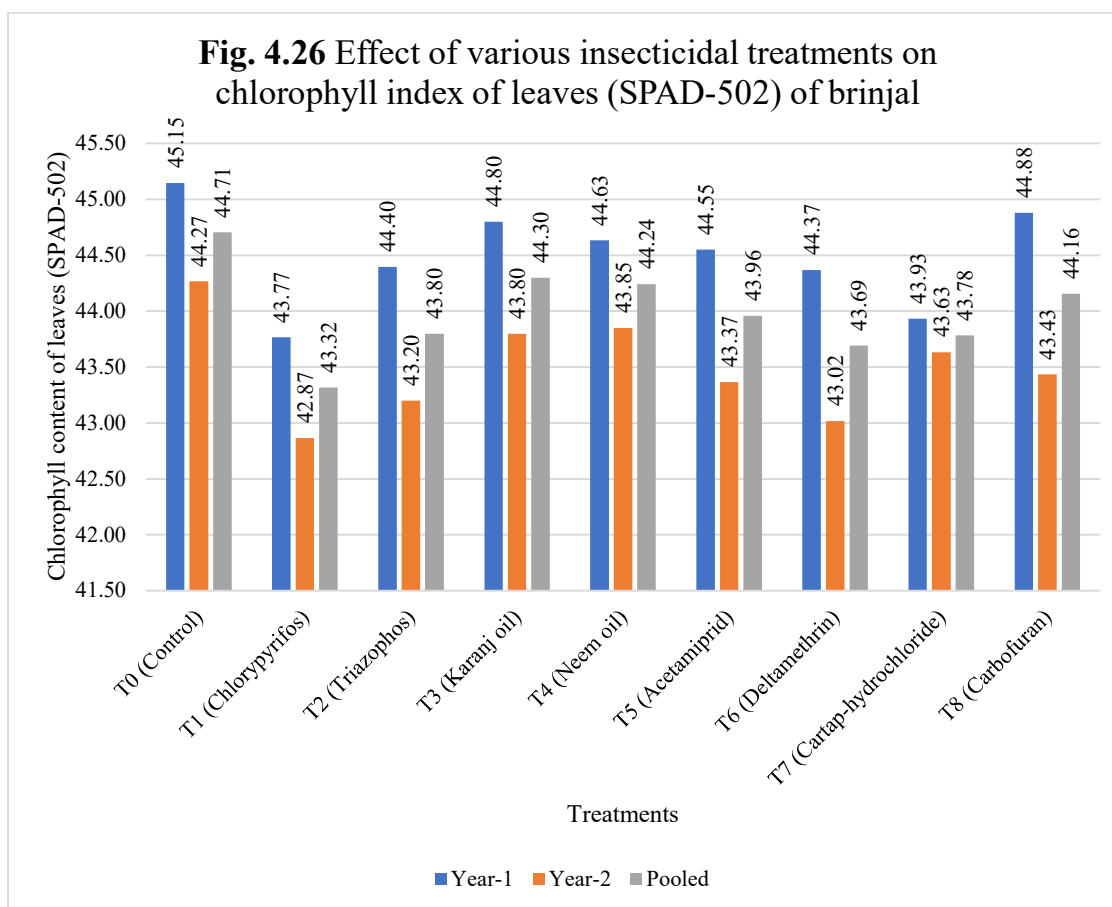
4.3.3 Chlorophyll index of leaves (SPAD-502)

The observations recorded on the chlorophyll index of leaves of brinjal impacted by various insecticidal treatments for the years 2023, 2024 and the pooled analysis are depicted in Table 4.26 and Fig. 4.26. It is evident that there was no significant variation in chlorophyll index of leaves with respect to various insecticidal treatments in brinjal. Among the selected

insecticides, the maximum chlorophyll index of leaves (45.15 and 44.27) was recorded in T₀ (Control), while the minimum chlorophyll index of leaves (43.77 and 42.87) was observed in T₁ (Chlorpyrifos 20% EC) during 2023 and 2024, respectively. Similarly, in the pooled analysis, the highest chlorophyll index of leaves (44.71) was observed in treatment T₀ (Control), while the lowest (43.32) was recorded in T₁ (Chlorpyrifos 20% EC). Some insecticides may not significantly affect the pathways involved in chlorophyll biosynthesis or degradation. If an insecticide does not directly impact nitrogen metabolism or photosynthetic pigments, changes in chlorophyll content will likely be minimal (Sidhu *et al.*, 2019). The findings agreed with the results revealed by (Gaikwad *et al.*, 2017), who suggested that pesticides can function as chemical stressors that disrupt the electron transport activity in PSII, cytochrome b6/f, or PSI. Additionally, pesticides may also modify the structure of the chloroplast or interfere with the Calvin cycle. The findings are in agreement with the results reported by (Nikam and Barwant, 2020), who suggested that the optimal application of synthetic insecticides had a non-significant impact on chlorophyll index compared to the control treatment in brinjal.

Table no. 4.26: Effect of various insecticidal treatments on chlorophyll index of leaves (SPAD-502) of brinjal

Treatments	Chlorophyll index of leaves (SPAD-502)		
	2023	2024	Pooled
T₀ (Control)	45.15 ^a ± 0.98	44.27 ^a ± 0.12	44.71 ^a ± 0.49
T₁ (Chlorpyrifos 20% EC)	43.77 ^a ± 1.07	42.87 ^a ± 0.99	43.32 ^a ± 0.49
T₂ (Triazophos 40% EC)	44.40 ^a ± 1.90	43.20 ^a ± 0.95	43.80 ^a ± 1.41
T₃ (Karanj oil 1%)	44.80 ^a ± 0.69	43.80 ^a ± 0.53	44.30 ^a ± 0.36
T₄ (Neem oil 1%)	44.63 ^a ± 0.55	43.85 ^a ± 1.20	44.24 ^a ± 0.77
T₅ (Acetamiprid 20% SP)	44.55 ^a ± 0.56	43.37 ^a ± 0.81	43.96 ^a ± 0.19
T₆ (Deltamethrin 2.8% EC)	44.37 ^a ± 0.15	43.00 ^a ± 1.63	43.69 ^a ± 0.84
T₇ (Cartap hydrochloride 50% SP)	43.93 ^a ± 1.62	43.63 ^a ± 1.45	43.78 ^a ± 1.53
T₈ (Carbofuran 3% CG)	44.88 ^a ± 1.13	43.43 ^a ± 0.78	44.16 ^a ± 0.61
CD (P=0.05)	NS	NS	NS
SE_m (±)	0.58	0.58	0.49
CV (per cent)	2.26	2.30	1.93



4.4 Residual studies of insecticide treatments in brinjal

Persistence is a key characteristic of an insecticide used to evaluate the compound's biological effectiveness. The chemical properties of insecticides, such as solubility and molecular structure, considerably influence their persistence in the environment. These characteristics determine the rates and pathways of pesticide degradation, as well as their interactions with environmental factors. According to Nath *et al.*, 2022, the initial deposition of insecticides is influenced by multiple factors, including the formulation composition, application rate, environmental conditions, physicochemical properties of the substrate, type of spraying equipment, droplet size, nozzle to plant surface distance and the characteristics of the carrier medium. Apart from deposition and the physical characteristics of the substance, chemical deposits, once laid on a surface, are exposed to several environmental conditions such as light intensity, relative humidity, temperature, and substrate properties.

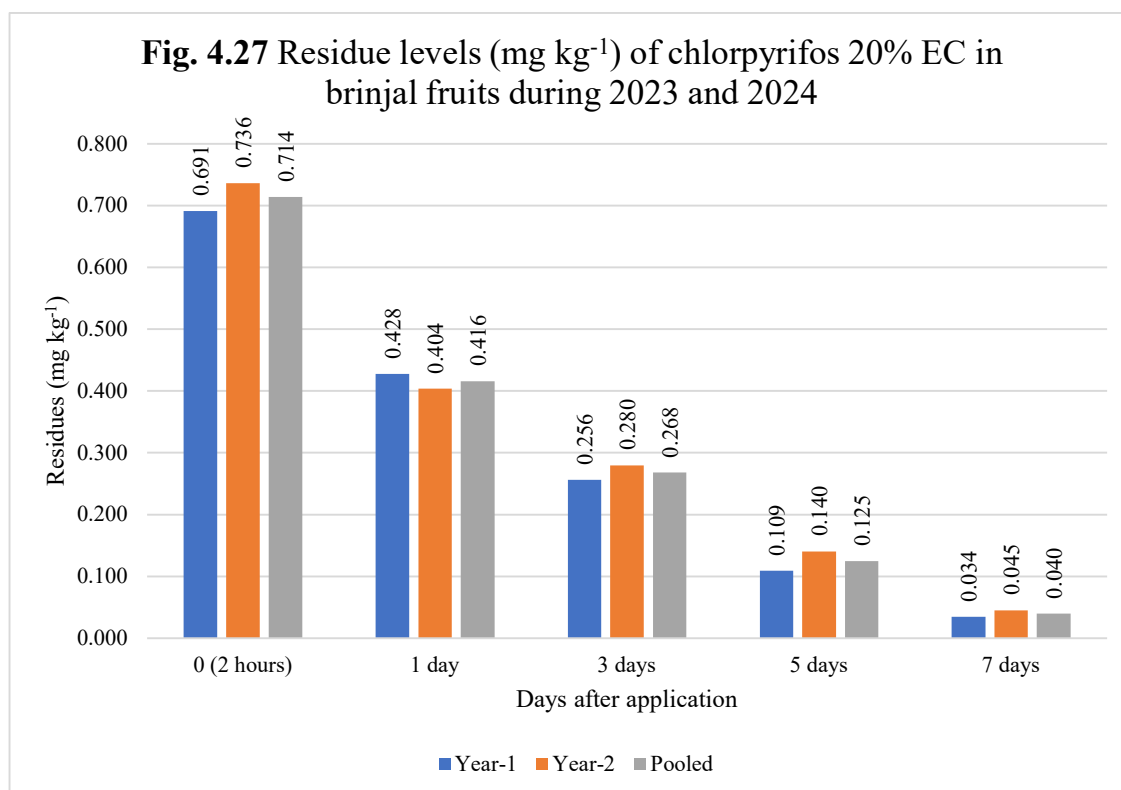
4.4.1 Chlorpyrifos 20% EC

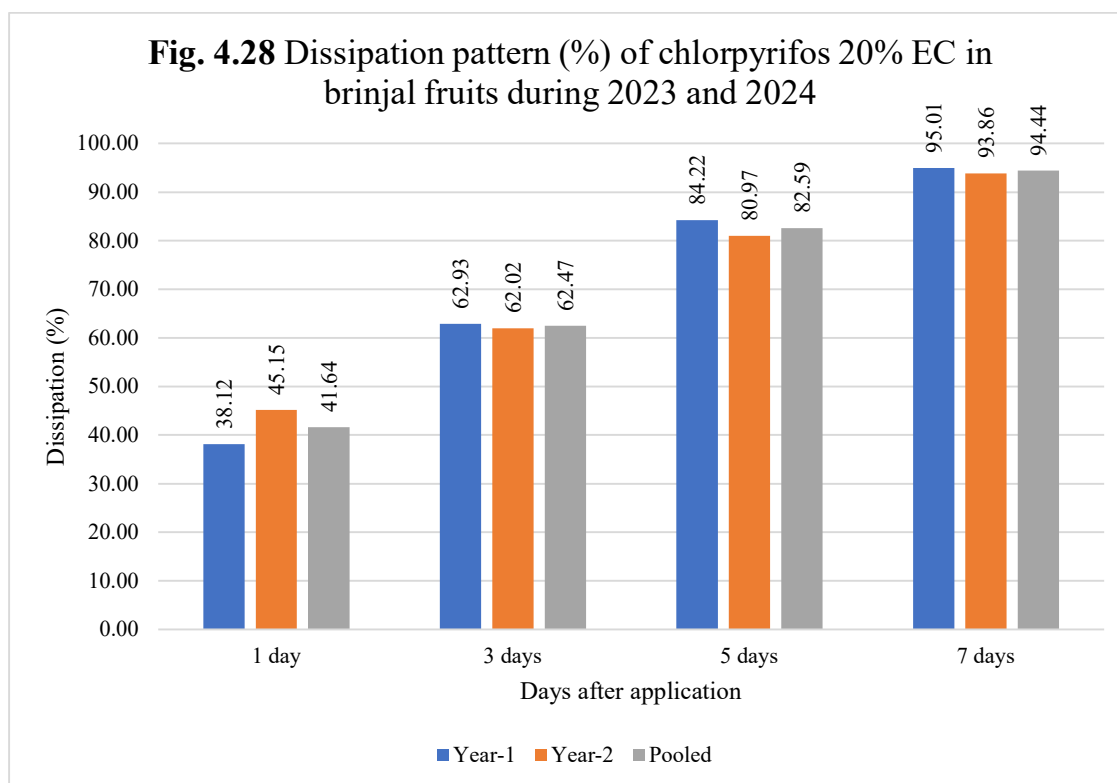
The data pertaining to the residue levels and dissipation pattern of chlorpyrifos 20% EC in brinjal fruits during 2023, 2024 and the pooled analysis are depicted in Table 4.27 and illustrated in Figures 4.27 and 4.28. The LOD and LOQ for chlorpyrifos were determined to be 0.01 and 0.03 mg kg⁻¹, respectively. The initial deposits of chlorpyrifos 20% EC were determined to be 0.691, 0.736 and 0.714 mg kg⁻¹ in 2023, 2024 and the pooled analysis, respectively. During 2023, the initial residues dissipated to 0.427, 0.256, 0.109 and 0.034 mg kg⁻¹, resulting in a decrease of 38.12, 62.93, 84.22 and 95.01 per cent after 1, 3, 5 and 7 days of spraying, respectively. In 2024, the dissipation trend showed residue levels were observed to be 0.404, 0.280, 0.140 and 0.045 mg kg⁻¹, corresponding to a decline of 45.15, 62.02, 80.97 and 93.86 per cent after 1, 3, 5 and 7 days, respectively. During the pooled analysis, the initial deposits dissipated to 0.416, 0.268, 0.125 and 0.040 mg kg⁻¹, contributing to a reduction of 41.64, 62.47, 82.59 and 94.44 per cent after 1, 3, 5, and 7 days, respectively. On the 10th day after spraying, the residues were found to be below the detection limit during both years and in the pooled analysis. All detected levels of chlorpyrifos residues in brinjal exceeded the maximum residue limit of 0.01 mg kg⁻¹ established by the European Union (EU). The aforementioned results are in close agreement with the findings of Ahmed *et al.*, 2021, who reported an initial deposit of 1.392 mg kg⁻¹ and detected residues up to the 7th day after application. However, Chandra *et al.*, 2014 reported that residue levels dissipated by 36.70 percent after the 1st day of spraying and declined by 99.4% after the 11th day of spraying at 100 g a.i. ha⁻¹. According to Momtaz and Khan (2024), the LOD and LOQ of chlorpyrifos for brinjal fruits were observed to be 0.011 and 0.034 mg kg⁻¹, respectively. The variation in residue levels from 0 to 7th day may be attributed to poor management or environmental photodegradation of pesticide residues. When exposed to sunlight, chlorpyrifos undergoes hydrolysis in the presence of water, releasing 3,5,6-trichloro-2-pyridinol, which further decomposes into diols and triols. Ultimately, the pyridinol ring cleaves to produce fragmented products (Iqbal *et al.*, 2007). The plant behaviour may be influenced by the physical and chemical properties of pesticides, including their metabolic rate and absorption by plants. Environmental factors such as wind, rain, sunlight, humidity, and temperature, along with chemical and physical processes such as plant growth and volatilization, interact to contribute to the dissipation of residues in and on plants (Ahmed *et al.*, 2021).

Table no. 4.27: Residue levels (mg kg⁻¹) and dissipation pattern (%) of chlorpyrifos 20% EC in brinjal fruits during 2023 and 2024

Days after spray	Residues (mg kg ⁻¹)			Dissipation (%)		
	2023	2024	Pooled	2023	2024	Pooled
0 (2 hrs)	0.691 ± 0.008	0.736 ± 0.006	0.714 ± 0.007	-	-	-
1	0.427 ± 0.011	0.404 ± 0.014	0.416 ± 0.011	38.12 ± 2.12	45.15 ± 2.29	41.64 ± 2.12
3	0.256 ± 0.011	0.280 ± 0.015	0.268 ± 0.002	62.93 ± 1.44	62.02 ± 2.24	62.47 ± 0.49
5	0.109 ± 0.012	0.140 ± 0.018	0.125 ± 0.014	84.22 ± 1.60	80.97 ± 2.38	82.59 ± 1.88
7	0.034 ± 0.010	0.045 ± 0.007	0.040 ± 0.006	95.01 ± 1.42	93.86 ± 1.04	94.44 ± 0.92
10	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
15	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L

B.D.L = Below Detection Limit; LOD = 0.01 mg kg; LOQ = 0.03 mg kg⁻¹





4.4.2 Triazophos 40% EC

The data presented in Table 4.28 and illustrated in Figures 4.29 and 4.30 indicates the residue levels and dissipation pattern of triazophos 40% EC in brinjal fruits during 2023, 2024 and the pooled analysis. The LOD and LOQ for triazophos were determined to be 0.01 and 0.05 mg kg⁻¹, respectively. The initial deposit of triazophos 40% EC was 1.391 mg kg⁻¹ in brinjal fruits during 2023. The residues declined to 1.129, 0.554, 0.248 and 0.080 mg kg⁻¹ on the 1st, 3rd, 5th and 7th days after application and the corresponding dissipation was 18.68, 60.02, 82.21 and 94.19 per cent, respectively. In 2024, the initial deposit was found to be 1.242 mg kg⁻¹. The residue levels decreased to 0.984, 0.453, 0.158 and 0.100 mg kg⁻¹, with a dissipation trend of 20.61, 63.70, 87.24 and 91.79 per cent on the 1st, 3rd, 5th and 7th days after spraying, respectively. In the pooled analysis, initial deposit in brinjal fruits was 1.317 mg kg⁻¹. The residues declined to 1.056, 0.504, 0.203 and 0.090 mg kg⁻¹, with a dissipation trend of 19.65, 61.86, 84.72 and 92.99 per cent on the 1st, 3rd, 5th and 7th days, respectively. On the 10th day after spraying, the residues were found to be below the detection limit during 2023, 2024 and in the pooled analysis. All detected levels of triazophos residues in brinjal exceeded the maximum residue limit (MRL) of 0.01 mg kg⁻¹ established by the European Union (EU). The present findings are in close agreement with those of Brar *et al.*, 2017, who reported an initial deposit of triazophos at 1.100 mg kg⁻¹ on brinjal fruits at the recommended dosage, along with

a similar dissipation trend in which the residues declined to 28.78 per cent after the 1st day of application, dissipated by 95.15 percent on the 7th day and decreased below the detection limit on the 10th day after application. Similarly, Deore *et al.*, 2018 reported an initial deposit of triazophos was 1.40 mg kg⁻¹, with 90.21 per cent dissipation observed by the 7th day after application and residue levels declined below the detection limit by the 10th day after spraying at a dosage of 500 g a.i. ha⁻¹. Patil *et al.*, 2018 also observed that the initial deposit of triazophos dissipated by 91.11 per cent on the 7th day and declined below the detection limit on the 10th day after application at the optimal dosage. Guru and Patil (2018) reported that the LOQ of triazophos for brinjal fruits was 0.05 mg kg⁻¹. Variations in application doses, matrix modifications, and environmental circumstances could all contribute to differences in results (Gogikar *et al.*, 2017). Environmental factors such as humidity and temperature significantly influence the dissipation of insecticides. Higher temperatures primarily accelerate photodegradation by increasing photochemical reactions. Similarly, humidity levels also influence the dissipation process (Zou *et al.*, 2024).

Table no. 4.28: Residue levels (mg kg⁻¹) and dissipation pattern (%) of triazophos 40% EC in brinjal fruits during 2023 and 2024

Days after spray	Residues (mg kg ⁻¹)			Dissipation (%)		
	2023	2024	Pooled	2023	2024	Pooled
0 (2 hrs)	1.391 ± 0.092	1.242 ± 0.158	1.317 ± 0.063	-	-	-
1	1.129 ± 0.028	0.984 ± 0.169	1.056 ± 0.081	18.68 ± 5.05	20.61 ± 10.07	19.65 ± 6.43
3	0.554 ± 0.012	0.453 ± 0.190	0.504 ± 0.098	60.02 ± 3.27	63.70 ± 13.44	61.86 ± 8.00
5	0.248 ± 0.032	0.158 ± 0.014	0.203 ± 0.020	82.21 ± 1.13	87.24 ± 1.15	84.72 ± 1.09
7	0.080 ± 0.012	0.100 ± 0.022	0.090 ± 0.010	94.19 ± 1.21	91.79 ± 2.73	92.99 ± 1.16
10	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
15	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L

B.D.L = Below Detection Limit; LOD = 0.02 mg kg⁻¹; LOQ = 0.05 mg kg⁻¹

Fig. 4.29 Residue levels (mg kg⁻¹) of triazophos 40% EC in brinjal fruits during 2023 and 2024

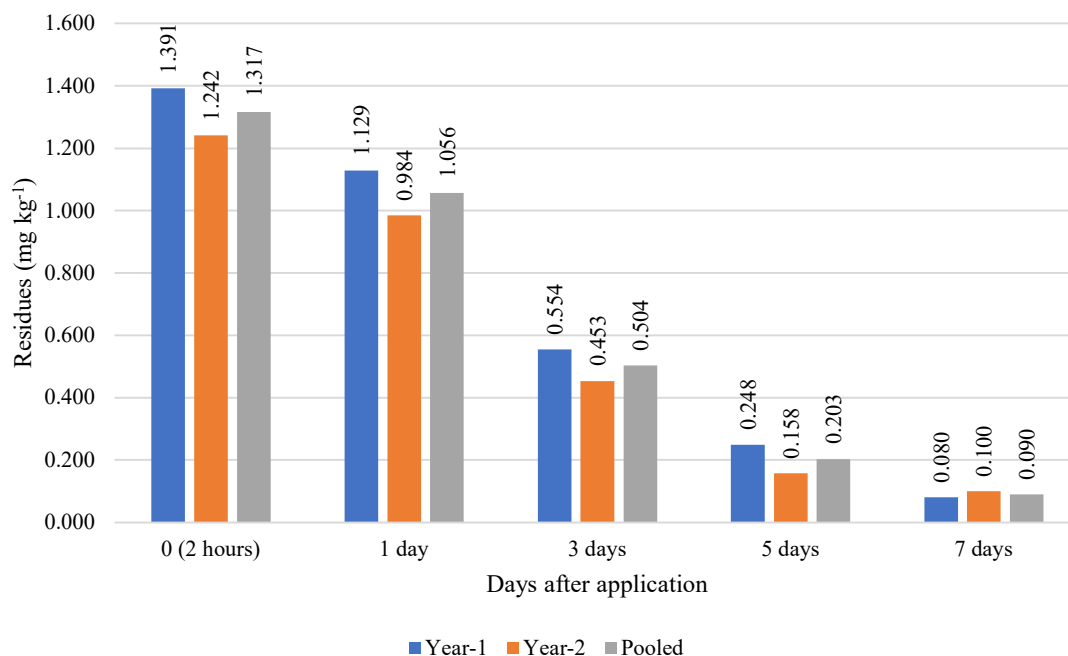
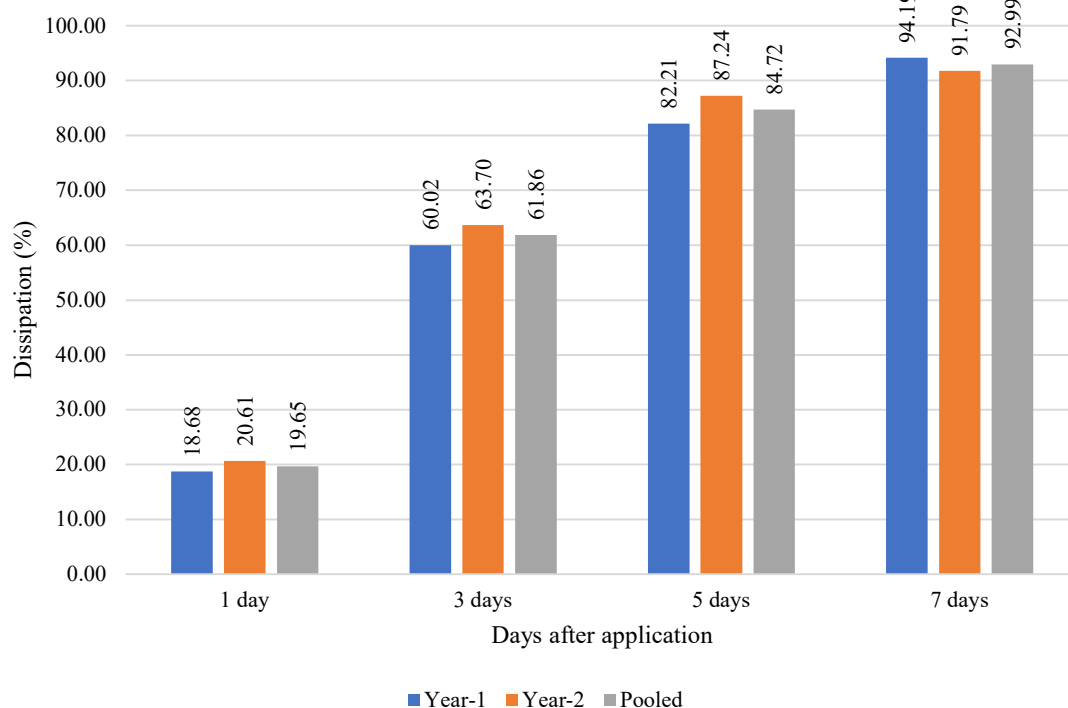


Fig. 4.30 Dissipation pattern (%) of triazophos 40% EC in brinjal fruits during 2023 and 2024



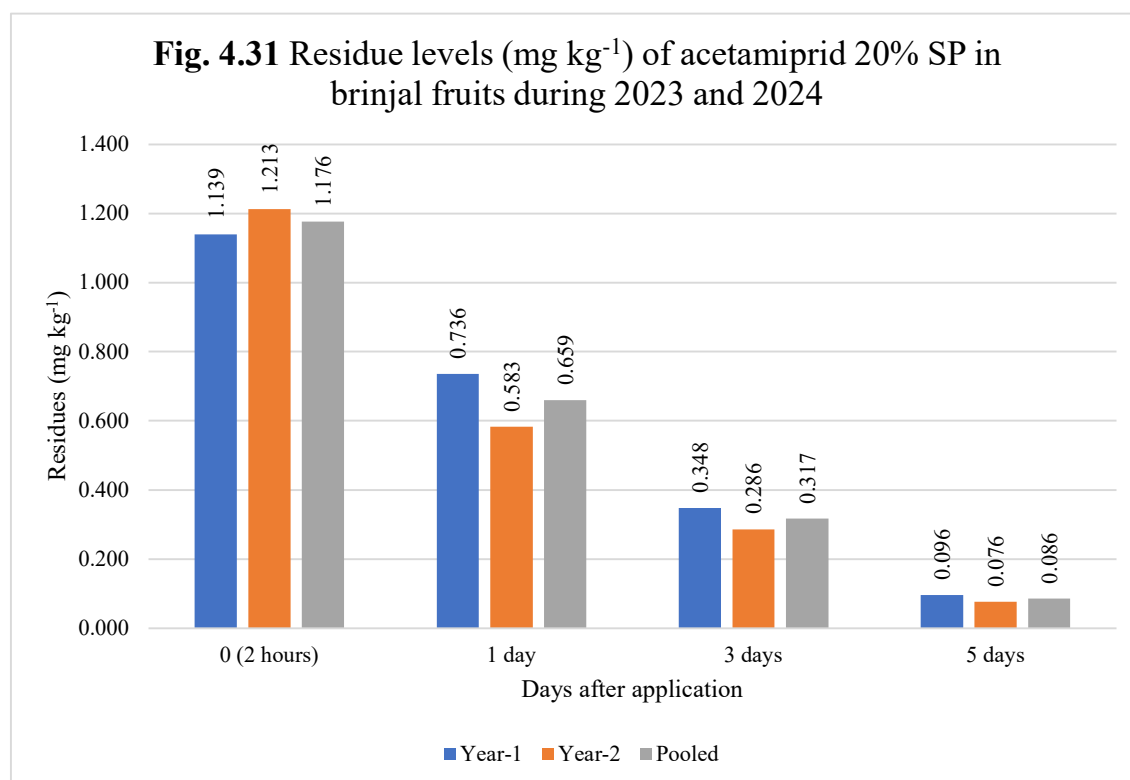
4.4.3 Acetamiprid 20% SP

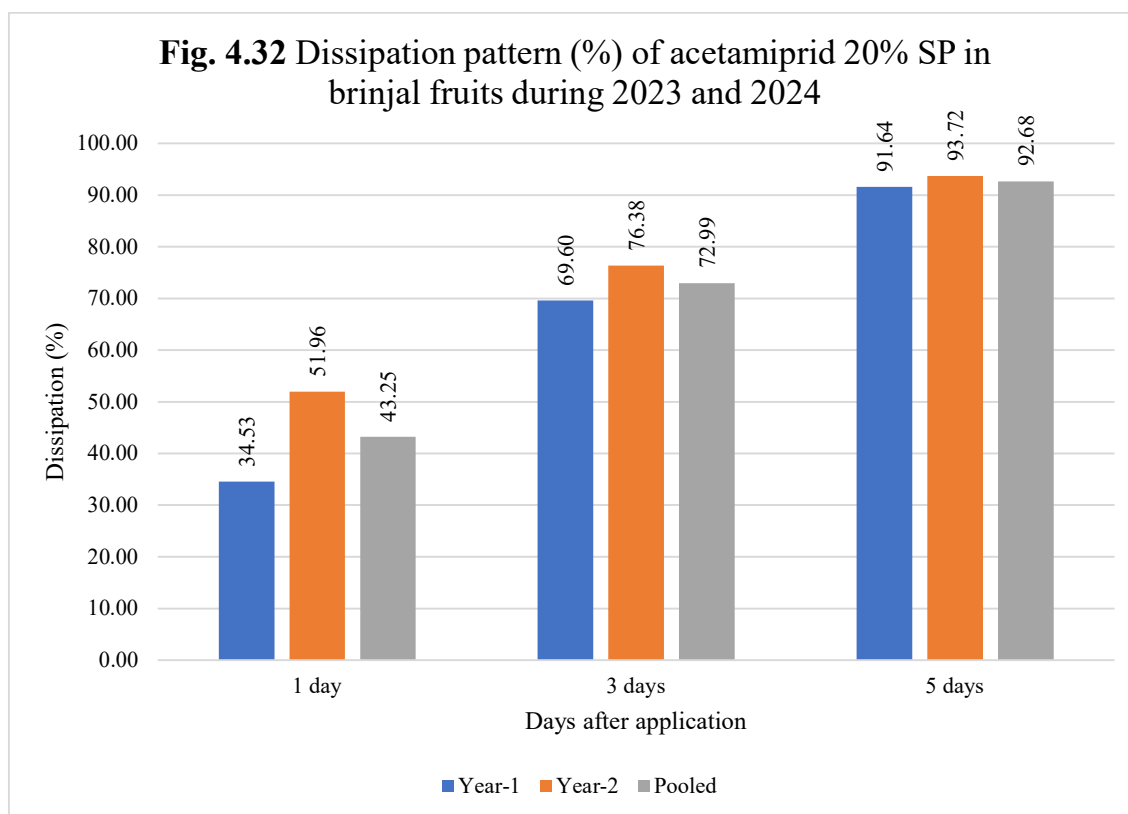
The results obtained for the residue levels and dissipation pattern of acetamiprid 20% SP in brinjal fruits during 2023, 2024 and the pooled analysis are depicted in Table 4.29 and illustrated in Figures 4.31 and 4.32. The LOD and LOQ for acetamiprid were determined to be 0.02 and 0.05 mg kg⁻¹, respectively. The results indicated a decrease in residue levels of acetamiprid 20% SP in brinjal fruits over time. The initial deposit of acetamiprid 20% SP was 1.139 mg kg⁻¹ in brinjal fruits during 2023. The residues declined to 0.736, 0.348 and 0.096 mg kg⁻¹ on the 1st, 3rd and 5th days after application, with a corresponding dissipation of 34.53, 69.60 and 91.64 per cent, respectively. During 2024, the initial deposit was found to be 1.213 mg kg⁻¹. The residue levels decreased to 0.583, 0.286 and 0.076 mg kg⁻¹, with a corresponding dissipation trend of 51.96, 76.38 and 93.72 per cent on the 1st, 3rd and 5th days after spraying. In the pooled analysis, the initial deposit in brinjal fruits was 1.176 mg kg⁻¹. The residues declined to 0.659, 0.317 and 0.086 mg kg⁻¹, with a corresponding dissipation trend of 43.25, 72.99 and 92.68 percent on the 1st, 3rd and 5th days, respectively. The residues of acetamiprid 20% SP were found to be below the detection limit on the 7th day after spraying in brinjal fruits during 2023, 2024 and in the pooled analysis. According to the European Union (EU), the maximum residue limit (MRL) of acetamiprid is 0.20 mg kg⁻¹, and residue levels were found to be below this limit on the 5th day after application. The present findings are in close agreement with those of Romeh *et al.*, 2013, who reported the initial deposit of acetamiprid below the detection limit on 7th day after spraying on brinjal fruits. However, Abdelfatah *et al.*, 2024 reported an initial deposit of acetamiprid on brinjal fruits was 1.258 mg kg⁻¹ at the recommended dosage, along with a similar dissipation trend in which the residues declined to 23.37 per cent after the 1st day of application, dissipated by 99.13 percent on the 7th day and decreased below the detection limit on the 10th day after application. According to Romeh *et al.*, 2013, the LOD and LOQ of acetamiprid for brinjal fruits were 0.02 and 0.05 mg kg⁻¹, respectively. Varying environmental conditions associated with open field sites could explain the higher dissipation rate (Singh *et al.*, 2023b). The growth dilution factor may also contribute to the fast degradation and reduced persistence of insecticide residues in plants (Fantke and Juraske, 2013). The physicochemical properties of the insecticide (e.g., hydrolysis, water solubility, vapor pressure); crop attributes (such as plant species, translocation, growth rate, excretion, and ease of penetration); environmental conditions (humidity, precipitation, temperature, and direct sunlight); microbial activity; the method of application; and the interval between applications are some of the factors that typically influence the degradation of insecticides applied to crops (Abdelfatah *et al.*, 2024).

Table no. 4.29: Residue levels (mg kg⁻¹) and dissipation pattern (%) of acetamiprid 20% SP in brinjal fruits during 2023 and 2024

Days after spray	Residues (mg kg ⁻¹)			Dissipation (%)		
	2023	2024	Pooled	2023	2024	Pooled
0 (2 hrs)	1.139 ± 0.163	1.213 ± 0.017	1.176 ± 0.090	-	-	-
1	0.736 ± 0.035	0.583 ± 0.014	0.659 ± 0.019	34.53 ± 9.32	51.96 ± 0.47	43.25 ± 4.43
3	0.348 ± 0.073	0.286 ± 0.007	0.317 ± 0.040	69.60 ± 2.29	76.38 ± 0.28	72.99 ± 1.27
5	0.096 ± 0.027	0.076 ± 0.003	0.086 ± 0.014	91.64 ± 1.24	93.72 ± 0.12	92.68 ± 0.64
7	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
10	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
15	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L

B.D.L = Below Detection Limit; LOD = 0.02 mg kg⁻¹; LOQ = 0.05 mg kg⁻¹





4.4.4 Deltamethrin 2.8% EC

The observations recorded on the residue levels and dissipation pattern of deltamethrin 2.8% EC for the years 2023, 2024 and the pooled analysis have been depicted in Table 4.30 and presented in Figures 4.33 and 4.34. The LOD and LOQ for deltamethrin were determined to be 0.01 and 0.03 mg kg⁻¹, respectively. The results indicated a decrease in residue levels of deltamethrin 2.8% EC in brinjal fruits over time. The initial deposit of deltamethrin 2.8% EC was 0.482 mg kg⁻¹ in brinjal fruits during 2023. The residues declined to 0.334, 0.163 and 0.034 mg kg⁻¹ on the 1st, 3rd and 5th days after application, with a corresponding dissipation of 29.70, 65.14 and 92.48 per cent, respectively. During 2024, the initial deposit was found to be 0.530 mg kg⁻¹. The residue levels decreased to 0.416, 0.185 and 0.054 mg kg⁻¹, with a corresponding dissipation of 20.94, 64.72 and 89.50 per cent on the 1st, 3rd and 5th days after spraying. In the pooled analysis, initial deposit in brinjal fruits was 0.506 mg kg⁻¹. The residues declined to 0.375, 0.174 and 0.044 mg kg⁻¹, with a corresponding dissipation of 25.32, 64.93 and 90.99 percent on the 1st, 3rd and 5th days, respectively. The residues of deltamethrin 2.8% EC were found to be below the detection limit on the 7th day after spraying in brinjal fruits during both years and in the pooled analysis. According to the European Union (EU), the maximum residue limit (MRL) of deltamethrin 2.8% EC is 0.40 mg kg⁻¹, and residue levels were found to be

below this limit on the 3rd day after application. The present findings are in close agreement with those of Patel *et al.*, 2016 who reported the initial deposit of deltamethrin on brinjal fruits was 0.25 mg kg⁻¹ at the recommended dosage, along with a similar dissipation trend in which the residues declined to 40.00 per cent after the 1st day of application, dissipated by 84.00 percent on the 4th day and decreased below the detection limit on the 7th day after application during the summer season. Sharma *et al.*, 2018 reported that the LOD and LOQ of deltamethrin for cucumber fruits were 0.01 and 0.05 mg kg⁻¹, respectively. The increased rate of dissipation may be attributed to variations in environmental conditions associated with open field sites (Singh *et al.*, 2023b). Photodegradation contributes significantly breakdown of pesticides, and factors such as soil characteristics and environmental conditions influence the rate of degradation. As a significant chemical process in pesticide degradation, photodegradation is strongly affected by both chemical and environmental factors. Weather, soil properties, sunlight exposure, and the chemical composition of the pesticide greatly influence the rate at which it degrades (Zhou *et al.*, 2024). The variation in residue levels from 0 to 7th day may be attributed to poor management or environmental photodegradation of pesticide residues.

Table no. 4.30: Residue levels (mg kg⁻¹) and dissipation pattern (%) of deltamethrin 2.8% EC in brinjal fruits during 2023 and 2024

Days after spray	Residues (mg kg ⁻¹)			Dissipation (%)		
	2023	2024	Pooled	2023	2024	Pooled
0 (2 hrs)	0.482 ± 0.078	0.530 ± 0.048	0.506 ± 0.063	-	-	-
1	0.334 ± 0.017	0.416 ± 0.018	0.375 ± 0.008	29.70 ± 8.98	20.94 ± 8.02	25.32 ± 8.16
3	0.163 ± 0.021	0.185 ± 0.019	0.174 ± 0.019	65.14 ± 10.19	64.72 ± 6.87	64.93 ± 8.52
5	0.034 ± 0.014	0.054 ± 0.017	0.044 ± 0.014	92.48 ± 4.08	89.50 ± 4.21	90.99 ± 3.89
7	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
10	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
15	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L

B.D.L = Below Detection Limit; LOD = 0.01 mg kg⁻¹; LOQ = 0.03 mg kg⁻¹

Fig. 4.33 Residue levels (mg kg⁻¹) of deltamethrin 2.8% EC in brinjal fruits during 2023 and 2024

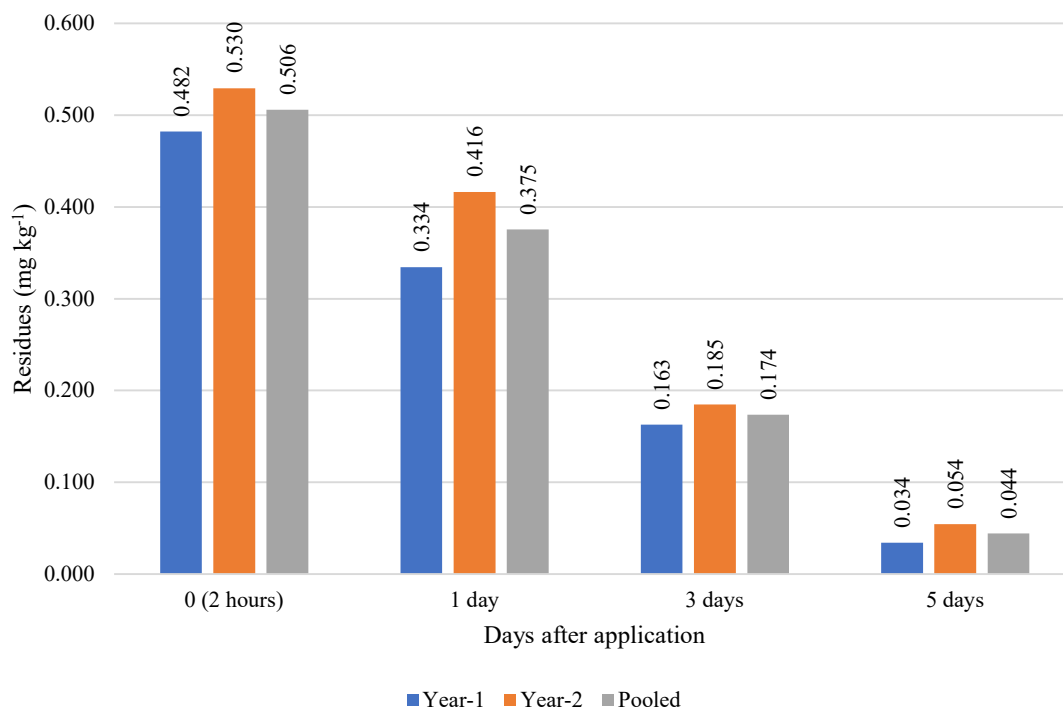
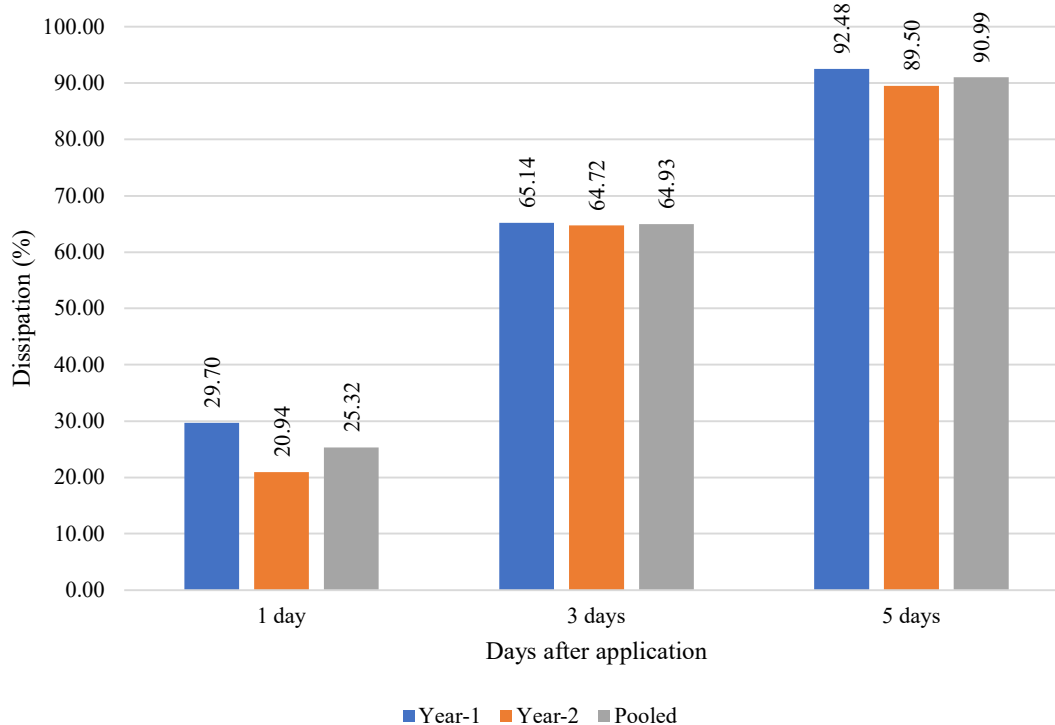


Fig. 4.34 Dissipation pattern (%) of deltamethrin 2.8% EC in brinjal fruits during 2023 and 2024



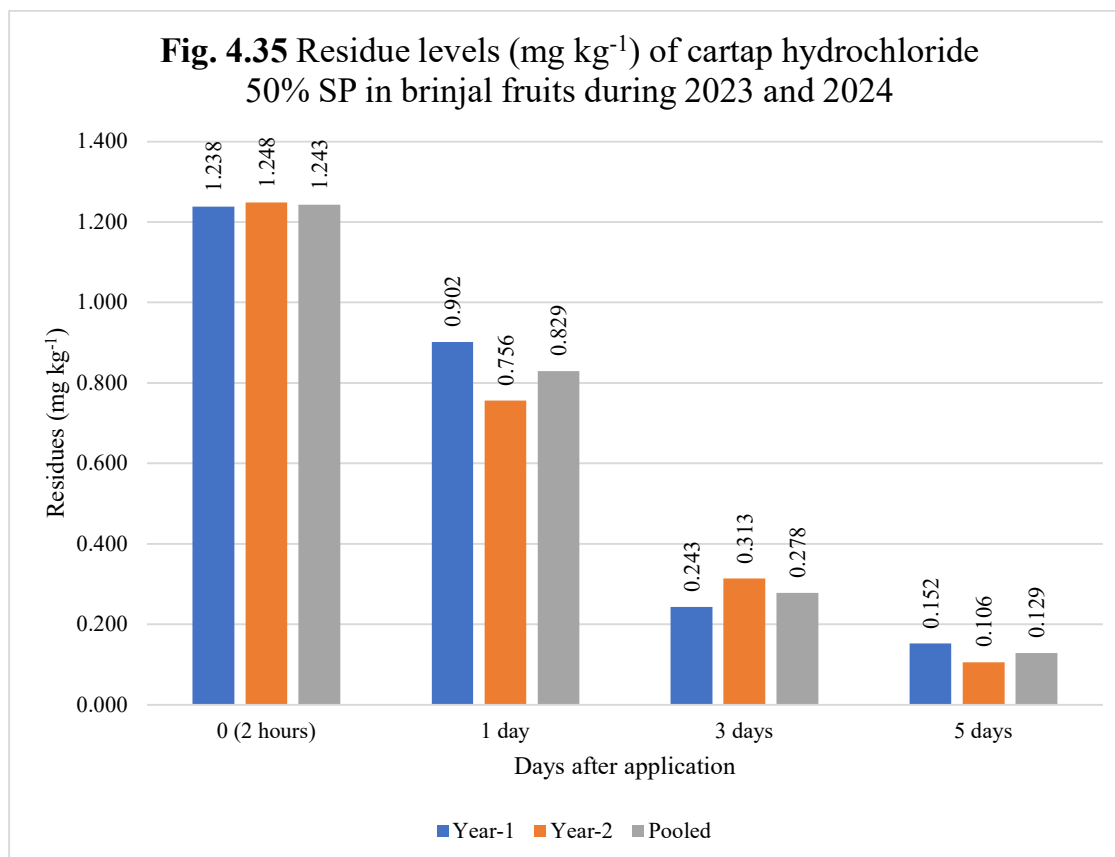
4.4.5 Cartap hydrochloride 50% SP

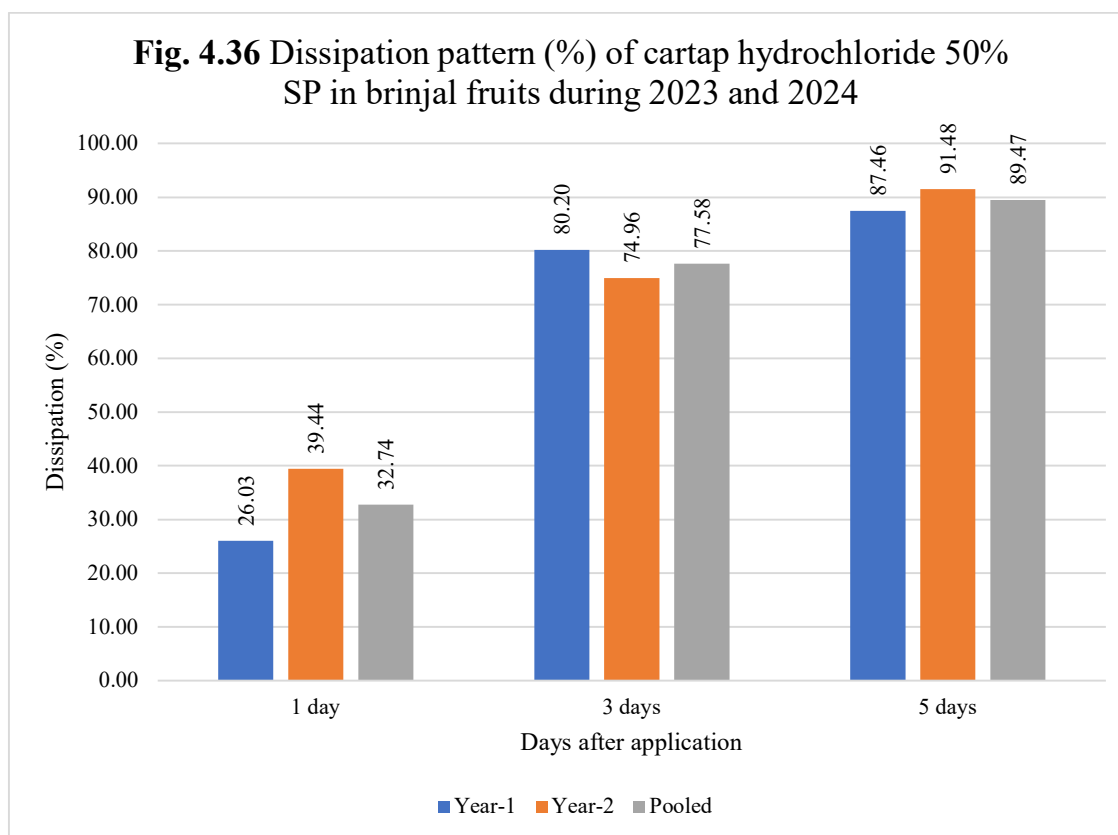
The data presented in Table 4.31 and depicted in Figures 4.35 and 4.36 indicate the residue levels and dissipation pattern of cartap hydrochloride 50% SP in brinjal fruits during 2023, 2024 and the pooled analysis. The LOD and LOQ for cartap hydrochloride were determined to be 0.03 and 0.10 mg kg⁻¹, respectively. The results indicated a decrease in residue levels of cartap hydrochloride 50% SP in brinjal fruits over time. The initial deposit of cartap hydrochloride 50% SP was 1.238 mg kg⁻¹ in brinjal fruits during 2023. The residues declined to 0.902, 0.243 and 0.152 mg kg⁻¹ on the 1st, 3rd and 5th days after application, with a corresponding dissipation of 26.03, 80.20 and 87.46 per cent, respectively. During 2024, the initial deposit was found to be 1.248 mg kg⁻¹. The residue levels decreased to 0.756, 0.313 and 0.106 mg kg⁻¹, with a corresponding dissipation trend of 39.44, 74.96 and 91.48 per cent on the 1st, 3rd and 5th days after spraying. In the pooled analysis, the initial deposit in brinjal fruits was 1.243 mg kg⁻¹. The residues declined to 0.829, 0.278 and 0.129 mg kg⁻¹, with a corresponding dissipation trend of 32.74, 77.58 and 89.47 percent on the 1st, 3rd and 5th days, respectively. The residues of cartap hydrochloride 50% SP were found to be below the detection limit on the 7th day after spraying in brinjal fruits during 2023, 2024 and in the pooled analysis. All detected levels of cartap hydrochloride residues in brinjal exceeded the maximum residue limit (MRL) of 0.02 mg kg⁻¹ established by the United Kingdom and other European Union nations. The present findings are in close agreement with those of Rao *et al.*, 2014, who reported that the initial deposit of cartap hydrochloride on brinjal fruits was 0.71 mg kg⁻¹ at the recommended dosage (500 a.i. g ha⁻¹), and residues decreased below the detection limit by the 7th day after spraying. Rao *et al.*, 2014 also suggested that the LOD of cartap hydrochloride for brinjal fruits was 0.05 mg kg⁻¹. Low amounts of cartap hydrochloride, when exposed to light, break down quickly, particularly when applied as a thin layer on inert surfaces or leaves. Although cartap hydrochloride photodegrades rapidly after application, it maintains residual activity in the field due to its translaminar action and fast penetration into leaf tissue. In addition to its high efficacy, it is a bio-rational product derived from a biological source, which makes it suitable for use in eco-friendly integrated pest management systems (Lee *et al.*, 2004; Rao *et al.*, 2014). Variations in findings could be attributed to differences in agroclimatic conditions, application techniques, and the amount applied.

Table no. 4.31: Residue levels (mg kg⁻¹) and dissipation pattern (%) of cartap hydrochloride 50% SP in brinjal fruits during 2023 and 2024

Days after spray	Residues (mg kg ⁻¹)			Dissipation (%)		
	2023	2024	Pooled	2023	2024	Pooled
0 (2 hrs)	1.238 ± 0.138	1.248 ± 0.015	1.243 ± 0.076	-	-	-
1	0.902 ± 0.102	0.756 ± 0.052	0.829 ± 0.044	26.03 ± 14.97	39.44 ± 3.65	32.74 ± 6.27
3	0.243 ± 0.002	0.313 ± 0.118	0.278 ± 0.060	80.20 ± 2.08	74.96 ± 9.06	77.58 ± 3.74
5	0.152 ± 0.022	0.106 ± 0.022	0.129 ± 0.022	87.46 ± 3.19	91.48 ± 1.85	89.47 ± 2.51
7	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
10	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
15	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L

B.D.L = Below Detection Limit; LOD = 0.03 mg kg⁻¹; LOQ = 0.10 mg kg⁻¹





4.4.6 Carbofuran 3% CG

The data pertaining to residues and dissipation pattern of carbofuran 3% CG in brinjal during 2023, 2024 and the pooled analysis are depicted in Table 4.32 and illustrated in Figures 4.37 and 4.38. The LOD and LOQ for carbofuran were determined to be 0.02 and 0.06 mg kg⁻¹, respectively. The initial deposits of carbofuran 3% CG were detected to be 0.332, 0.393 and 0.362 mg kg⁻¹ during 2023, 2024 and the pooled analysis. During 2023, the initial residues dissipated to 0.219, 0.124, 0.076, 0.060 and 0.036 mg kg⁻¹, resulting in a decrease of 33.50, 62.34, 77.21, 81.42 and 89.18 per cent after 1, 3, 5, 7 and 10 days of spraying, respectively. In 2024, the dissipation trend showed residue levels of carbofuran 3% CG were 0.256, 0.173, 0.134, 0.081 and 0.039 mg kg⁻¹, leading to a decline of 34.62, 55.86, 65.94, 79.26 and 90.04 per cent after 1, 3, 5, 7 and 10 days, respectively. During the pooled analysis, the initial deposits dissipated to 0.237, 0.149, 0.105, 0.071 and 0.037 mg kg⁻¹, contributing to a reduction of 34.06, 59.10, 71.58, 80.34 and 89.61 per cent over the same time intervals. On the 15th day after spraying, the residues of carbofuran 3% CG were found to be below the detection limit during both years and in the pooled analysis. All detected levels of carbofuran residues in brinjal exceeded the maximum residue limit (MRL) of 0.002 mg/kg established by European commission. The present findings are in close agreement with those of Yeasmin *et al.*, 2019,

who reported that the initial deposit of carbofuran on brinjal fruits was 0.071 and 0.067 mg kg⁻¹ at the recommended dosage in both varieties (BARI-8 and UTTARA). Iqbal *et al.*, 2007 reported that the initial deposit of carbofuran on brinjal fruit was 0.095 mg kg⁻¹ at optimal dosage. Boonkhao *et al.*, 2022 reported that the LOD and LOQ of carbofuran for vegetable were 0.02 and 0.10 mg kg⁻¹, respectively. The fate and degradation of carbofuran in the environment are primarily controlled by biodegradation. According to Baharudin *et al.*, 2024, carbofuran typically breaks down through multiple processes, including oxidation, hydrolysis, photolysis, and microbial degradation. Variations in agroclimatic conditions, application methods, physicochemical properties of the product, and the quantity applied in the field may all contribute to differences in the results.

Table no. 4.32: Residue levels (mg kg⁻¹) and dissipation pattern (%) of carbofuran 3% CG in brinjal fruits during 2023 and 2024

Days after spray	Residues (mg kg ⁻¹)			Dissipation (%)		
	2023	2024	Pooled	2023	2024	Pooled
0 (2 hrs)	0.332 ± 0.028	0.393 ± 0.024	0.362 ± 0.026	-	-	-
1	0.219 ± 0.023	0.256 ± 0.018	0.237 ± 0.020	33.50 ± 11.22	34.62 ± 8.06	34.06 ± 9.62
3	0.124 ± 0.023	0.173 ± 0.015	0.149 ± 0.019	62.34 ± 8.12	55.86 ± 5.23	59.10 ± 6.63
5	0.076 ± 0.015	0.134 ± 0.044	0.105 ± 0.029	77.21 ± 3.81	65.94 ± 9.97	71.58 ± 6.78
7	0.060 ± 0.017	0.081 ± 0.027	0.071 ± 0.019	81.42 ± 6.67	79.26 ± 7.68	80.34 ± 6.46
10	0.036 ± 0.003	0.039 ± 0.008	0.037 ± 0.005	89.18 ± 1.64	90.04 ± 2.54	89.61 ± 2.02
15	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L

B.D.L = Below Detection Limit; LOD = 0.02 mg kg⁻¹; LOQ = 0.06 mg kg⁻¹

Fig. 4.37 Residue levels (mg kg⁻¹) of carbofuran 3% CG in brinjal fruits during 2023 and 2024

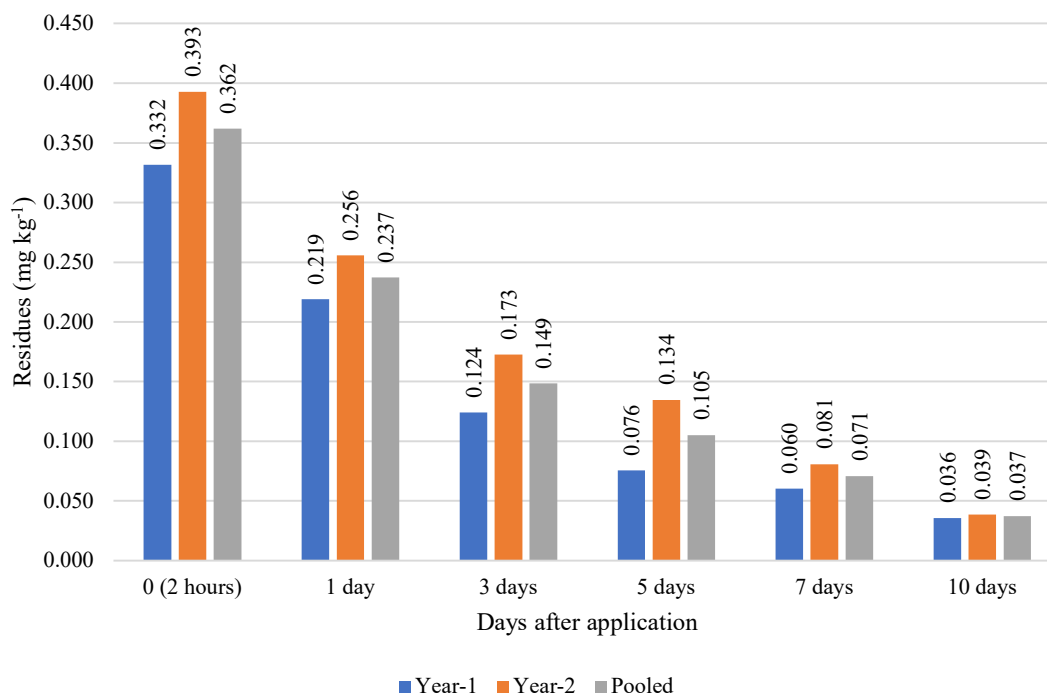
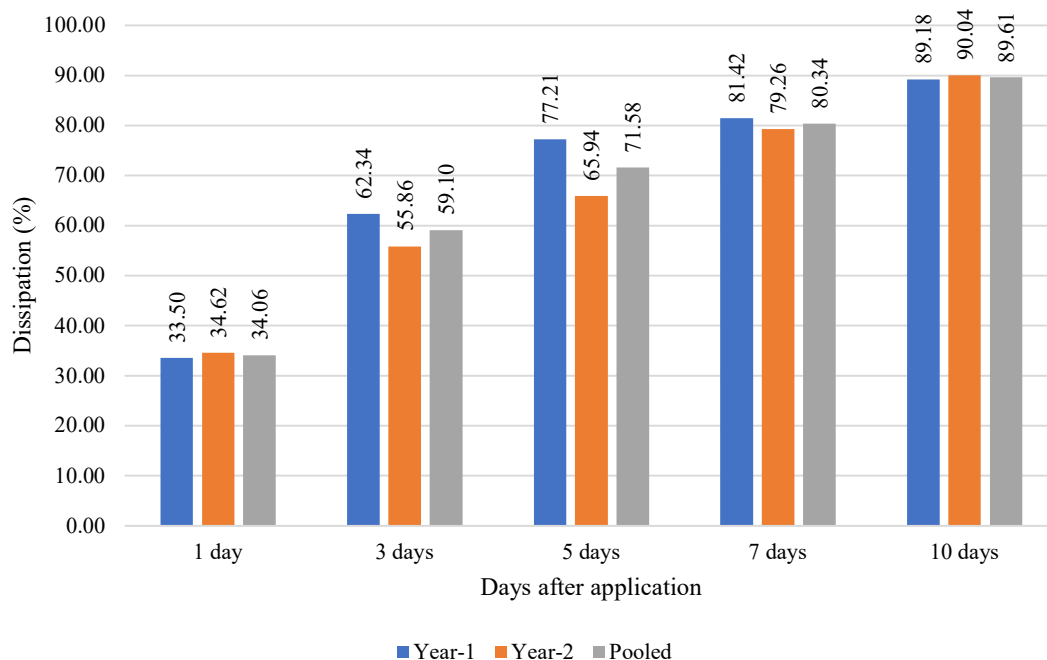


Fig. 4.38 Dissipation pattern (%) of carbofuran 3% CG in brinjal fruits during 2023 and 2024



4.5 Seasonal incidence of shoot and fruit borer on brinjal

The seasonal incidence of *Leucinodes orbonalis* on brinjal was recorded from June to October in 2023 and 2024. Data on the incidence of *Leucinodes orbonalis* and various meteorological parameters are presented in Tables 4.33 to 4.35 and illustrated in Figures 4.39 to 4.42.

4.5.1 Shoot infestation

The data pertaining to per cent shoot damage in brinjal observed from 23rd to 43rd SMW during 2023, 2024 and the pooled analysis are provided in Tables 4.33 to 4.35 and illustrated in Figures 4.39 to 4.42. It is evident from the data that the observations on shoot infestation levels varied periodically. In 2023, shoot damage by *Leucinodes orbonalis* began at 6.78% during the 5th week after transplanting (27th SMW) and peaked at 28.78% in the 36th SMW, coinciding with a maximum temperature of 34.92 °C, minimum of 24.71 °C, 92.00% morning and 60.86% evening relative humidity, 10.27 sunshine hours and no rainfall. In 2024, initial damage was 4.20% in the 4th week after transplanting (26th SMW), peaking at 32.68% during the 35th SMW, with corresponding weather conditions of 33.27 °C (max), 25.25 °C (min), 94.39% morning RH, 73.68% evening RH, 0.47 mm rainfall and 5.78 sunshine hours. Pooled data showed initial damage of 2.10% in the 4th week (26th SMW), peaking at 29.75% in the 36th SMW, associated with 34.53 °C max., 25.46 °C min. temperatures, 93.54% morning RH, 67.29% evening RH, 0.81 mm rainfall, and 8.63 sunshine hours. The present findings were in close agreement with those of Nayak *et al.*, 2023 who reported that shoot infestation ranged from 0.64 to 30.84% and 0.75 to 32.74% during the first and second years of investigation, respectively. Similarly, Kolhe *et al.*, 2020 who suggested that the per cent shoot infestation in brinjal during the *kharif* season ranged from 3.85 to 33.50%.

4.5.2 Fruit infestation (number basis)

The data related to per cent fruit damage (number basis) in brinjal observed from 23rd to 43rd SMW during 2023, 2024 and the pooled analysis are depicted in Tables 4.33 to 4.35 and illustrated in Figures 4.39 to 4.42. It is evident from the data that fruit infestation levels varied periodically. In 2023, fruit infestation ranged from 3.48% (31st SMW) to a peak of 40.62% (37th SMW), associated with temperatures of 34.24 °C (max.), 25.99 °C (min.), 91.00% morning RH, 70.00% evening RH, 0.57 mm rainfall and 3.01 sunshine hours. The lowest infestation occurred at 35.43 °C (max.), 27.59 °C (min.), 90.86% morning RH, 68.71% evening RH, 8.66 mm rainfall, and 5.91 sunshine hours. In 2024, infestation varied between 4.68% (31st SMW) and 45.75% (38th SMW), with peak infestation corresponding to 34.68 °C (max.), 24.53 °C (min.), 94.17% morning RH, 64.48% evening RH, no rainfall, and 7.46 sunshine

hours. The lowest infestation was recorded at 4.68%, associated with the 35.60 °C (max.), 28.11 °C (min), 92.58% morning RH, 77.52% evening RH, 2.46 mm rainfall, and 5.34 sunshine hours. Pooled data showed infestation levels from 4.08% (31st SMW) to 41.27% (38th SMW), with peak infestation at 33.16 °C (max), 24.23 °C (min), 93.09% morning RH, 67.78% evening RH, 1.22 mm rainfall, and 5.26 sunshine hours. Similar findings were observed by Nayak *et al.*, 2023 who reported that fruit infestation on a number basis ranged from 6.09 to 30.27% and 5.47 to 26.32% during the first and second years of research, respectively. Similarly, Haq and Rizvi (2023) also reported that fruit infestation on a number basis ranged from 27.45 to 53.26% and 27.12 to 53.11% during both individual years of the experiment.

4.5.3 Fruit infestation (weight basis)

The data pertaining to per cent fruit damage (weight basis) in brinjal observed from 23rd to 43rd SMW during 2023, 2024 and the pooled analysis, are presented in Tables 4.33 to 4.35 and illustrated in Figures 4.39 to 4.42. In 2023, fruit infestation (weight basis) ranged from 1.24% (31st SMW) to 37.22% (37th SMW), with peak infestation occurring at 34.24 °C (max.), 25.99 °C (min.), 91.00% morning RH, 70.00% evening RH, 0.57 mm rainfall and 3.01 sunshine hours. The lowest infestation of 1.24% corresponded to 35.43 °C (max.), 27.59 °C (min.), 90.86% morning RH, 68.71% evening RH, 8.66 mm rainfall and 5.91 sunshine hours. In 2024, infestation ranged from 1.64% (31st SMW) to 42.78% (38th SMW), with peak infestation recorded under 34.68 °C (max.), 24.53 °C (min.), 94.17% morning RH, 64.48% evening RH, no rainfall and 7.46 sunshine hours. The lowest infestation of 1.64% was observed at 35.60 °C (max), 28.11 °C (min), 92.58% morning RH, 77.52% evening RH, 2.46 mm rainfall, and 5.34 sunshine hours. Pooled data showed infestation from 1.44% to 37.25%, with the highest at 38th SMW (33.16 °C max, 24.23 °C min, 93.09% morning RH, 67.78% evening RH, 1.22 mm rainfall, and 5.26 sunshine hours) and the lowest at 31st SMW (35.51 °C max, 27.85 °C min, 91.72% morning RH, 73.12% evening RH, 5.56 mm rainfall, and 5.63 sunshine hours). The present findings were closely supported by those of Mahore *et al.*, 2025 who reported that per cent fruit infestation on a weight basis ranged from 6.67 to 30.12% and 3.16 to 29.95% during two years of investigation. Similarly, Haq and Rizvi (2023) also reported that fruit infestation on a weight basis ranged from 21.63 to 47.22% and 21.25 to 47.05% during both individual years of the experiment.

Table no. 4.33: Population dynamics of *L. orbonalis* on brinjal under field conditions during the year 2023

SMW	Shoot Damage (%)	Fruit infestation (%)		Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs)
		Number basis	Weight basis	Max. (°C)	Min. (°C)	Morning (%)	Evening (%)		
23	0.00	0.00	0.00	37.57	22.14	79.43	34.57	3.37	11.34
24	0.00	0.00	0.00	36.29	23.71	84.43	45.86	5.89	9.56
25	0.00	0.00	0.00	37.86	27.57	80.86	51.57	2.31	5.86
26	0.00	0.00	0.00	35.71	27.00	82.71	56.14	0.34	4.71
27	6.78	0.00	0.00	33.57	25.29	86.71	65.57	21.89	4.57
28	7.48	0.00	0.00	33.57	25.86	88.43	66.14	1.63	2.50
29	10.41	0.00	0.00	34.57	27.43	86.43	70.00	7.17	2.01
30	12.44	0.00	0.00	33.57	27.00	90.86	72.71	8.57	3.27
31	14.24	3.48	1.24	35.43	27.59	90.86	68.71	8.66	5.91
32	21.48	10.12	6.84	34.29	26.86	90.29	73.00	0.83	4.21
33	23.24	17.28	13.12	34.71	27.29	90.57	72.14	0.47	5.79
34	25.22	19.42	16.44	34.71	26.86	92.00	70.00	0.31	5.01
35	26.70	24.58	20.64	33.57	26.48	91.71	64.29	1.60	8.91
36	28.78	29.68	25.78	34.92	24.71	92.00	60.86	0.00	10.27
37	24.10	40.62	37.22	34.24	25.99	91.00	70.00	0.57	3.01
38	20.12	36.78	31.72	31.65	23.93	92.00	71.08	2.44	3.07
39	19.22	34.55	29.84	33.76	21.21	93.00	60.23	0.34	9.30
40	18.74	30.45	26.87	33.79	17.79	92.51	48.48	0.14	9.83
41	17.84	27.58	24.10	32.33	18.70	91.89	53.21	1.00	8.39
42	15.78	23.24	19.58	28.19	15.46	92.01	52.20	0.60	8.44
43	12.78	19.25	16.38	30.27	13.71	92.59	47.06	0.06	7.96

Table no. 4.34: Population dynamics of *L. orbonalis* on brinjal under field conditions during the year 2024

SMW	Shoot Damage (%)	Fruit infestation (%)		Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs)
		Number basis	Weight basis	Max. (°C)	Min. (°C)	Morning (%)	Evening (%)		
23	0.00	0.00	0.00	39.81	23.25	75.90	28.60	1.33	6.28
24	0.00	0.00	0.00	43.36	25.66	71.07	26.66	0.00	6.48
25	0.00	0.00	0.00	39.85	27.05	72.69	39.72	0.00	8.23
26	4.20	0.00	0.00	36.58	27.61	85.68	60.49	0.40	8.39
27	7.78	0.00	0.00	34.08	26.51	88.89	69.00	0.54	3.53
28	9.42	0.00	0.00	36.42	27.08	90.22	62.56	0.00	4.90
29	12.78	0.00	0.00	37.13	27.98	87.99	65.18	0.20	5.33
30	14.94	0.00	0.00	35.47	27.79	90.26	73.07	0.00	5.77
31	17.22	4.68	1.64	35.60	28.11	92.58	77.52	2.46	5.34
32	21.68	11.32	7.14	33.79	26.64	91.20	74.22	3.36	5.62
33	26.78	17.48	14.42	32.53	27.12	93.83	72.48	4.57	5.44
34	28.72	21.62	18.74	35.10	26.11	94.82	73.06	3.13	6.03
35	32.68	29.78	24.94	33.27	25.25	94.39	73.68	0.47	5.78
36	30.72	32.88	28.08	34.13	26.22	95.08	73.72	1.63	6.98
37	28.64	36.82	31.52	34.64	24.97	93.79	68.21	0.34	7.43
38	26.12	45.75	42.78	34.68	24.53	94.17	64.48	0.00	7.46
39	23.72	41.98	38.02	33.62	24.25	94.06	68.49	0.20	6.54
40	22.82	38.65	35.17	35.48	21.56	94.04	60.61	1.43	9.62
41	18.68	34.78	30.40	33.43	17.91	93.32	50.41	0.00	9.23
42	15.82	28.44	24.88	34.11	17.80	93.43	47.57	0.00	9.36
43	13.11	22.45	19.68	32.77	16.42	93.65	52.55	0.00	9.10

Table no. 4.35: Population dynamics of *L. orbonalis* on brinjal under field conditions during the pooled analysis

SMW	Shoot Damage (%)	Fruit infestation (%)		Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs)
		Number basis	Weight basis	Max. (°C)	Min. (°C)	Morning (%)	Evening (%)		
23	0.00	0.00	0.00	38.69	22.70	77.67	31.58	2.35	8.81
24	0.00	0.00	0.00	39.82	24.69	77.75	36.26	2.94	8.02
25	0.00	0.00	0.00	38.86	27.31	76.77	45.65	1.16	7.04
26	2.10	0.00	0.00	36.15	27.30	84.20	58.31	0.37	6.55
27	7.28	0.00	0.00	33.82	25.90	87.80	67.28	11.21	4.05
28	8.45	0.00	0.00	34.99	26.47	89.32	64.35	0.81	3.70
29	11.60	0.00	0.00	35.85	27.70	87.21	67.59	3.69	3.67
30	13.69	0.00	0.00	34.52	27.40	90.56	72.89	4.29	4.52
31	15.73	4.08	1.44	35.51	27.85	91.72	73.12	5.56	5.63
32	21.58	10.72	6.99	34.04	26.75	90.74	73.61	2.09	4.92
33	25.01	17.38	13.77	33.62	27.20	92.20	72.31	2.52	5.62
34	26.97	20.52	17.59	34.91	26.48	93.41	71.53	1.72	5.52
35	29.69	27.18	22.79	33.42	25.86	93.05	68.98	1.04	7.35
36	29.75	31.28	26.93	34.53	25.46	93.54	67.29	0.81	8.63
37	26.37	38.72	34.37	34.44	25.48	92.39	69.11	0.46	5.22
38	23.12	41.27	37.25	33.16	24.23	93.09	67.78	1.22	5.26
39	21.47	38.27	33.93	33.69	22.73	93.53	64.36	0.27	7.92
40	20.78	34.55	31.02	34.64	19.68	93.28	54.54	0.79	9.73
41	18.26	31.18	27.25	32.88	18.31	92.61	51.81	0.50	8.81
42	15.80	25.84	22.23	31.15	16.63	92.72	49.88	0.30	8.90
43	12.95	20.85	18.03	31.52	15.06	93.12	49.80	0.03	8.53

Fig. 4.39 Population dynamics of *L. orbonalis* on brinjal under field conditions during the year 2023

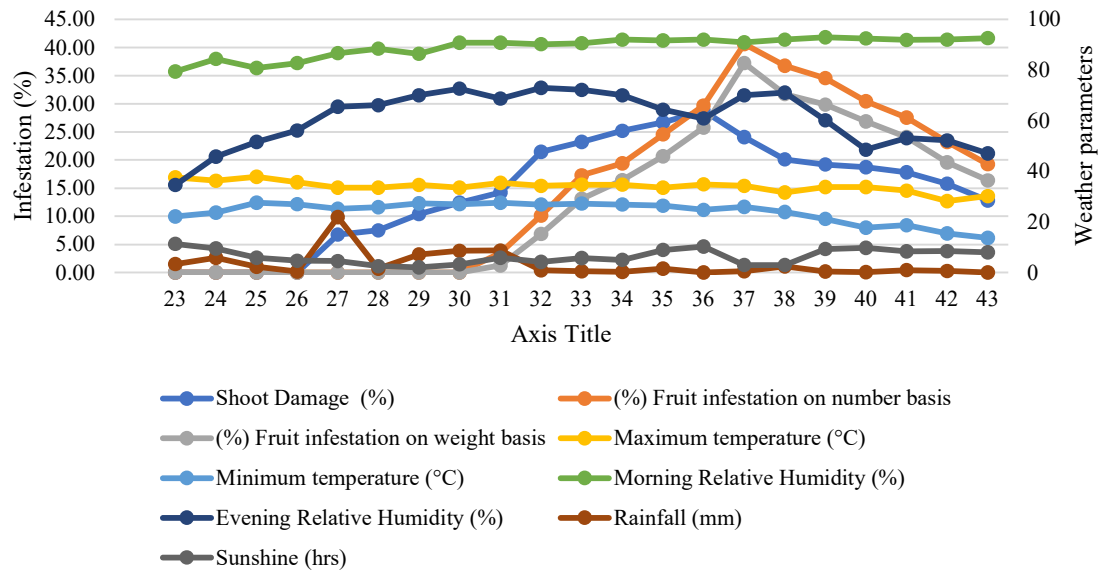


Fig. 4.40 Population dynamics of *L. orbonalis* on brinjal under field conditions during the year 2024

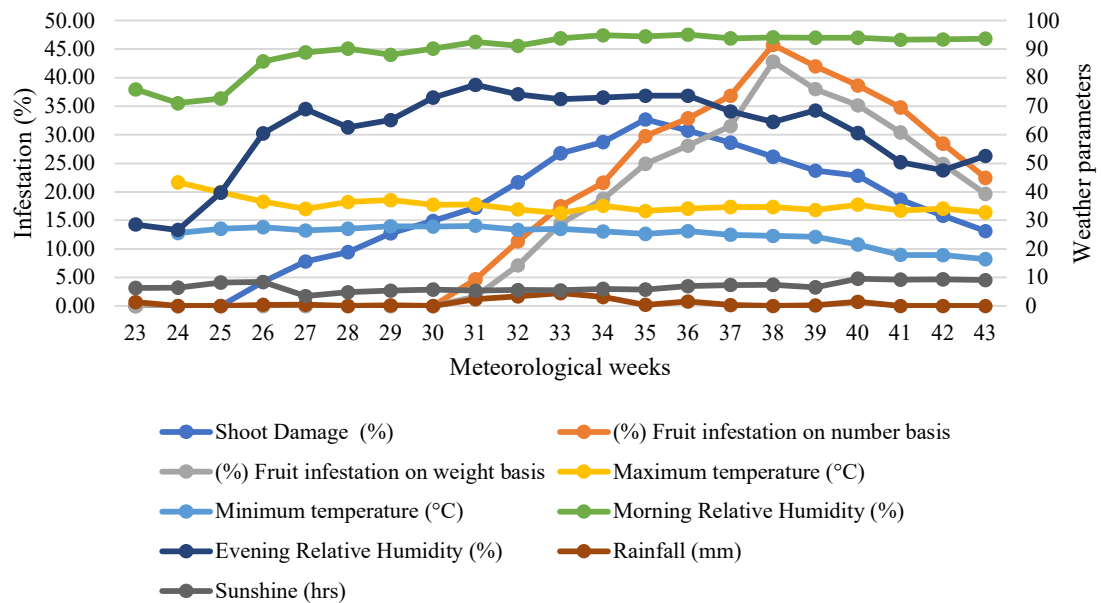
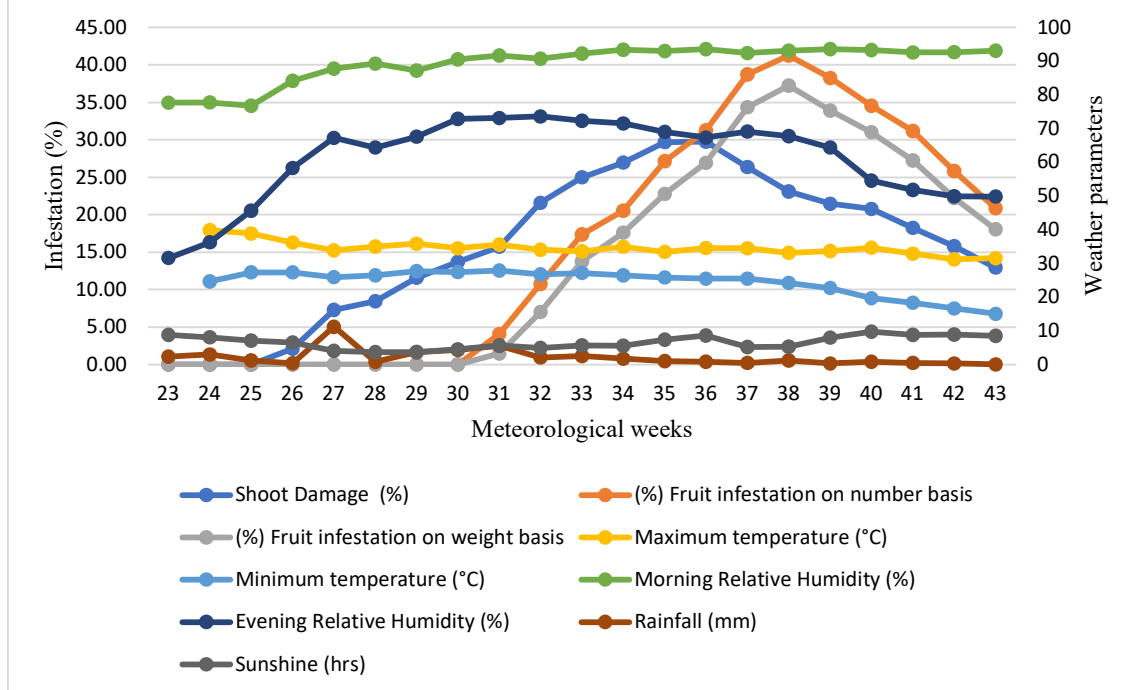


Fig. 4.41 Population dynamics of *L. orbonalis* on brinjal under field conditions during the pooled analysis



4.5.4 Correlation study of brinjal shoot and fruit borer with meteorological parameters

The correlation coefficient (r) for 2023, 2024 and the pooled analysis was calculated to determine the association between climatic factors, including maximum and minimum temperatures, morning and evening relative humidity, rainfall, sunshine hours and the incidence of brinjal shoot and fruit borer.

4.5.4.1 Per cent Shoot infestation of *Leucinodes orbonalis*

The data depicted in Tables 4.36 to 4.38 indicate the correlation between shoot infestation and weather parameters during 2023, 2024 and the pooled analysis. In 2023, shoot infestation showed non-significant negative correlations with maximum temperature, minimum temperature, and rainfall ($r = -0.382, -0.026, -0.363$), but significant positive correlations with morning ($r = 0.847$) and evening relative humidity ($r = 0.521$). Sunshine hours showed a weak, non-significant positive correlation ($r = 0.028$). In 2024, infestation was significantly negatively correlated with maximum temperature ($r = -0.734$) and non-significant with minimum temperature ($r = -0.048$), while morning and evening relative humidity showed significant positive correlations ($r = 0.838, 0.723$), and rainfall and sunshine hours had non-significant positive correlations ($r = 0.385, 0.003$). Pooled data revealed a strong negative correlation with maximum temperature ($r = -0.633$), non-significant negative correlations with

minimum temperature and rainfall ($r = -0.034, -0.258$), and significant positive correlations with morning and evening relative humidity ($r = 0.860, 0.662$); sunshine hours showed no significant association ($r = 0.007$). These results are consistent with Haq and Rizvi (2023) and Abirami *et al.*, 2021, who also reported negative correlations with temperature and rainfall, and positive correlations with relative humidity.

4.5.4.2 Fruit infestation of *Leucinodes orbonalis* (number basis)

The data presented in Tables 4.36 to 4.38 indicate the correlation between fruit infestation on a number basis and weather parameters during 2023, 2024 and pooled analysis. In 2023, fruit infestation was moderately negatively correlated with maximum temperature ($r = -0.469$) and rainfall ($r = -0.512$), weakly with minimum temperature ($r = -0.400$), and strongly positively with morning relative humidity ($r = 0.720$). Evening RH and sunshine hours showed weak positive correlations ($r = 0.106$ and 0.235). In 2024, it was significantly negatively correlated with maximum ($r = -0.573$) and minimum temperatures ($r = -0.507$), weakly with rainfall ($r = -0.020$), strongly positively with morning RH ($r = 0.648$), moderately with sunshine hours ($r = 0.485$), and weakly with evening RH ($r = 0.247$). Pooled data indicated significant negative correlation with maximum temperature ($r = -0.595$), moderate with minimum temperature and rainfall ($r = -0.463$ and -0.512), strong positive with morning RH ($r = 0.696$), and weak positive with evening RH and sunshine hours ($r = 0.192$ and 0.403). These findings align with those of Haq and Rizvi (2023) and Kassi *et al.*, 2019, who also reported negative correlations with temperature and rainfall and positive correlations with relative humidity.

4.5.4.3 Fruit infestation of *Leucinodes orbonalis* (weight basis)

The data presented in Tables 4.36 to 4.38 indicate the correlation between fruit infestation on a weight basis and weather parameters during 2023, 2024 and pooled analysis. In 2023, fruit infestation (weight basis) was moderately negatively correlated with maximum temperature ($r = -0.458$) and rainfall ($r = -0.503$), weakly with minimum temperature ($r = -0.403$), and strongly positively with morning relative humidity ($r = 0.698$); evening humidity and sunshine hours showed weak positive correlations ($r = 0.088$ and 0.229). In 2024, infestation correlated negatively with maximum and minimum temperatures ($r = -0.547$ and -0.513) and weakly with rainfall ($r = -0.060$), while morning RH showed a strong positive correlation ($r = 0.626$), sunshine hours a moderate positive correlation ($r = 0.497$), and evening RH weakly positive ($r = 0.218$). Pooled data revealed strong negative correlation with maximum temperature ($r = -0.579$), moderate with minimum temperature and rainfall ($r = -0.472$ and -0.514), strong positive with morning RH ($r = 0.676$), and weak positive correlations with evening RH and sunshine hours ($r = 0.167$ and 0.405). These results align with Haq and Rizvi (2023) and

Sheojat *et al.*, 2022, who reported negative correlations of fruit infestation with temperature and rainfall and positive correlations with relative humidity.

Table no. 4.36: Correlation coefficients (r) between *Leucinodes orbonalis* and weather parameters under field conditions during 2023

Sr. no.	Insect Pest	Max. Temperature (°C)	Min. Temperature (°C)	Morning RH (%)	Evening RH (%)	Rainfall (mm)	Sunshine (hrs)
i.	Shoot infestation (%)	-0.382 ^{NS}	-0.026 ^{NS}	0.847 ^{**}	0.521 [*]	-0.363 ^{NS}	0.028 ^{NS}
ii.	Fruit infestation (%) (number basis)	-0.469 [*]	-0.400 ^{NS}	0.720 ^{**}	0.106 ^{NS}	-0.512 [*]	0.235 ^{NS}
iii.	Fruit infestation (%) (Weight basis)	-0.458 [*]	-0.403 ^{NS}	0.698 ^{**}	0.088 ^{NS}	-0.503 [*]	0.229 ^{NS}

*=sig. at 5 %, ** = sig. at 1 % and NS = non-sig.

Table no. 4.37: Correlation coefficients (r) between *Leucinodes orbonalis* and weather parameters under field conditions during 2024

Sr. no.	Insect Pest	Max. Temperature (°C)	Min. Temperature (°C)	Morning RH (%)	Evening RH (%)	Rainfall (mm)	Sunshine (hrs)
i.	Shoot infestation (%)	-0.734 ^{**}	-0.048 ^{NS}	0.838 ^{**}	0.723 ^{**}	0.385 ^{NS}	0.003 ^{NS}
ii.	Fruit infestation (%) (number basis)	-0.573 ^{**}	-0.507 [*]	0.648 ^{**}	0.247 ^{NS}	-0.020 ^{NS}	0.485 [*]
iii.	Fruit infestation (%) (Weight basis)	-0.547 [*]	-0.513 [*]	0.626 ^{**}	0.218 ^{NS}	-0.060 ^{NS}	0.497 [*]

*=sig. at 5 %, ** = sig. at 1 % and NS = non-sig.

Table no. 4.38 Correlation coefficients (r) between *Leucinodes orbonalis* and weather parameters under field conditions in the pooled analysis

Sr. no.	Insect Pest	Max. Temperature (°C)	Min. Temperature (°C)	Morning RH (%)	Evening RH (%)	Rainfall (mm)	Sunshine (hrs)
i.	Shoot infestation (%)	-0.633**	-0.034 ^{NS}	0.860**	0.662**	-0.258 ^{NS}	0.007 ^{NS}
ii.	Fruit infestation (%) (number basis)	-0.595**	-0.463*	0.696**	0.192 ^{NS}	-0.512*	0.403 ^{NS}
iii.	Fruit infestation (%) (Weight basis)	-0.579**	-0.472*	0.676**	0.167 ^{NS}	-0.514*	0.405 ^{NS}

*=sig. at 5 %, ** = sig. at 1 % and NS = non-sig.

4.6 Efficacy of pesticides against shoot and fruit borer in brinjal

4.6.1 Effect of various insecticides on infestation of fruit borer on a number basis

The data related to effect of various insecticidal treatments on infestation of fruit borer on a number basis are presented in Tables 4.39 to 4.41 and depicted in Figures 4.42 to 4.44 during 2023, 2024 and the pooled analysis. The observations were recorded one day prior to the application and there after 1, 3, 5, 7, 10 and 14 days of spraying. The findings of the present investigation are detailed below:

4.6.1.1 First spray

One day before first spray

The data recorded on per cent fruit infestation on a number basis one day before the first spray revealed that there were no significant variations among the different insecticidal treatments during 2023, 2024, and in the pooled analysis (Tables 4.39 to 4.41 and Figures 4.42 to 4.44). The fruit infestation levels one day before the spray ranged from 13.87 to 15.40 per cent among the different insecticidal treatments in 2023. In 2024, the infestation levels ranged from 16.87 to 18.33 per cent one day before the spray. In the pooled analysis, fruit damage ranged from 15.37 to 16.87 per cent one day before the spray among the different insecticidal treatments.

First day after first spray

The data observed on per cent fruit infestation on a number basis one day after the first spray indicated that all synthetic insecticides significantly reduced the fruit infestation compared to botanical insecticides and the untreated control. Among the various insecticidal treatments, the

minimum fruit infestation (5.58%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (7.21%), whereas the maximum fruit infestation (28.58%) was recorded in treatment T₀ (Control), followed by treatment T₈ (26.64%) during 2023. In 2024, the minimum fruit infestation (8.22%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₅ (12.62%). The maximum fruit infestation (28.20%) was recorded in treatment T₈ (Carbofuran 3% CG) which was *at par* with treatment T₀ (26.38%). In the pooled analysis, the minimum fruit infestation (6.90%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (10.84%), whereas the maximum fruit infestation (27.48%) was observed in treatment T₀ (Control) which was *at par* with treatment T₈ (27.42%).

Three days after first spray

The data observed on per cent fruit infestation on a number basis three days after the first spray revealed that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. Among the various insecticidal treatments, the minimum fruit infestation (2.48%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (5.12%), whereas the maximum fruit infestation (32.42%) was recorded in T₀ (Control), followed by the treatment T₄ (30.38%) in 2023. During 2024, the minimum fruit infestation (5.18%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (8.72%), whereas the maximum fruit infestation (28.62%) was recorded in treatment T₀ (Control), followed by treatment T₆ (26.12%). In the pooled analysis, the minimum fruit infestation (3.83%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (6.92%), whereas the maximum fruit infestation (30.52%) was recorded in treatment T₀ (Control), followed by treatment T₄ (28.25%).

Five days after first spray

The data observed on per cent fruit infestation on a number basis five days after the first spray indicated that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. During 2023, the minimum fruit infestation (8.33%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (10.19%), whereas the maximum fruit infestation (34.39%) was recorded in T₀ (Control), followed by treatment T₈ (30.22%). During 2024, the lowest fruit infestation (12.36%) was observed in treatment T₆ (Deltamethrin 2.8% EC) which was *at par* with treatment T₇ (12.76%), followed by treatment T₅ (15.48%). The highest fruit infestation (32.18%) was recorded in T₈ (Carbofuran 3% CG) which was *at par* with treatment T₀ (31.59%). In the pooled analysis, the minimum fruit infestation (10.54%) was recorded in treatment T₇ (Cartap hydrochloride 50%

SP) which was *at par* with treatment T₆ (11.27%), followed by treatment T₅ (13.78%), whereas the maximum fruit infestation (32.99%) was observed in T₀ (Control), followed by treatment T₈ (31.20%).

Seven days after first spray

The data recorded on per cent fruit infestation on a number basis seven days after the first spray showed significant variation among different insecticidal treatments. In the first year, the minimum fruit infestation (9.47%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.52%), whereas the maximum fruit infestation (35.12%) was recorded in T₀ (Control), followed by treatment T₈ (32.38%). During the second year, the lowest fruit infestation (10.32%) was observed in treatment T₇ (Cartap hydrochloride 50% SP) which was *at par* with treatment T₃ (11.83%), whereas the maximum fruit infestation (34.82%) was observed in T₀ (Control) which was *at par* with treatment T₈ (34.42%). In the pooled analysis, the minimum fruit infestation (9.90%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₃ (12.38%), whereas the maximum fruit infestation (34.97%) was recorded in T₀ (Control), followed by treatment T₈ (33.40%).

Ten days after first spray

The data observed on per cent fruit infestation on a number basis ten days after the first spray showed significant variation among different insecticidal treatments. In the first year, minimum fruit infestation (12.53%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (16.21%), whereas the maximum fruit infestation (36.72%) was recorded in T₀ (Control), followed by treatment T₈ (34.47%). During the second year, lowest fruit infestation (13.68%) was observed in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (17.61%), whereas the highest fruit infestation (36.92%) was recorded in T₀ (Control) which was *at par* with treatment T₈ (36.28%). In the pooled analysis, minimum fruit infestation (13.10%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (16.91%), whereas the maximum fruit infestation (36.82%) was recorded in T₀ (Control), followed by treatment T₈ (35.38%).

Fourteen days after first spray

The data recorded on per cent fruit infestation on a number basis fourteen days after the first spray revealed a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. During 2023, the lowest fruit infestation (17.04%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₅ (20.42%), whereas the maximum fruit infestation (37.12%) was recorded in treatment T₀ (Control) which was *at par* with treatment T₈ (35.27%). During 2024, the minimum fruit infestation (16.23%) was

recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (21.84%), whereas the maximum fruit infestation (39.22%) was recorded in treatment T₀ (Control), followed by treatment T₈ (37.68%). In the pooled analysis, the minimum fruit infestation (16.64%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₅ (21.82%), whereas the maximum fruit infestation (38.17%) was recorded in treatment T₀ (Control), followed by treatment T₈ (36.48%).

4.6.1.2 Second spray

First day after second spray

The data observed on per cent fruit infestation on a number basis one day after the second spray indicated that all synthetic insecticides significantly reduced fruit infestation compared to botanical insecticides and the untreated control. Among the various insecticidal treatments, the minimum fruit infestation (6.18%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (8.60%), whereas the maximum fruit infestation (38.12%) was recorded in treatment T₀ (Control), followed by treatment T₄ (29.92%) during 2023. In 2024, the minimum fruit infestation (7.24%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.26%), whereas the maximum fruit infestation (41.63%) was recorded in treatment T₀ (Control), followed by treatment T₄ (28.39%). In the pooled analysis, the minimum fruit infestation (6.71%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (10.43%), whereas the maximum fruit infestation (39.88%) was recorded in treatment T₀ (Control), followed by treatment T₄ (29.16%).

Three days after second spray

The data observed on per cent fruit infestation on a number basis three days after the second spray revealed that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. Among the various insecticidal treatments, the minimum fruit infestation (3.48%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (6.68%), whereas the maximum fruit infestation (39.48%) was recorded in treatment T₀ (Control), followed by treatment T₄ (30.52%) during 2023. In 2024, the minimum fruit infestation (5.82%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (9.48%), whereas the maximum fruit infestation (44.13%) was recorded in treatment T₀ (Control), followed by treatment T₄ (32.51%). In the pooled analysis, the minimum fruit infestation (4.65%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (8.08%), whereas the maximum fruit infestation (41.81%) was recorded in treatment T₀ (Control), followed by treatment T₄ (31.52%).

Five days after second spray

The data observed on per cent fruit infestation on a number basis five days after the second spray indicated a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. During 2023, the minimum fruit infestation (8.93%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (12.26%), whereas the maximum fruit infestation (40.22%) was recorded in T₀ (Control), followed by treatment T₈ (31.67%). During 2024, the lowest fruit infestation (10.14%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (14.82%), whereas the highest fruit damage (47.38%) was recorded in T₀ (Control), followed by treatment T₈ (34.48%). In the pooled analysis, lowest fruit infestation (9.54%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (13.54%), whereas the highest fruit infestation (43.80%) was recorded in T₀ (Control), followed by treatment T₈ (33.08%).

Seven days after second spray

The data observed on per cent fruit infestation on a number basis seven days after the second spray indicated a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. Among the various treatments, the minimum fruit infestation (12.08, 15.42 and 13.75%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (14.33, 16.54 and 15.44%), whereas the maximum fruit infestation (42.84, 48.74 and 45.79%) was recorded in T₀ (Control), followed by treatment T₈ (35.72, 38.34 and 37.03%) during 2023, 2024 and in the pooled analysis, respectively.

Ten days after second spray

The data observed on per cent fruit infestation on a number basis ten days after the second spray showed significant variation among different insecticidal treatments. In the first year, the minimum fruit infestation (15.94%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), which was *at par* with treatment T₆ (17.21%), whereas the maximum fruit infestation (44.28%) was recorded in T₀ (Control), followed by treatment T₈ (40.78%). During the second year, the lowest fruit infestation (17.56%) was observed in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (18.36%), whereas the highest fruit infestation (49.38%) was recorded in T₀ (Control), followed by treatment T₄ (41.82%). In the pooled analysis, the minimum fruit infestation (16.75%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (17.79%), whereas the maximum fruit infestation (46.83%) was recorded in T₀ (Control), followed by treatment T₈ (40.98%).

Fourteen days after second spray

The data observed on per cent fruit infestation on a number basis fourteen days after the second spray revealed that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. In the first year, the minimum fruit infestation (18.65%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), which was *at par* with treatment T₆ (19.25%), whereas the maximum fruit infestation (46.68%) was recorded in T₀ (Control), followed by treatment T₈ (44.68%). During 2024, the minimum fruit infestation (20.58%) was recorded in treatment T₆ (Deltamethrin 2.8% EC), followed by the treatment T₇ (22.26%), whereas the maximum fruit infestation (51.58%) was recorded in T₀ (Control), followed by treatment T₈ (46.62%). In the pooled analysis, the minimum fruit infestation (19.91%) was recorded in treatment T₆ (Deltamethrin 2.8% EC) which was *at par* with treatment T₇ (20.46%), whereas the maximum fruit infestation (49.13%) was recorded in T₀ (Control), followed by treatment T₈ (45.65%).

4.6.1.3 Mean (first and second spray)

The observations related to percent fruit infestation on a number basis varied significantly among the various insecticidal treatments in brinjal. The minimum mean fruit infestation (10.06, 12.07 and 11.06%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.64, 15.19 and 13.91%), while the maximum mean fruit infestation (38.00, 40.03 and 39.02%) was recorded in T₀ (Control), followed by T₈ (32.67, 33.91 and 33.29%) during 2023, 2024 and the pooled analysis. The overall findings of per cent fruit infestation on a number basis indicated that T₇ (Cartap hydrochloride 50% SP) was recorded to be the most effective insecticidal treatment against *Leucinodes orbonalis*. The order of efficacy of eight insecticides was cartap-hydrochloride 50% SP > deltamethrin 2.8% EC > acetamiprid 20% SP > chlorpyrifos 20% EC > triazophos 40% EC > karanj oil 1% > neem oil 1% > carbofuran 3% CG. The untreated control was found to be the least effective against percent fruit infestation caused by shoot and fruit borer in brinjal. The present findings were also supported by Khanzada *et al.*, 2018 who reported that cartap hydrochloride was moderately effective against fruit infestation on a number basis. In contrast, Senapati (2006) reported the highest efficacy of cartap hydrochloride against fruit infestation as compared to other treatments. The variation in findings might be due to attributed to ecological factors and other variables such as spraying technique, sprayer pressure, frequency of spraying, and the interval between sprays (Latif *et al.*, 2010).

4.6.2 Effect of various insecticides on infestation of fruit borer on weight basis

The data recorded on effect of various insecticidal treatments on infestation of fruit borer on a weight basis are depicted in Tables 4.42 to 4.44 and Figures 4.45 to 4.47 during 2023, 2024 and the pooled analysis. The observations were recorded one day prior to the application and there after 1, 3, 5, 7, 10 and 14 days of spraying. The findings of the present investigation are discussed below:

4.6.2.1 First spray

One day before first spray

The data recorded on percent fruit infestation on a weight basis one day before the first spray revealed that there were no significant variations among the different insecticidal treatments during 2023, 2024, and in the pooled analysis (Tables 4.42 to 4.44 and Figures 4.45 to 4.47). The fruit infestation levels one day before the spray ranged from 10.22 to 11.76 per cent among the different insecticidal treatments in 2023. In 2024, the infestation levels ranged from 11.65 to 13.19 per cent one day before the spray. In the pooled analysis, fruit infestation ranged from 10.93 to 12.47 per cent one day before the spray among the different insecticidal treatments.

First day after first spray

The data observed on per cent fruit infestation on a weight basis one day after the first spray indicated that all synthetic insecticides significantly reduced the fruit infestation compared to botanical insecticides and the untreated control. Among the various insecticidal treatments, the minimum fruit infestation (5.08%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (6.71%), whereas the maximum fruit infestation (27.02%) was recorded in treatment T₀ (Control), followed by treatment T₈ (26.14%) during 2023. In 2024, the minimum fruit infestation (6.97%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₅ (11.37%). The maximum fruit infestation (26.95%) was recorded in treatment T₈ (Carbofuran 3% CG) followed by treatment T₀ (25.13%). In the pooled analysis, the minimum fruit infestation (6.03%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (9.97%), whereas the maximum fruit infestation (26.55%) was recorded in treatment T₈ (Carbofuran 3% CG), followed by treatment T₀ (26.08%).

Three days after first spray

The data observed on per cent fruit infestation on a weight basis three days after the first spray revealed a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. Among the various insecticidal treatments, the minimum fruit infestation (1.98%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment

T₆ (4.62%), whereas the maximum fruit infestation (30.13%) was recorded in T₀ (Control) which was *at par* with treatment T₄ (29.88%) in 2023. During 2024, the minimum fruit infestation (3.93%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (7.47%), whereas the maximum fruit infestation (27.37%) was recorded in treatment T₀ (Control), followed by treatment T₄ (24.87%). In the pooled analysis, the minimum fruit infestation (2.96%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (6.05%), whereas the maximum fruit infestation (28.75%) was recorded in treatment T₀ (Control), followed by treatment T₄ (27.38%).

Five days after first spray

The data recorded on per cent fruit infestation on a weight basis five days after the first spray indicated that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. During 2023, the minimum fruit infestation (7.83%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP) followed by treatment T₆ (9.69%), whereas the maximum fruit infestation (32.08%) was recorded in T₀ (Control), followed by treatment T₈ (29.72%). During 2024, the lowest fruit infestation (11.11%) was observed in treatment T₆ (Deltamethrin 2.8% EC) which was *at par* with treatment T₇ (11.51%), followed by treatment T₅ (14.23%). The highest fruit infestation (30.93%) was recorded in T₈ (Carbofuran 3% CG) which was *at par* with treatment T₀ (30.34%). In the pooled analysis, the minimum fruit infestation (9.67%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP) which was *at par* with treatment T₆ (10.40%), followed by treatment T₅ (12.90%), whereas the maximum fruit infestation (31.21%) was recorded in T₀ (Control), followed by treatment T₈ (30.33%).

Seven days after first spray

The data recorded on per cent fruit infestation on a weight basis seven days after the first spray showed significant variation among different insecticidal treatments. In the first year, the minimum fruit infestation (8.97%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.02%), whereas the maximum fruit infestation (34.18%) was recorded in T₀ (Control), followed by treatment T₈ (31.88%). During the second year, the lowest fruit infestation (9.07%) was observed in treatment T₇ (Cartap hydrochloride 50% SP) which was *at par* with T₃ (10.58%), whereas the maximum fruit infestation (33.57%) was recorded in T₀ (Control) which was *at par* with treatment T₈ (33.17%). In the pooled analysis, the minimum fruit infestation (9.02%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₃ (11.51%), whereas the maximum fruit infestation (33.88%) was recorded in T₀ (Control), followed by treatment T₈ (32.53%).

Ten days after first spray

The data recorded on per cent fruit infestation on a weight basis ten days after the first spray showed significant variation among different insecticidal treatments. In the first year, minimum fruit infestation (12.03%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (15.71%), whereas the maximum fruit infestation (35.22%) was recorded in T₀ (Control), followed by treatment T₈ (33.97%). During the second year, lowest fruit infestation (12.43%) was observed in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (16.36%), whereas the highest fruit infestation (35.67%) was recorded in T₀ (Control) which was *at par* with treatment T₈ (35.03%). In the pooled analysis, minimum fruit infestation (12.23%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (16.04%), whereas the maximum fruit infestation (35.45%) was recorded in T₀ (Control), which was *at par* with treatment T₈ (34.50%).

Fourteen days after first spray

The data recorded on per cent fruit infestation on a weight basis fourteen days after the first spray revealed a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. During 2023, the lowest fruit infestation (16.54%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₅ (19.92%), whereas the maximum fruit infestation (36.12%) was recorded in treatment T₀ (Control) followed by treatment T₈ (34.77%). During 2024, the minimum fruit infestation (14.98%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (20.59%), whereas the maximum fruit infestation (37.97%) was recorded in treatment T₀ (Control), followed by treatment T₈ (36.43%). In the pooled analysis, the minimum fruit infestation (15.76%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₅ (20.95%), whereas the maximum fruit infestation (37.05%) was recorded in treatment T₀ (Control), followed by treatment T₈ (35.60%).

4.6.2.2 Second spray

First day after second spray

The data recorded on per cent fruit infestation on a weight basis one day after the second spray indicated that all synthetic insecticides significantly reduced fruit infestation compared to botanical insecticides and the untreated control. Among the various insecticidal treatments, the minimum fruit infestation (5.94%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (8.10%), whereas the maximum fruit infestation (37.04%) was recorded in treatment T₀ (Control), followed by treatment T₄ (29.42%) during 2023. In 2024, the minimum fruit infestation (5.99%) was recorded in treatment T₇ (Cartap hydrochloride 50%

SP), followed by treatment T₆ (11.01%), whereas the maximum fruit infestation (40.38%) was recorded in treatment T₀ (Control), followed by treatment T₄ (27.48%). In the pooled analysis, the minimum fruit infestation (5.97%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (9.55%), whereas the maximum fruit infestation (38.71%) was recorded in treatment T₀ (Control), followed by treatment T₄ (28.45%).

Three days after second spray

The data observed on per cent fruit infestation on a weight basis three days after the second spray revealed that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. Among the various insecticidal treatments, the minimum fruit infestation (3.32%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (6.18%), whereas the maximum fruit infestation (38.12%) was recorded in treatment T₀ (Control), followed by treatment T₄ (30.02%) during 2023. In 2024, the minimum fruit infestation (4.57%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (8.23%), whereas the maximum fruit infestation (42.88%) was recorded in treatment T₀ (Control), followed by treatment T₄ (31.58%). In the pooled analysis, the minimum fruit infestation (3.95%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (7.21%), whereas the maximum fruit infestation (40.50%) was recorded in treatment T₀ (Control), followed by treatment T₄ (30.80%).

Five days after second spray

The data recorded on per cent fruit infestation on a weight basis five days after the second spray indicated a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. During 2023, the minimum fruit infestation (8.74%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (11.80%), whereas the maximum fruit infestation (39.38%) was recorded in T₀ (Control), followed by treatment T₈ (28.17%). During 2024, the lowest fruit infestation (8.89%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (13.57%), whereas the highest fruit infestation (46.13%) was recorded in T₀ (Control), followed by treatment T₈ (33.23%). In the pooled analysis, lowest fruit infestation (8.82%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.69%), whereas the highest fruit infestation (42.76%) was recorded in T₀ (Control), followed by treatment T₈ (30.70%).

Seven days after second spray

The data recorded on per cent fruit infestation on a weight basis seven days after the second spray indicated a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. Among the various treatments, the minimum fruit infestation (11.88,

14.17 and 13.03%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by the treatment T₆ (13.98, 15.29 and 14.64%), whereas the maximum fruit infestation (41.22, 47.49 and 44.36%) was recorded in T₀ (Control), followed by treatment T₈ (34.64, 37.09 and 35.87%) during 2023, 2024 and in the pooled analysis, respectively.

Ten days after second spray

The observations recorded on per cent fruit infestation on a weight basis ten days after the second spray showed significant variation among different insecticidal treatments. In the first year, the minimum fruit infestation (15.54%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), which was *at par* with treatment T₆ (16.92%), whereas the maximum fruit infestation (43.08%) was recorded in T₀ (Control), followed by treatment T₈ (37.56%).

During the second year, the lowest fruit infestation (16.31%) was observed in treatment T₇ (Cartap hydrochloride 50% SP) which was *at par* with treatment T₆ (17.11%), whereas the highest fruit infestation (48.13%) was recorded in T₀ (Control), followed by treatment T₄ (40.82%). In the pooled analysis, the minimum fruit infestation (15.93%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP) which was *at par* with the treatment T₆ (17.02%), whereas the maximum fruit infestation (45.61%) was recorded in T₀ (Control), followed by treatment T₈ (38.75%).

Fourteen days after second spray

The data observed on per cent fruit infestation on a weight basis fourteen days after the second spray revealed that there was a significant variation in fruit infestation with respect to various insecticidal treatments in brinjal. In the first year, the minimum fruit infestation (18.40%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), which was *at par* with treatment T₆ (18.75%), whereas the maximum fruit infestation (45.12%) was recorded in T₀ (Control), followed by treatment T₈ (41.78%). During 2024, the minimum fruit infestation (19.33%) was recorded in treatment T₆ (Deltamethrin 2.8% EC) which was *at par* with T₇ (21.01%), whereas the maximum fruit infestation (50.33%) was recorded in T₀ (Control), followed by treatment T₈ (45.37%). In the pooled analysis, the minimum fruit infestation (19.04%) was recorded in treatment T₆ (Deltamethrin 2.8% EC) which was *at par* with treatment T₇ (19.71%), whereas the maximum fruit infestation (47.73%) was recorded in T₀ (Control), followed by treatment T₈ (43.58%).

4.6.2.3 Mean (first and second spray)

The observations related to percent fruit infestation on a weight basis varied significantly among the various insecticidal treatments in brinjal. The minimum mean fruit infestation (9.69, 10.82 and 10.26%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by

treatment T₆ (12.17, 13.94 and 13.06%), while the maximum mean fruit infestation (36.56, 38.79 and 37.67%) was recorded in T₀ (Control), followed by T₈ (31.44, 32.67 and 32.05%) during 2023, 2024 and the pooled analysis. The overall findings of per cent fruit infestation on a weight basis indicated that T₇ (Cartap hydrochloride 50% SP) was the most effective insecticidal treatment against *Leucinodes orbonalis*. The order of efficacy of eight insecticides was: Cartap-hydrochloride 50% SP > Deltamethrin 2.8% EC > Acetamiprid 20% SP > Chlorpyrifos 20% EC > Triazophos 40% EC > Karanj oil 1% > Neem oil 1% > Carbofuran 3% CG. The untreated control was found to be the least effective against percent fruit infestation on a weight basis caused by shoot and fruit borer in brinjal. The present findings were also supported by Khandre *et al.*, 2012, who reported that cartap hydrochloride was moderately effective against per cent fruit damage on a weight basis in brinjal. Similarly, Khanzada *et al.*, 2018 also reported that cartap hydrochloride was moderately effective against fruit infestation on a weight basis. In contrast, Senapati (2006) reported the highest efficacy of cartap hydrochloride against fruit infestation as compared to other treatments. The variation in findings might be due to attributed to ecological factors and other variables such as spraying technique, sprayer pressure, frequency of spraying, and the interval between sprays (Latif *et al.*, 2010).

Table no. 4.39: Effect of various insecticidal treatments on fruit infestation (%) by number basis due to incidence of fruit borer after the first and second sprays in brinjal during 2023

Treatment	First spray							Second spray						Mean
	Before spray	1st D.A.S	3rd D.A.S	5th D.A.S	7 th D.A.S	10 th D.A.S	14 th D.A.S	1st D.A.S	3rd D.A.S	5 th D.A.S	7 th D.A.S	10 th D.A.S	14 th D.A.S	
T ₀ (Control)	15.40 ^a (23.11)	28.58 ^a (32.32)	32.42 ^a (34.71)	34.39 ^a (35.91)	35.12 ^a (36.34)	36.72 ^a (37.30)	37.12 ^a (37.54)	38.12 ^a (38.13)	39.48 ^a (38.93)	40.22 ^a (39.36)	42.84 ^a (40.88)	44.28 ^a (41.72)	46.68 ^a (43.10)	38.00 (36.87)
T ₁ (Chlorpyrifos 20% EC)	13.87 ^a (21.86)	11.53 ^c (19.85)	8.47 ^{ef} (16.92)	16.80 ^d (24.20)	20.07 ^d (26.62)	23.84 ^c (29.23)	26.32 ^d (30.87)	13.60 ^f (21.64)	12.47 ^c (20.68)	18.27 ^c (25.31)	20.38 ^{de} (26.84)	22.24 ^g (28.14)	28.47 ^c (32.25)	18.54 (24.95)
T ₂ (Triazophos 40% EC)	14.40 ^a (22.30)	11.80 ^c (20.09)	9.32 ^c (17.78)	17.87 ^d (25.01)	24.93 ^c (29.95)	28.07 ^d (31.99)	30.87 ^c (33.75)	17.47 ^c (24.71)	19.87 ^d (26.47)	22.42 ^d (28.26)	24.36 ^c (29.57)	27.12 ^c (31.38)	27.58 ^f (31.68)	21.81 (27.15)
T ₃ (Karanj oil 1%)	14.80 ^a (22.63)	17.80 ^d (24.95)	23.32 ^d (28.88)	14.87 ^c (22.68)	12.93 ^f (21.07)	29.07 ^d (32.63)	33.87 ^b (35.59)	26.34 ^d (30.88)	29.92 ^b (33.16)	22.68 ^d (28.44)	18.72 ^{ef} (25.64)	32.84 ^d (34.96)	34.88 ^d (36.20)	24.77 (29.05)
T ₄ (Neem oil 1%)	14.67 ^a (22.52)	24.22 ^c (29.48)	30.38 ^b (33.45)	22.61 ^c (28.39)	13.28 ^f (21.37)	32.56 ^c (34.79)	33.68 ^b (35.47)	29.92 ^b (33.16)	30.52 ^b (33.54)	26.67 ^c (31.10)	21.68 ^d (27.75)	37.62 ^c (37.83)	39.12 ^c (38.72)	28.52 (31.35)
T ₅ (Acetamiprid 20% SP)	14.53 ^a (22.41)	9.58 ^f (18.03)	7.65 ^f (16.06)	12.07 ^f (20.33)	16.13 ^c (23.68)	18.89 ^f (25.76)	20.42 ^c (26.86)	12.60 ^f (20.79)	9.48 ^f (17.93)	14.27 ^f (22.19)	18.32 ^f (25.34)	24.68 ^f (29.79)	25.40 ^g (30.26)	15.79 (23.03)
T ₆ (Deltamethrin 2.8% EC)	14.37 ^a (22.27)	7.21 ^g (15.57)	5.12 ^g (13.08)	10.19 ^g (18.61)	12.52 ^f (20.72)	16.21 ^g (23.74)	22.08 ^c (28.03)	8.60 ^g (17.05)	6.68 ^g (14.98)	12.26 ^g (20.50)	14.33 ^g (22.25)	17.21 ^h (24.51)	19.25 ^h (26.02)	12.64 (20.56)
T ₇ (Cartap hydrochloride 50% SP)	13.93 ^a (21.92)	5.58 ^h (13.66)	2.48 ^h (9.06)	8.33 ^h (16.77)	9.47 ^g (17.93)	12.53 ^h (20.73)	17.04 ^f (24.38)	6.18 ^h (14.39)	3.48 ^h (10.75)	8.93 ^h (17.39)	12.08 ^h (20.34)	15.94 ^h (23.53)	18.65 ^h (25.59)	10.06 (18.19)
T ₈ (Carbofuran 3% CG)	14.87 ^a (22.68)	26.64 ^b (31.07)	24.87 ^c (29.92)	30.22 ^b (33.35)	32.38 ^b (34.68)	34.47 ^b (35.95)	35.27 ^{ab} (36.44)	28.34 ^c (32.16)	26.96 ^c (31.28)	31.67 ^b (34.25)	35.72 ^b (36.70)	40.78 ^b (39.69)	44.68 ^b (41.95)	32.67 (33.86)
CD (P=0.05)	1.72	0.94	1.10	1.69	1.89	1.81	2.08	1.50	1.92	1.80	1.84	2.09	1.91	
SE _m (±)	0.58	0.31	0.36	0.56	0.62	0.60	0.69	0.50	0.63	0.60	0.61	0.69	0.63	
CV (per cent)	6.85	3.38	3.92	5.20	5.50	4.02	4.18	4.26	5.53	4.71	4.54	4.10	3.47	

Figures in parentheses are values transformed using the arc sine method; D.A.S = Days after Spraying.

Fig. 4.42 Effect of various insecticidal treatments on fruit infestation (%) by number basis due to incidence of fruit borer after the first and second sprays in brinjal during 2023

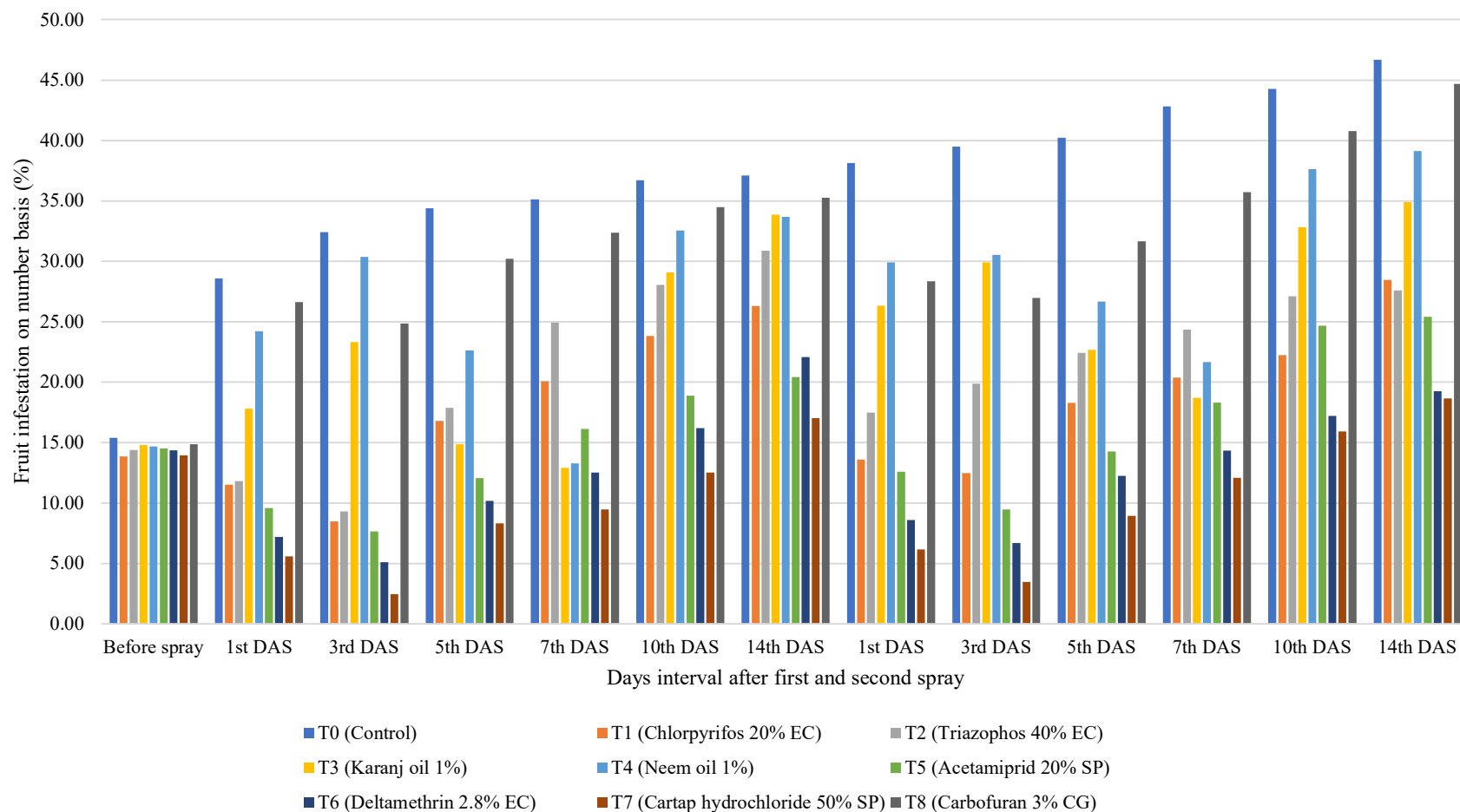


Table no. 4.40: Effect of various insecticidal treatments on fruit infestation (%) by number basis due to incidence of fruit borer after the first and second sprays in brinjal during 2024

Treatment	First spray							Second spray						Mean
	Before spray	1st D.A.S	3rd D.A.S	5th D.A.S	7 th D.A.S	10 th D.A.S	14 th D.A.S	1st D.A.S	3rd D.A.S	5 th D.A.S	7 th D.A.S	10 th D.A.S	14 th D.A.S	
T ₀ (Control)	18.33 ^a (25.35)	26.38 ^a (30.90)	28.62 ^a (32.34)	31.59 ^a (34.20)	34.82 ^a (36.16)	36.92 ^a (37.42)	39.22 ^a (38.77)	41.63 ^a (40.18)	44.13 ^a (41.63)	47.38 ^a (43.50)	48.74 ^a (44.28)	49.38 ^a (44.64)	51.58 ^a (45.91)	40.03 (38.10)
T ₁ (Chlorpyrifos 20% EC)	16.87 ^a (24.25)	13.25 ^d (21.34)	10.64 ^e (19.04)	18.43 ^c (25.43)	22.67 ^c (28.44)	25.28 ^d (30.18)	28.48 ^e (32.25)	15.68 ^f (23.33)	13.54 ^f (21.59)	20.75 ^e (27.10)	24.78 ^d (29.85)	25.34 ^f (30.22)	27.76 ^f (31.79)	20.55 (26.52)
T ₂ (Triazophos 40% EC)	17.40 ^a (24.65)	14.21 ^d (22.15)	12.12 ^d (20.37)	19.24 ^c (26.02)	25.33 ^b (30.22)	30.68 ^c (33.63)	31.72 ^d (34.28)	19.28 ^c (26.05)	21.38 ^c (27.54)	24.56 ^c (29.71)	28.12 ^c (32.02)	29.48 ^c (32.89)	31.18 ^c (33.94)	23.94 (28.73)
T ₃ (Karanj oil 1%)	17.80 ^a (24.95)	19.92 ^c (26.51)	22.42 ^c (28.26)	16.96 ^d (24.32)	11.83 ^f (20.12)	31.38 ^c (34.07)	35.61 ^c (36.64)	24.48 ^d (29.65)	28.98 ^c (32.57)	21.28 ^d (27.47)	19.68 ^c (26.34)	36.54 ^d (37.19)	38.72 ^d (38.48)	25.65 (29.74)
T ₄ (Neem oil 1%)	17.67 ^a (24.85)	22.48 ^b (28.30)	26.12 ^b (30.74)	20.82 ^b (27.15)	16.68 ^{de} (24.11)	34.74 ^b (36.11)	36.52 ^{bc} (37.18)	28.39 ^b (32.20)	32.51 ^b (34.76)	24.32 ^c (29.55)	20.37 ^c (26.83)	41.82 ^b (40.29)	43.58 ^c (41.31)	29.03 (31.80)
T ₅ (Acetamiprid 20% SP)	17.53 ^a (24.75)	12.62 ^d (20.81)	9.12 ^f (17.58)	15.48 ^c (23.17)	18.78 ^d (25.68)	21.14 ^c (27.37)	23.22 ^f (28.81)	15.72 ^f (23.36)	11.24 ^g (19.59)	18.35 ^f (25.36)	21.12 ^c (27.36)	25.24 ^f (30.16)	27.58 ^f (31.68)	18.30 (25.05)
T ₆ (Deltamethrin 2.8% EC)	17.37 ^a (24.63)	14.48 ^d (22.37)	8.72 ^f (17.18)	12.36 ^f (20.58)	15.24 ^c (22.98)	17.61 ^f (24.81)	21.84 ^g (27.86)	12.26 ^g (20.50)	9.48 ^h (17.93)	14.82 ^g (22.64)	16.54 ^f (24.00)	18.36 ^g (25.37)	20.58 ^h (26.98)	15.19 (22.91)
T ₇ (Cartap hydrochloride 50% SP)	17.00 ^a (24.35)	8.22 ^e (16.66)	5.18 ^g (13.16)	12.76 ^f (20.93)	10.32 ^f (18.74)	13.68 ^g (21.71)	16.23 ^h (23.76)	7.24 ^h (15.61)	5.82 ⁱ (13.96)	10.14 ^h (18.57)	15.42 ^g (23.12)	17.56 ^h (24.77)	22.26 ^g (28.15)	12.07 (20.27)
T ₈ (Carbofuran 3% CG)	17.80 ^a (24.95)	28.20 ^a (32.08)	25.27 ^b (30.18)	32.18 ^a (34.56)	34.42 ^a (35.92)	36.28 ^a (37.04)	37.68 ^b (37.87)	27.47 ^c (31.61)	24.84 ^d (29.89)	34.48 ^b (35.96)	38.34 ^b (38.26)	41.18 ^c (39.92)	46.62 ^b (43.06)	33.91 (34.72)
CD (P=0.05)	1.77	1.92	1.12	1.46	2.46	1.23	1.37	0.16	0.78	0.50	1.97	0.61	0.37	
SE _m (±)	0.59	0.64	0.37	0.48	0.81	0.41	0.45	0.05	0.26	0.17	0.65	0.20	0.12	
CV (per cent)	5.85	6.20	3.89	4.19	6.66	2.55	2.61	0.44	2.08	1.19	4.36	1.10	0.61	

Figures in parentheses are values transformed using the arc sine method; D.A.S = Days after Spraying.

Fig. 4.43 Effect of various insecticidal treatments on fruit infestation (%) by number basis due to incidence of fruit borer after the first and second sprays in brinjal during 2024

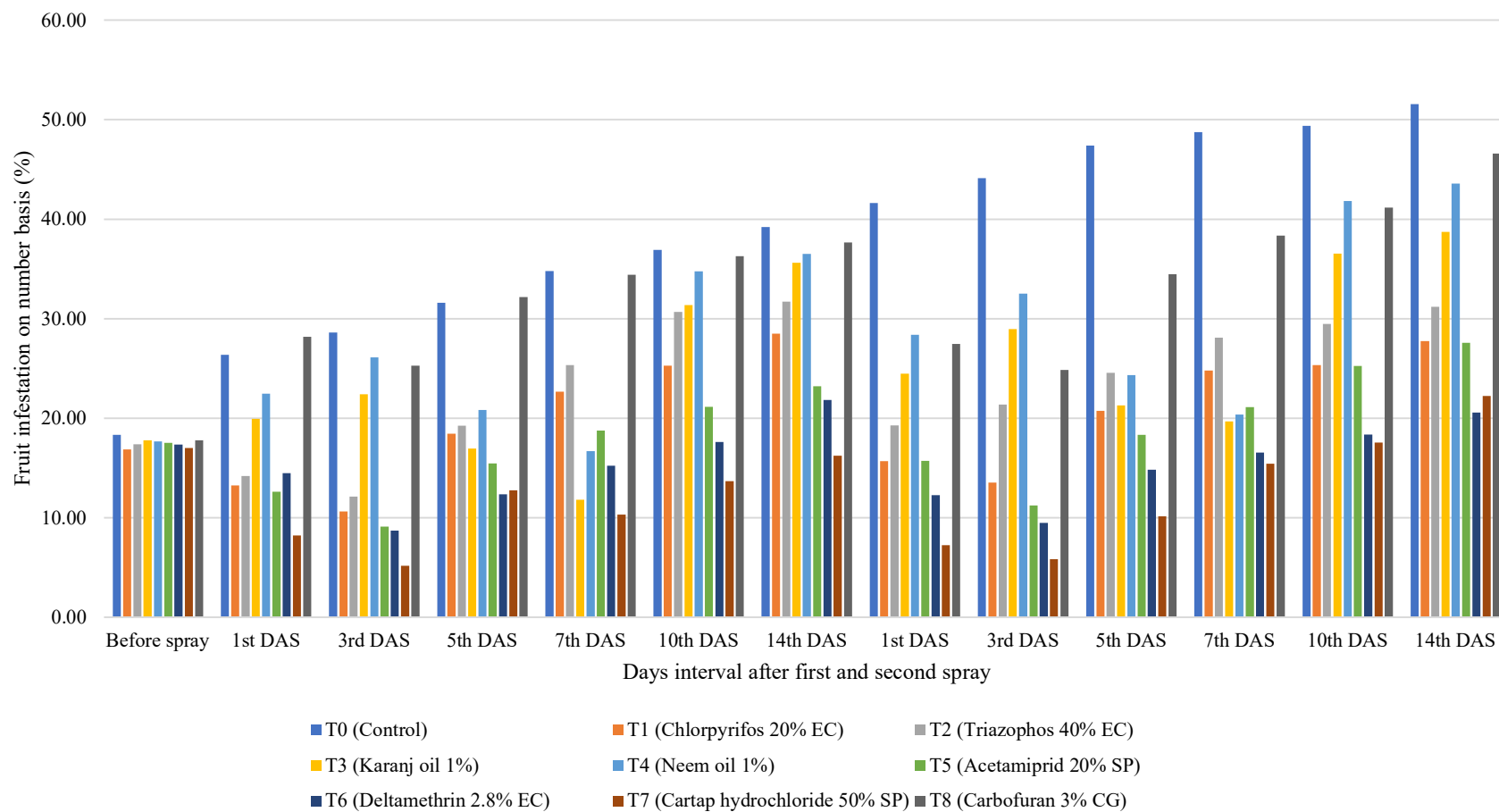


Table no. 4.41: Effect of various insecticidal treatments on fruit infestation (%) by number basis due to incidence of fruit borer after the first and second sprays in brinjal during the pooled analysis

Treatment	First spray							Second spray						Mean
	Before spray	1st D.A.S	3rd D.A.S	5th D.A.S	7 th D.A.S	10 th D.A.S	14th D.A.S	1st D.A.S	3rd D.A.S	5 th D.A.S	7th D.A.S	10th D.A.S	14th D.A.S	
T ₀ (Control)	16.87 ^a (24.25)	27.48 ^a (31.62)	30.52 ^a (33.54)	32.99 ^a (35.06)	34.97 ^a (36.25)	36.82 ^a (37.36)	38.17 ^a (38.16)	39.88 ^a (39.16)	41.81 ^a (40.28)	43.80 ^a (41.44)	45.79 ^a (42.58)	46.83 ^a (43.18)	49.13 ^a (44.50)	39.02 (37.49)
T ₁ (Chlorpyrifos 20% EC)	15.37 ^a (23.08)	12.39 ^d (20.61)	9.56 ^f (18.01)	17.62 ^d (24.82)	21.37 ^d (27.54)	24.56 ^c (29.71)	27.40 ^c (31.56)	14.64 ^f (22.50)	13.01 ^f (21.14)	19.51 ^f (26.21)	22.58 ^d (28.37)	23.79 ^g (29.19)	28.12 ^f (32.02)	19.55 (25.75)
T ₂ (Triazophos 40% EC)	15.90 ^a (23.50)	13.01 ^d (21.14)	10.72 ^c (19.11)	18.56 ^d (25.52)	25.13 ^c (30.09)	29.38 ^d (32.82)	31.30 ^d (34.02)	18.38 ^c (25.38)	20.63 ^c (27.01)	23.49 ^d (28.99)	26.24 ^c (30.81)	28.30 ^c (32.14)	29.38 ^c (32.82)	22.88 (27.95)
T ₃ (Karanj oil 1%)	16.30 ^a (23.81)	18.86 ^c (25.74)	22.87 ^d (28.57)	15.92 ^c (23.51)	12.38 ^g (20.60)	30.23 ^d (33.35)	34.74 ^c (36.12)	25.41 ^d (30.27)	29.45 ^c (32.87)	21.98 ^c (27.96)	19.20 ^f (25.99)	34.69 ^d (36.08)	36.80 ^d (37.35)	25.21 (29.40)
T ₄ (Neem oil 1%)	16.17 ^a (23.71)	23.35 ^b (28.90)	28.25 ^b (32.11)	21.72 ^c (27.78)	14.98 ^f (22.77)	33.65 ^c (35.46)	35.10 ^c (36.33)	29.16 ^b (32.68)	31.52 ^b (34.15)	25.50 ^c (30.33)	21.02 ^{de} (27.29)	39.72 ^c (39.07)	41.35 ^c (40.02)	28.78 (31.58)
T ₅ (Acetamiprid 20% SP)	16.03 ^a (23.60)	11.10 ^c (19.46)	8.39 ^g (16.83)	13.78 ^f (21.79)	17.45 ^c (24.69)	20.01 ^f (26.57)	21.82 ^f (27.85)	14.16 ^f (22.10)	10.36 ^g (18.78)	16.31 ^g (23.82)	19.72 ^{ef} (26.36)	24.96 ^f (29.97)	26.49 ^g (30.98)	17.05 (24.06)
T ₆ (Deltamethrin 2.8% EC)	15.87 ^a (23.47)	10.84 ^c (19.23)	6.92 ^h (15.25)	11.27 ^g (19.62)	13.88 ^f (21.87)	16.91 ^g (24.28)	21.96 ^f (27.94)	10.43 ^g (18.84)	8.08 ^h (16.51)	13.54 ^h (21.59)	15.44 ^g (23.13)	17.79 ^h (24.94)	19.91 ^h (26.50)	13.91 (21.78)
T ₇ (Cartap hydrochloride 50% SP)	15.47 ^a (23.16)	6.90 ^f (15.23)	3.83 ⁱ (11.29)	10.54 ^g (18.95)	9.90 ^h (18.34)	13.10 ^h (21.22)	16.64 ^g (24.07)	6.71 ^h (15.01)	4.65 ⁱ (12.45)	9.54 ⁱ (17.99)	13.75 ^h (21.77)	16.75 ⁱ (24.16)	20.46 ^h (26.89)	11.06 (19.27)
T ₈ (Carbofuran 3% CG)	16.33 ^a (23.84)	27.42 ^a (31.58)	25.07 ^c (30.05)	31.20 ^b (33.96)	33.40 ^b (35.30)	35.38 ^b (36.50)	36.48 ^b (37.15)	27.90 ^c (31.89)	25.90 ^d (30.59)	33.08 ^b (35.11)	37.03 ^b (37.48)	40.98 ^b (39.80)	45.65 ^b (42.50)	33.29 (34.29)
CD (P=0.05)	1.75	1.13	0.70	1.22	1.40	1.00	1.37	0.76	1.03	0.89	1.75	1.00	1.00	
SE _m (±)	0.58	0.38	0.23	0.40	0.46	0.33	0.45	0.25	0.34	0.30	0.58	0.33	0.33	
CV (per cent)	6.30	3.86	2.48	3.63	3.94	2.14	2.67	2.10	2.86	2.22	4.09	1.88	1.74	

Figures in parentheses are values transformed using the arc sine method; D.A.S = Days after Spraying.

Fig. 4.44 Effect of various insecticidal treatments on fruit infestation (%) by number basis due to incidence of fruit borer after the first and second sprays in brinjal during the pooled analysis

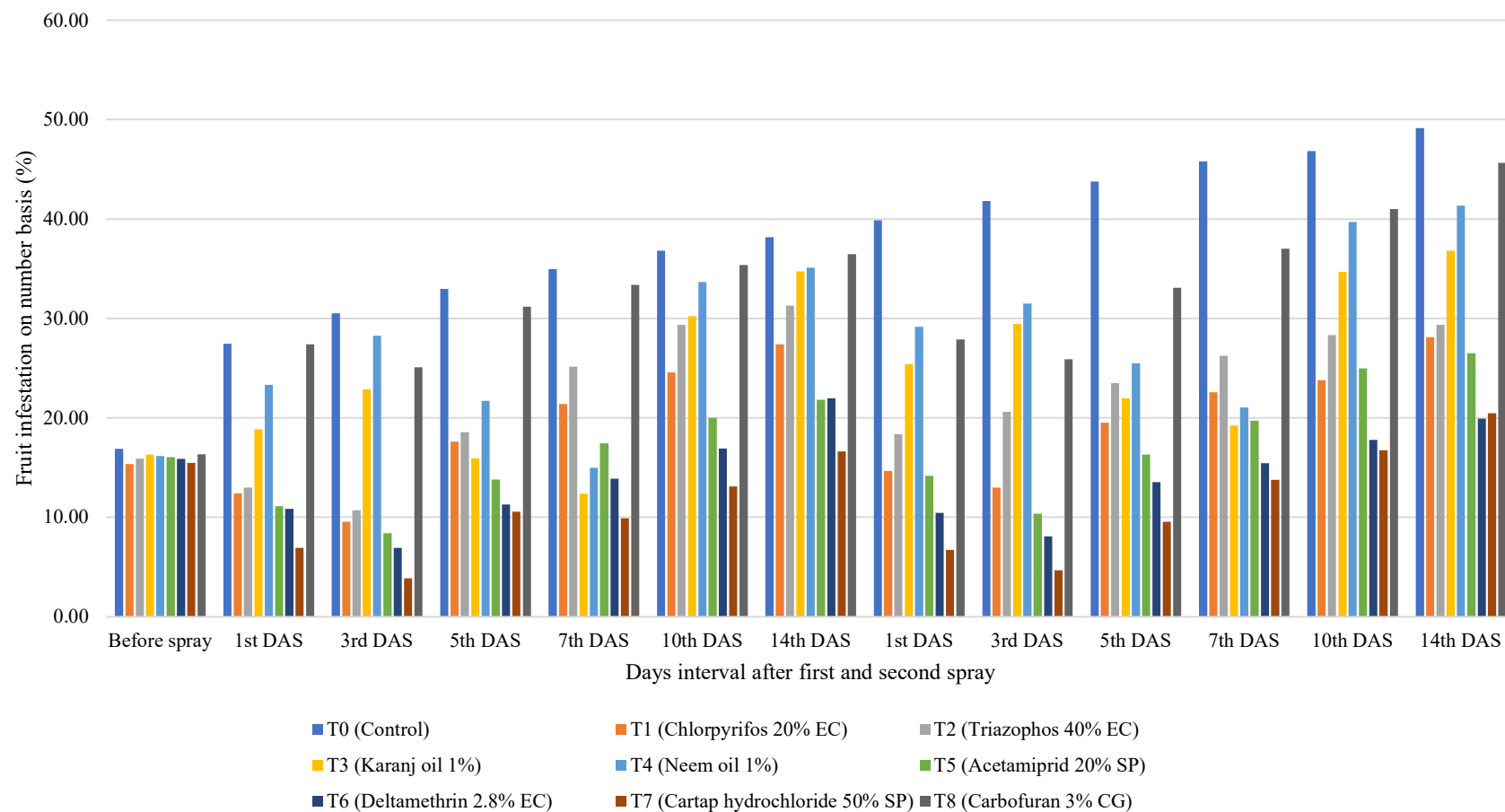


Table no. 4.42: Effect of various insecticidal treatments on fruit infestation (%) by weight basis due to incidence of fruit borer after the first and second sprays in brinjal during 2023

Treatment	First spray							Second spray						Mean
	Before spray	1st D.A.S	3rd D.A.S	5th D.A.S	7 th D.A.S	10 th D.A.S	14th D.A.S	1st D.A.S	3rd D.A.S	5 th D.A.S	7th D.A.S	10th D.A.S	14th D.A.S	
T ₀ (Control)	11.76 ^a (20.06)	27.02 ^a (31.32)	30.13 ^a (33.29)	32.08 ^a (34.50)	34.18 ^a (35.78)	35.22 ^a (36.40)	36.12 ^a (36.94)	37.04 ^a (37.49)	38.12 ^a (38.13)	39.38 ^a (38.87)	41.22 ^a (39.94)	43.08 ^a (41.02)	45.12 ^a (42.20)	36.56 (35.84)
T ₁ (Chlorpyrifos 20% EC)	10.22 ^a (18.64)	11.03 ^c (19.40)	7.97 ^c (16.40)	16.30 ^c (23.81)	19.57 ^d (26.26)	23.34 ^f (28.89)	25.82 ^c (30.54)	13.10 ^c (21.22)	11.97 ^c (20.24)	17.77 ^c (24.93)	19.88 ^d (26.48)	21.74 ^f (27.79)	25.44 ^{ef} (30.29)	17.83 (24.22)
T ₂ (Triazophos 40% EC)	10.75 ^a (19.14)	11.30 ^c (19.64)	8.82 ^d (17.28)	17.37 ^d (24.63)	24.43 ^c (29.62)	27.57 ^c (31.68)	30.37 ^d (33.44)	16.42 ^d (23.90)	18.32 ^d (25.34)	21.12 ^d (27.36)	23.08 ^c (28.71)	26.12 ^d (30.74)	27.08 ^c (31.36)	21.00 (26.37)
T ₃ (Karanj oil 1%)	11.15 ^a (19.50)	17.30 ^d (24.58)	22.82 ^c (28.54)	14.37 ^f (22.28)	12.43 ^{fg} (20.65)	28.57 ^d (32.31)	33.37 ^c (35.29)	25.84 ^c (30.55)	28.42 ^{bc} (32.22)	21.06 ^d (27.32)	17.22 ^c (24.52)	30.32 ^c (33.41)	34.36 ^d (35.89)	23.84 (28.23)
T ₄ (Neem oil 1%)	11.13 ^a (19.49)	23.72 ^c (29.15)	29.88 ^a (33.14)	22.11 ^c (28.05)	12.78 ^f (20.95)	32.06 ^c (34.49)	33.18 ^c (35.17)	29.42 ^b (32.85)	30.02 ^b (33.22)	25.17 ^c (30.11)	21.18 ^{cd} (27.40)	32.12 ^c (34.52)	37.74 ^c (37.90)	27.45 (30.50)
T ₅ (Acetamiprid 20% SP)	10.79 ^a (19.18)	9.08 ^f (17.54)	7.15 ^c (15.51)	11.57 ^g (19.89)	15.63 ^c (23.29)	18.39 ^g (25.40)	19.92 ^g (26.51)	12.14 ^c (20.39)	8.98 ^f (17.44)	13.77 ^f (21.78)	17.48 ^c (24.71)	24.18 ^c (29.45)	24.12 ^f (29.41)	15.20 (22.35)
T ₆ (Deltamethrin 2.8% EC)	10.72 ^a (19.11)	6.71 ^g (15.02)	4.62 ^f (12.41)	9.69 ^h (18.14)	12.02 ^g (20.29)	15.71 ^h (23.35)	21.58 ^f (27.68)	8.10 ^f (16.54)	6.18 ^{fg} (14.39)	11.80 ^g (20.09)	13.98 ^f (21.96)	16.92 ^g (24.29)	18.75 ^g (25.66)	12.17 (19.92)
T ₇ (Cartap hydrochloride 50% SP)	10.27 ^a (18.69)	5.08 ^h (13.03)	1.98 ^g (8.09)	7.83 ⁱ (16.25)	8.97 ^h (¹⁷ 43)	12.03 ⁱ (20.30)	16.54 ^h (24.00)	5.94 ^g (14.11)	3.32 ^g (10.50)	8.74 ^h (17.20)	11.88 ^g (20.16)	15.54 ^g (23.22)	18.40 ^g (25.40)	9.69 (17.57)
T ₈ (Carbofuran 3% CG)	10.98 ^a (19.35)	26.14 ^b (30.75)	24.37 ^b (29.58)	29.72 ^b (33.04)	31.88 ^b (34.38)	33.97 ^b (35.65)	34.77 ^b (36.13)	27.84 ^b (31.85)	26.46 ^c (30.96)	28.17 ^b (32.06)	34.64 ^b (36.05)	37.56 ^b (37.80)	41.78 ^b (40.27)	31.44 (32.91)
CD (P=0.05)	1.79	0.55	0.83	0.45	0.46	0.30	0.43	1.91	3.02	1.70	1.98	1.93	1.94	
SE _m (±)	0.60	0.18	0.28	0.15	0.15	0.10	0.14	0.63	1.00	0.56	0.66	0.64	0.64	
CV (per cent)	9.52	2.06	3.11	1.43	1.37	0.68	0.87	5.61	9.05	4.70	5.10	4.02	3.67	

Figures in parentheses are values transformed using the arc sine method; D.A.S = Days after Spraying.

Fig. 4.45 Effect of various insecticidal treatments on fruit infestation (%) by weight basis due to incidence of fruit borer after the first and second sprays in brinjal during 2023

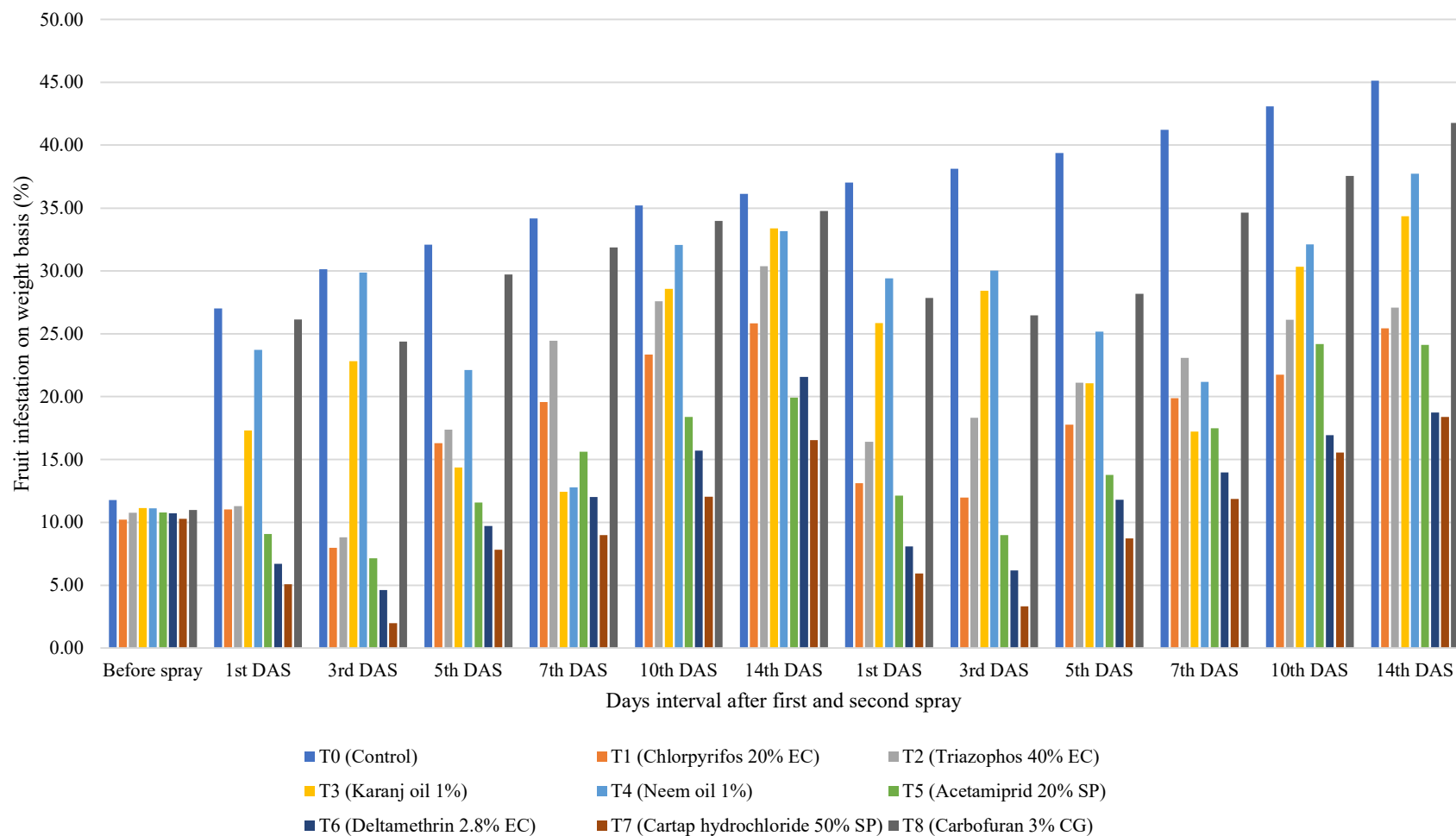


Table no. 4.43: Effect of various insecticidal treatments on fruit infestation (%) by weight basis due to incidence of fruit borer after the first and second sprays in brinjal during 2024

Treatment	First spray							Second spray						Mean
	Before spray	1st D.A.S	3rd D.A.S	5th D.A.S	7th D.A.S	10th D.A.S	14th D.A.S	1st D.A.S	3rd D.A.S	5th D.A.S	7th D.A.S	10th D.A.S	14th D.A.S	
T ₀ (Control)	13.19 ^a (21.29)	25.13 ^b (30.09)	27.37 ^a (31.55)	30.34 ^a (33.42)	33.57 ^a (35.41)	35.67 ^a (36.67)	37.97 ^a (38.04)	40.38 ^a (39.45)	42.88 ^a (40.91)	46.13 ^a (42.78)	47.49 ^a (43.56)	48.13 ^a (43.93)	50.33 ^a (45.19)	38.79 (37.10)
T ₁ (Chlorpyrifos 20% EC)	11.65 ^a (19.95)	12.00 ^f (20.27)	9.39 ^{de} (17.85)	17.18 ^{bc} (24.49)	21.42 ^c (27.57)	24.03 ^c (29.36)	27.23 ^c (31.46)	14.43 ^c (22.33)	12.29 ^f (20.53)	19.50 ^d (26.21)	23.53 ^d (29.02)	24.09 ^c (29.40)	26.51 ^f (30.99)	19.30 (25.34)
T ₂ (Triazophos 40% EC)	12.16 ^a (20.41)	12.96 ^c (21.10)	10.87 ^d (19.25)	17.99 ^{bc} (25.10)	24.08 ^b (29.39)	29.43 ^b (32.86)	30.47 ^d (33.51)	18.03 ^d (25.13)	20.13 ^c (26.66)	23.31 ^c (28.87)	26.87 ^c (31.22)	28.23 ^d (32.10)	29.93 ^c (33.17)	22.69 (27.60)
T ₃ (Karanj oil 1%)	12.57 ^a (20.76)	18.67 ^d (25.60)	21.17 ^c (27.40)	15.71 ^{cd} (23.35)	10.58 ^f (18.98)	30.13 ^b (33.29)	34.36 ^c (35.89)	23.23 ^c (28.82)	27.73 ^c (31.78)	20.03 ^d (26.59)	18.43 ^c (25.43)	35.29 ^c (36.45)	37.47 ^d (37.75)	24.40 (28.62)
T ₄ (Neem oil 1%)	12.53 ^a (20.73)	21.68 ^c (27.75)	24.87 ^b (29.92)	19.68 ^b (26.34)	15.65 ^{de} (23.31)	33.58 ^a (35.41)	35.70 ^c (36.69)	27.48 ^b (31.62)	31.58 ^b (34.19)	23.20 ^c (28.79)	19.12 ^c (25.93)	40.82 ^b (39.71)	42.73 ^c (40.82)	28.01 (30.86)
T ₅ (Acetamiprid 20% SP)	12.19 ^a (20.44)	11.37 ^g (19.71)	7.87 ^c (16.30)	14.23 ^d (22.16)	17.53 ^d (24.75)	19.89 ^d (26.49)	21.97 ^g (27.95)	14.47 ^c (22.36)	9.99 ^g (18.43)	17.11 ^c (24.44)	19.87 ^c (26.47)	23.99 ^c (29.33)	26.33 ^f (30.87)	17.06 (23.82)
T ₆ (Deltamethrin 2.8% EC)	12.13 ^a (20.39)	13.23 ^c (21.33)	7.47 ^c (15.87)	11.11 ^c (19.47)	13.99 ^c (21.97)	16.36 ^c (23.86)	20.59 ^f (26.99)	11.01 ^f (19.38)	8.23 ^g (16.67)	13.57 ^f (21.62)	15.29 ^f (23.02)	17.11 ^f (24.44)	19.33 ^g (26.08)	13.94 (21.62)
T ₇ (Cartap hydrochloride 50% SP)	11.69 ^a (19.99)	6.97 ^h (15.31)	3.93 ^f (11.44)	11.51 ^c (19.84)	9.07 ^f (17.53)	12.43 ^f (20.65)	14.98 ^h (22.77)	5.99 ^g (14.17)	4.57 ^h (12.35)	8.89 ^g (17.35)	14.17 ^g (22.12)	16.31 ^f (23.82)	21.01 ^g (27.28)	10.82 (18.82)
T ₈ (Carbofuran 3% CG)	12.50 ^a (20.70)	26.95 ^a (31.28)	24.02 ^b (29.35)	30.93 ^a (33.79)	33.17 ^a (35.17)	35.03 ^a (36.29)	36.43 ^b (37.13)	26.22 ^b (30.80)	23.59 ^d (29.06)	33.23 ^b (35.20)	37.09 ^b (37.52)	39.93 ^b (39.19)	45.37 ^b (42.35)	32.67 (33.68)
CD (P=0.05)	1.76	0.28	2.18	2.52	2.50	2.40	0.67	2.06	2.26	2.08	2.23	2.40	2.36	
SE _m (±)	0.59	0.09	0.72	0.84	0.83	0.79	0.22	0.68	0.75	0.69	0.74	0.79	0.78	
CV (per cent)	8.30	0.98	8.20	7.71	7.19	5.22	1.32	5.86	6.44	5.23	5.17	5.22	4.07	

Figures in parentheses are values transformed using the arc sine method; D.A.S = Days after Spraying.

Fig. 4.46 Effect of various insecticidal treatments on fruit infestation (%) by weight basis due to incidence of fruit borer after the first and second sprays in brinjal during 2024

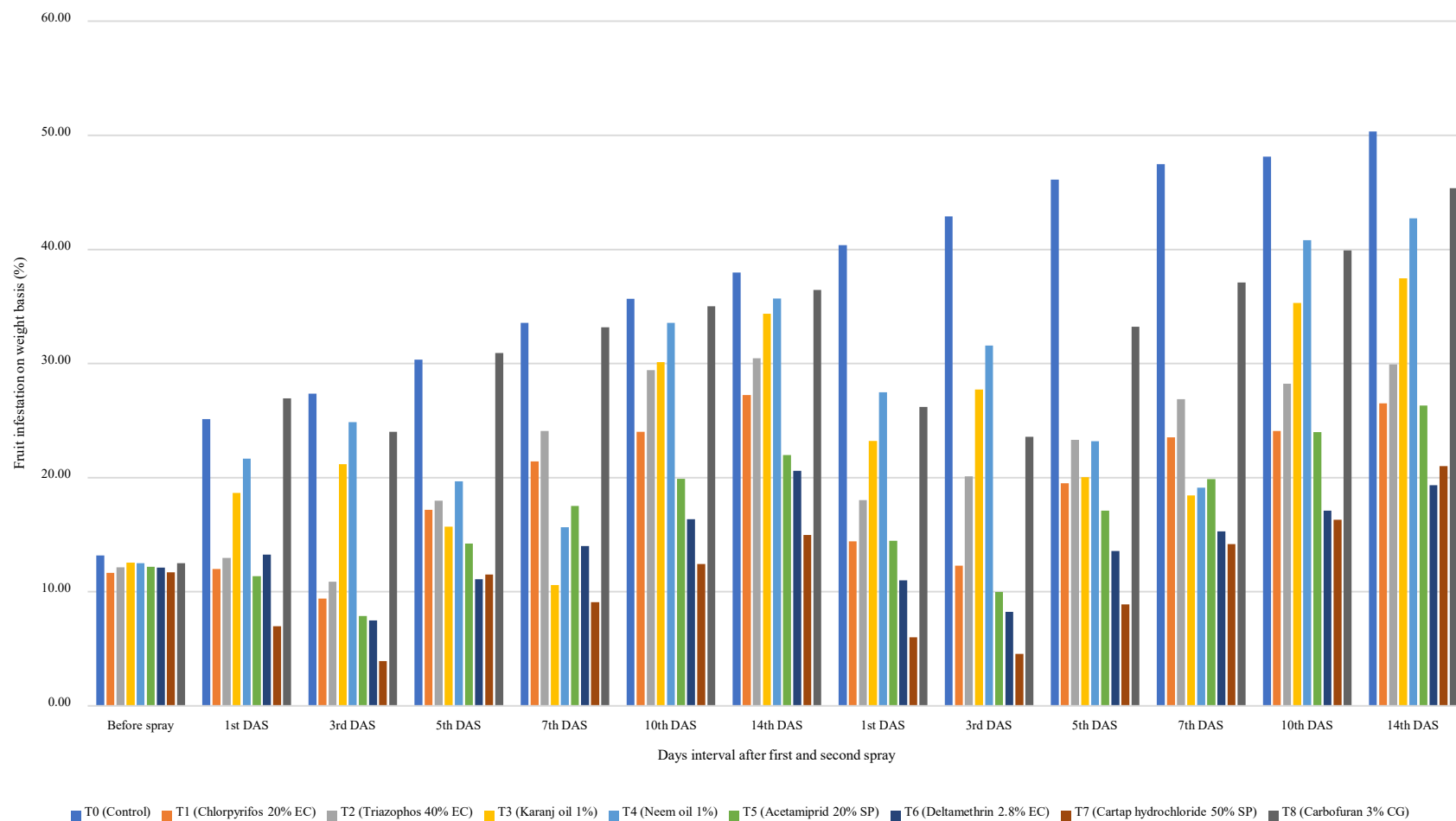
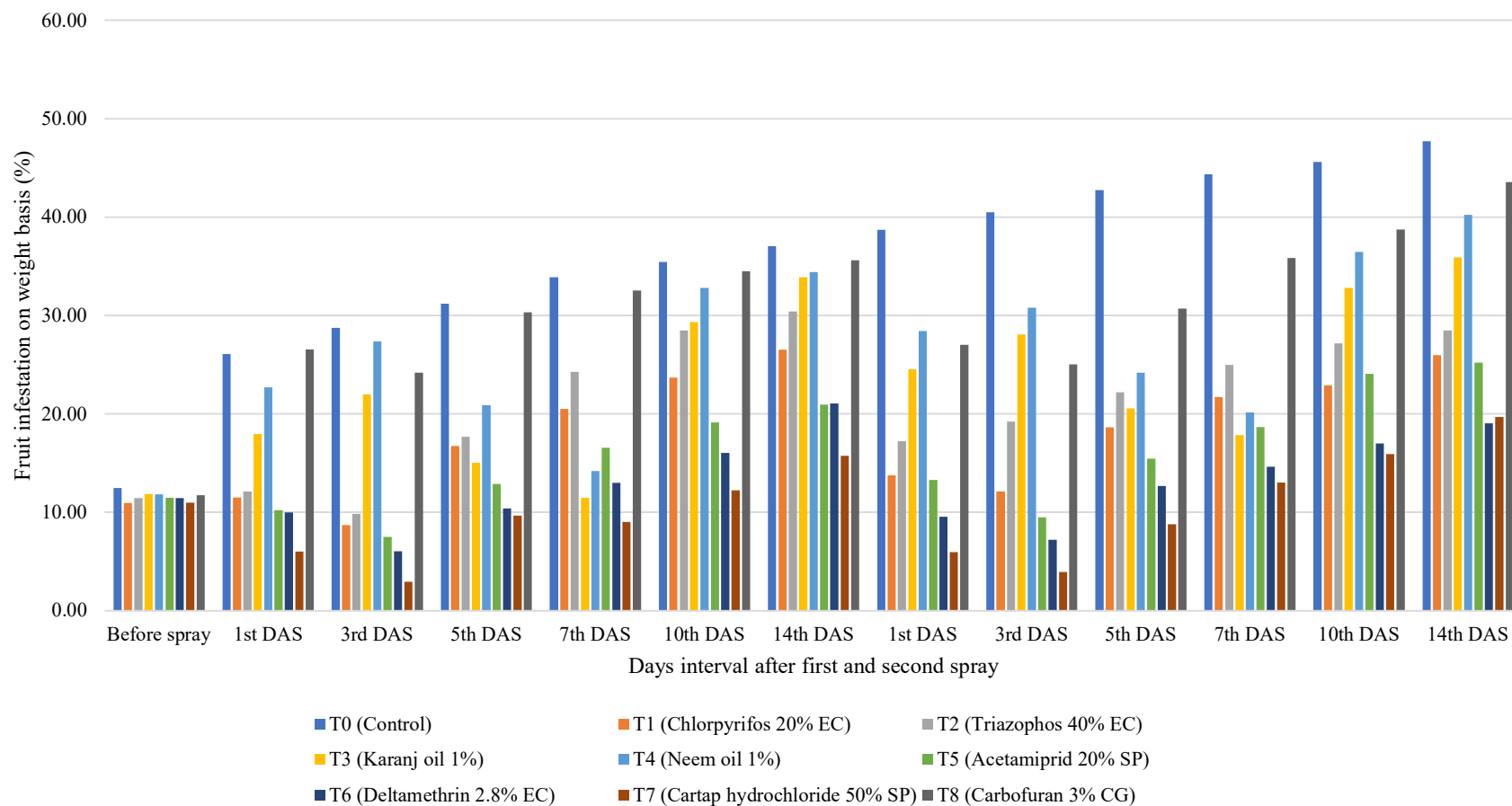


Table no. 4.44: Effect of various insecticidal treatments on fruit infestation (%) by weight basis due to incidence of fruit borer after the first and second sprays in brinjal during pooled analysis

Treatment	First spray							Second spray						Mean
	Before spray	1st D.A.S	3rd D.A.S	5th D.A.S	7 th D.A.S	10 th D.A.S	14th D.A.S	1st D.A.S	3rd D.A.S	5 th D.A.S	7th D.A.S	10th D.A.S	14th D.A.S	
T ₀ (Control)	12.47 ^a (20.68)	26.08 ^b (30.71)	28.75 ^a (32.43)	31.21 ^a (33.96)	33.88 ^a (35.59)	35.45 ^a (36.54)	37.05 ^a (37.49)	38.71 ^a (38.48)	40.50 ^a (39.52)	42.76 ^a (40.84)	44.36 ^a (41.76)	45.61 ^a (42.48)	47.73 ^a (43.70)	37.67 (36.47)
T ₁ (Chlorpyrifos 20% EC)	10.93 ^a (19.31)	11.52 ^f (19.84)	8.68 ^{ef} (17.14)	16.74 ^c (24.15)	20.50 ^d (26.92)	23.69 ^d (29.12)	26.53 ^f (31.00)	13.77 ^c (21.78)	12.13 ^f (20.39)	18.64 ^f (25.58)	21.71 ^d (27.77)	22.92 ^f (28.60)	25.98 ^f (30.64)	18.57 (24.79)
T ₂ (Triazophos 40% EC)	11.45 ^a (19.78)	12.13 ^c (20.38)	9.85 ^c (18.29)	17.68 ^c (24.87)	24.26 ^c (29.51)	28.50 ^c (32.27)	30.42 ^c (33.48)	17.23 ^d (24.52)	19.23 ^c (26.01)	22.22 ^d (28.12)	24.98 ^c (29.98)	27.18 ^c (31.42)	28.51 ^c (32.27)	21.85 (26.99)
T ₃ (Karanj oil 1%)	11.86 ^a (20.14)	17.99 ^d (25.09)	22.00 ^d (27.97)	15.04 ^d (22.82)	11.51 ^g (19.83)	29.35 ^c (32.81)	33.87 ^d (35.59)	24.54 ^c (29.69)	28.08 ^c (32.00)	20.55 ^c (26.95)	17.83 ^f (24.97)	32.81 ^d (34.94)	35.92 ^d (36.82)	24.12 (28.43)
T ₄ (Neem oil 1%)	11.83 ^a (20.12)	22.70 ^c (28.45)	27.38 ^b (31.55)	20.90 ^b (27.20)	14.22 ^f (22.15)	32.82 ^b (34.95)	34.44 ^c (35.93)	28.45 ^b (32.23)	30.80 ^b (33.71)	24.19 ^c (29.46)	20.15 ^{de} (26.67)	36.47 ^c (37.15)	40.24 ^c (39.37)	27.73 (30.69)
T ₅ (Acetamiprid 20% SP)	11.49 ^a (19.82)	10.23 ^g (18.65)	7.51 ^f (15.91)	12.90 ^c (21.05)	16.58 ^c (24.03)	19.14 ^c (25.95)	20.95 ^g (27.24)	13.31 ^c (21.39)	9.49 ^g (17.94)	15.44 ^g (23.14)	18.68 ^{ef} (25.61)	24.09 ^f (29.39)	25.23 ^f (30.15)	16.13 (23.10)
T ₆ (Deltamethrin 2.8% EC)	11.43 ^a (19.76)	9.97 ^g (18.41)	6.05 ^g (14.24)	10.40 ^f (18.82)	13.01 ^f (21.14)	16.04 ^f (23.61)	21.09 ^g (27.34)	9.55 ^f (18.00)	7.21 ^h (15.57)	12.69 ^h (20.87)	14.64 ^g (22.49)	17.02 ^g (24.36)	19.04 ^g (25.87)	13.06 (20.81)
T ₇ (Cartap hydrochloride 50% SP)	10.98 ^a (19.35)	6.03 ^h (14.21)	2.96 ^h (9.90)	9.67 ^f (18.12)	9.02 ^h (17.48)	12.23 ^g (20.47)	15.76 ^h (23.39)	5.97 ^g (14.14)	3.95 ⁱ (11.46)	8.82 ⁱ (17.47)	13.03 ^g (21.16)	15.93 ^g (23.52)	19.71 ^g (26.35)	10.26 (18.22)
T ₈ (Carbofuran 3% CG)	11.74 ^a (20.04)	26.55 ^a (31.01)	24.20 ^c (29.47)	30.33 ^a (33.41)	32.53 ^b (34.77)	34.50 ^a (35.97)	35.60 ^b (36.63)	27.03 ^b (31.33)	25.03 ^d (30.02)	30.70 ^b (33.65)	35.87 ^b (36.79)	38.75 ^b (38.50)	43.58 ^b (41.31)	32.05 (33.30)
CD (P=0.05)	1.78	0.29	1.25	1.31	1.29	1.20	0.41	1.64	1.03	1.42	1.75	1.59	0.41	
SE _m (±)	0.59	0.10	0.42	0.43	0.43	0.40	0.13	0.54	0.34	0.47	0.58	0.53	0.13	
CV (per cent)	8.87	1.06	4.71	4.10	3.80	2.66	0.82	4.75	3.01	3.73	4.27	3.15	0.82	

Figures in parentheses are values transformed using the arc sine method; D.A.S = Days after Spraying.

Fig. 4.47 Effect of various insecticidal treatments on fruit infestation (%) by weight basis due to incidence of fruit borer after the first and second sprays in brinjal during pooled analysis



4.7 Economics of various insecticidal treatment

The economics of different treatments were determined based on the expenditures involved from field preparation to crop harvesting. The total cost of cultivation, gross returns, net returns, and benefit-cost (B:C) ratio were estimated and are presented in Tables 4.45 to 4.49. The data indicate that both gross and net returns are positively influenced by the application of various insecticidal treatments.

Among the various insecticidal treatments, the highest total cost of cultivation (Rs. 1,79,323.50/ha) was observed in treatment T₄ (Neem oil 1%), followed by treatment T₅ (Rs. 1,76,421.50/ha), whereas the lowest total cost of cultivation (Rs. 1,75,086.50/ha) was recorded in T₀ (Control), followed by T₂ (Rs. 1,75,405.25/ha).

The maximum gross returns (Rs. 4,36,171.85, 4,83,487.41 and 4,59,829.63) were observed in T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (Rs. 4,14,423.70, 4,52,970.86 and 4,33,697.28), while the minimum (Rs. 2,52,053.33, 2,55,484.44 and 2,53,768.89) were recorded in T₀ (Control), followed by T₈ (Rs. 2,77,232.59, 2,89,443.95 and 2,83,338.27) during 2023, 2024 and the pooled analysis.

The maximum net returns (Rs. 2,60,576.88, 3,07,892.44 and 2,84,234.66) were observed in T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (Rs. 2,39,012.20, 2,77,559.36 and 2,58,285.78), while the minimum (Rs. 76,966.83, 80,397.94 and 78,682.39) were recorded in T₀ (Control), followed by T₈ (Rs. 1,01,552.84, 1,13,764.20 and 1,07,658.52) in 2023, 2024 and the pooled analysis.

The highest benefit-cost (B:C) ratio (1.48, 1.75, 1.62) was observed in T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (1.36, 1.58, 1.47), while the lowest B:C ratio (0.44, 0.46, 0.45) was recorded in T₀ (Control), followed by T₈ (0.58, 0.65, 0.61) in 2023, 2024 and the pooled analysis.

The economics of cultivation plays a key role in decision-making regarding the adoption of techniques and understanding various operations from the farmer's perspective. The findings indicated that T₇ (Cartap hydrochloride 50% SP) produced the highest benefit-cost (B:C) ratio. This may be attributed to the higher productivity of brinjal, which leads to a higher market value of brinjal fruits. By reducing the stress caused by insect pests, insecticidal treatment may minimize losses from pest infestations and enhance the B:C ratio of brinjal. The present findings are in close agreement with the findings of Udikeri *et al.*, 2024, who reported that application of insecticidal treatments resulted in maximum yield, leading to a higher benefit-cost ratio in brinjal.

Table no. 4.45: Cost of cultivation of brinjal for different operations

S. No.	Operation/inputs	Requirements ha ⁻¹	Rate (Rs.)	Total cost of cultivation (Rs.)
A.	Fixed cost			
1	Land rent/ Lease	4 months	1,00,000 per year	33,333.00
2	Raising of nursery seedlings	184 trays	148.48/tray	27,320.00
3	Main field preparation			
a	Tractor ploughing, harrowing and levelling	10 hrs.	1000/hr.	10,000.00
b	Cleaning of stubbles and weeds	7-man days (8 hrs.)	500/day	3,500.00
c	Bed preparation	10-man days (8 hrs.)	600/day	6,000.00
4	Transplanting	20-man days	500/day	10,000
5	Irrigation			
a	Irrigation equipment	14 irrigations	1000/irrigation	14,000.00
b	Irrigation labours (2 labours in each irrigation)	28-man days	500/day	14,000.00
6	Intercultural operations			
a	Weeding and hoeing	8-man days	600/day	4,800.00
b	Gap filling	5-man days	500/day	2,500.00
c	Maintenance	2-man days	700/day	1,400.00
d	Top dressing (Nitrogen)	3-man days	700/day	2,100.00
7	Insecticides application	8-man days	400/day	3,200.00
8	Harvesting	15-man days	500/day	7,500.00
	Total A			1,39,653.00
B.	Variable cost			
1	Seed cost	300g	115/10g	3,450
2	Organic manures			
a	Farm-yard manure	15 tonnes	750/tonnes	11,250
b	FYM application	6-man days	500/day	3,000
3	Inorganic fertilizers			
a	Urea	270 kg	8/kg	2,160
b	SSP	382.85 kg	9/kg	3,446
c	MOP	49.40 kg	16/kg	790
	Inorganic fertilizers application	6-man days	500/day	3,000
4	Miscellaneous charges	5% of total cost of cultivation		8,337
	Total B			35,434
	Total cost (A+B) =			1,75,086.50

Table no. 4.46: Total cost of cultivation of brinjal per hectare area

Treatments	Quantity applied (lit or kg/ha)	Insecticide cost (Rs/lit or kg)	Treatments cost (Rs/ha)	Fixed cost + variable cost (Rs/ha)	Total cost (Rs/ha)
T₀ (Control)	0	0	0	1,75,086.50	1,75,086.50
T₁ (Chlorpyrifos 20% EC)	1.000	320	320	1,75,086.50	1,75,406.50
T₂ (Triazophos 40% EC)	0.750	425	318.75	1,75,086.50	1,75,405.25
T₃ (Karanj oil 1%)	3.750	349	1308.75	1,75,086.50	1,76,395.25
T₄ (Neem oil 1%)	2.000	2118.5	4237	1,75,086.50	1,79,323.50
T₅ (Acetamiprid 20% SP)	0.750	1780	1335	1,75,086.50	1,76,421.50
T₆ (Deltamethrin 2.8% EC)	0.500	650	325	1,75,086.50	1,75,411.50
T₇ (Cartap hydrochloride 50% SP)	0.375	1355.92	508.47	1,75,086.50	1,75,594.97
T₈ (Carbofuran 3% CG)	7.000	84.75	593.25	1,75,086.50	1,75,679.75

Table no. 4.47: Economics of brinjal cultivation under various insecticidal treatments during 2023

Treatment	Total cost of cultivation (Rs.)	Yield (t/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit Cost ratio
T₀ (Control)	1,75,086.50	21.00	2,52,053.33	76,966.83	0.44
T₁ (Chlorpyrifos 20% EC)	1,75,406.50	30.92	3,71,016.30	1,95,609.80	1.12
T₂ (Triazophos 40% EC)	1,75,405.25	29.13	3,49,576.30	1,74,171.05	0.99
T₃ (Karanj oil 1%)	1,76,395.25	27.34	3,28,077.04	1,51,681.79	0.86
T₄ (Neem oil 1%)	1,79,323.50	25.57	3,06,820.74	1,27,497.24	0.71
T₅ (Acetamiprid 20% SP)	1,76,421.50	32.72	3,92,580.74	2,16,159.24	1.23
T₆ (Deltamethrin 2.8% EC)	1,75,411.50	34.54	4,14,423.70	2,39,012.20	1.36
T₇ (Cartap hydrochloride 50% SP)	1,75,594.97	36.35	4,36,171.85	2,60,576.88	1.48
T₈ (Carbofuran 3% CG)	1,75,679.75	23.10	2,77,232.59	1,01,552.84	0.58

*Selling price of brinjal fruits = Rs. 12 (Mandi price)

Table no. 4.48: Economics of brinjal cultivation under various insecticidal treatments during 2024

Treatment	Total cost of cultivation (Rs.)	Yield (t/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit Cost ratio
T₀ (Control)	1,75,086.50	18.25	2,55,484.44	80,397.94	0.46
T₁ (Chlorpyrifos 20% EC)	1,75,406.50	30.17	4,22,419.75	2,47,013.25	1.41
T₂ (Triazophos 40% EC)	1,75,405.25	27.89	3,90,482.47	2,15,077.22	1.23
T₃ (Karanj oil 1%)	1,76,395.25	26.26	3,67,684.94	1,91,289.69	1.08
T₄ (Neem oil 1%)	1,79,323.50	24.15	3,38,060.25	1,58,736.75	0.89
T₅ (Acetamiprid 20% SP)	1,76,421.50	31.93	4,47,080.49	2,70,658.99	1.53
T₆ (Deltamethrin 2.8% EC)	1,75,411.50	32.36	4,52,970.86	2,77,559.36	1.58
T₇ (Cartap hydrochloride 50% SP)	1,75,594.97	34.53	4,83,487.41	3,07,892.44	1.75
T₈ (Carbofuran 3% CG)	1,75,679.75	20.67	2,89,443.95	1,13,764.20	0.65

*Selling price of brinjal fruits = Rs. 14 (Mandi price)

Table no. 4.49: Economics of brinjal cultivation under various insecticidal treatments in the pooled analysis

Treatment	Total cost of cultivation (Rs.)	Yield (t/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit Cost ratio
T₀ (Control)	1,75,086.50	19.63	2,53,768.89	78,682.39	0.45
T₁ (Chlorpyrifos 20% EC)	1,75,406.50	30.55	3,96,718.02	2,21,311.52	1.26
T₂ (Triazophos 40% EC)	1,75,405.25	28.51	3,70,029.38	1,94,624.13	1.11
T₃ (Karanj oil 1%)	1,76,395.25	26.80	3,47,880.99	1,71,485.74	0.97
T₄ (Neem oil 1%)	1,79,323.50	24.86	3,22,440.49	1,43,116.99	0.80
T₅ (Acetamiprid 20% SP)	1,76,421.50	32.32	4,19,830.62	2,43,409.12	1.38
T₆ (Deltamethrin 2.8% EC)	1,75,411.50	33.45	4,33,697.28	2,58,285.78	1.47
T₇ (Cartap hydrochloride 50% SP)	1,75,594.97	35.44	4,59,829.63	2,84,234.66	1.62
T₈ (Carbofuran 3% CG)	1,75,679.75	21.89	2,83,338.27	1,07,658.52	0.61

*Selling price of brinjal fruits = Rs. 13 (Mandi price)

The present study, entitled “**Residual studies of promising pesticides in Brinjal,**” was conducted in the main agricultural research field of the Department of Vegetable Science, Lovely Professional University, Phagwara, Punjab, during the *kharif* seasons of 2023 and 2024, aiming to achieve the following objectives: i) To identify the best treatment for growth, yield and quality of brinjal, ii) To estimate the residual effect of the treatments in brinjal, iii) To evaluate the efficacy of pesticides against shoot and fruit borer in brinjal, iv) To study the Benefit Cost ratio of treatments. To accomplish these objectives, two field trials were carried out during the years 2023 and 2024. The seeds of the brinjal hybrid Navkiran were sown in May (2023 and 2024) in pro-trays (99 cells) to raise the nursery for transplantation in the main field. The investigation consisted of nine treatments applied at recommended doses, including T₀ (Control-water spray), T₁ (Chlorpyrifos 20% EC), T₂ (Triazophos 40% EC), T₃ (Karanj oil 1%), T₄ (Neem oil 1%), T₅ (Acetamiprid 20% SP), T₆ (Deltamethrin 2.8% EC), T₇ (Cartap-hydrochloride 50% SP), T₈ (Carbofuran 3% CG), using a randomized block design with three replicates over two years of research. The seedlings were transplanted into 27 plots, each measuring 1.80 x 4.50 meters, with a spacing of 60 x 45 centimetres, during the first week of July on both 2023 and 2024. The treatments were applied 20 days after transplantation using knapsack sprayer. Observations were recorded on various growth, yield and quality characteristics, including plant height (cm), shoot length (cm), root length (cm), number of leaves, number of branches per plant, stem diameter (cm), days to flower initiation, days to 50 percent flowering, number of flowers per plant, days to fruit formation, days to harvesting, leaf area (cm²), leaf area index (LAI), number of shoot damage, incidence of shoot borer (%), number of fruits per plant, fruit length (cm), fruit width (cm), fruit yield per plant (kg), fruit yield per plot (kg), yield per hectare (t), yield increase over control per hectare (%), incidence of fruit borer (%), TSS (°Brix), titratable acidity (%), crude protein (%), chlorophyll index of leaves (SPAD-502). Observations on residual studies consisted of residual analysis and the dissipation rate of insecticides in brinjal fruit. Observations on seasonal incidence consisted of weekly recordings of shoot and fruit borer population along with correlation analysis with meteorological parameters such as temperature, humidity, rainfall and sunshine hours. Observations on efficacy of pesticides included percent shoot infestation (%) and fruit infestation (%). Observations on the economics of cultivation consisted of total cost of cultivation (Rs/ha), gross return (Rs/ha), net return (Rs/ha) and benefit-cost ratio (B:C). Five randomly selected plants were tagged for recording observations and means values for each

replication were calculated for statistical analysis. SPSS (Version 25.0) statistical software was used to analyze all recorded observations.

The significant findings of the present experiment are summarized under the following sub-headings:

5.1 Growth parameters

- i. During both years and the pooled analysis, the highest plant height (76.45, 76.31 and 76.38 cm) was recorded in T₇ (Cartap hydrochloride 20% EC), while the lowest plant height (73.36, 72.23 and 72.80 cm) was observed in T₀ (Control), respectively.
- ii. During both years and the pooled analysis, the maximum number of leaves (33.67, 32.80 and 33.23) were observed in treatment T₇ (Cartap hydrochloride 20% EC), whereas the minimum number of leaves (22.13, 20.80 and 21.47) were recorded in treatment T₀ (Control), respectively.
- iii. The highest shoot length of 61.29, 61.08 and 61.19 cm was observed in treatment T₆ (Deltamethrin 2.8% EC) whereas the lowest shoot length of 60.12, 59.17 and 59.65 cm was observed in treatment T₀ (Control) during 2023, 2024 and the pooled data.
- iv. The highest root length (15.33, 15.53 and 15.43 cm) was recorded in T₇ (Cartap hydrochloride 20% EC), whereas the lowest value (13.24, 13.06 and 13.15 cm) was observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis.
- v. During both years and the pooled analysis, the maximum number of branches (21.87, 21.53 and 21.70 cm) was recorded in T₇ (Cartap hydrochloride 20% EC) while the minimum (13.07, 12.93 and 13.00 cm) was observed in T₀ (Control), respectively.
- vi. The maximum stem diameter (2.95, 2.85 and 2.90 cm) was recorded in treatment T₇ (Cartap hydrochloride 20% EC) whereas the minimum (1.84, 1.74 and 1.79 cm) was recorded in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively.
- vii. The minimum days to flower initiation (38.93, 38.13 and 38.53) was recorded in treatment T₆ (Deltamethrin 2.8% EC), whereas the maximum days to flower initiation (40.40, 39.87 and 40.13) was observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively.
- viii. The minimum days to 50% flowering (49.87, 49.60 and 49.73) was recorded in treatment T₆ (Deltamethrin 2.8% EC), while the maximum days to 50% flowering (51.40, 51.27 and 51.33) was observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis, respectively.

- ix. The maximum number of flowers per plant (8.47, 8.20 and 8.33) was recorded in T₇ (Cartap hydrochloride 20% EC), while the minimum number of flowers per plant (4.07, 3.53 and 3.80) was observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis.
- x. The treatment T₇ (Cartap hydrochloride 20% EC) had the minimum days to fruit formation (63.80, 63.53 and 63.67), while treatment T₀ (Control) observed the maximum days to fruit formation (65.27, 65.00 and 65.13) in both years and the pooled analysis, respectively.
- xi. During both years and the pooled analysis, the minimum days to first harvesting (67.87, 67.53 and 67.70) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), while the maximum days to first harvesting (69.40, 69.13 and 69.27) was observed in treatment T₀ (Control), respectively.
- xii. The highest leaf area (49.38, 49.02 and 49.20 cm²) was recorded in T₇ (Cartap hydrochloride 20% EC), whereas the lowest (38.87, 38.17 and 38.52 cm²) was recorded in treatment T₀ (Control) in both years and the pooled analysis.
- xiii. The maximum leaf area index (0.62, 0.60 and 0.61) was recorded in T₇ (Cartap hydrochloride 20% EC), whereas the minimum (0.32, 0.29 and 0.31) was observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis.
- xiv. The treatment T₇ (Cartap hydrochloride 20% EC) had the lowest number of shoot damage (0.73, 1.33 and 1.03), while treatment T₀ (Control) recorded the highest number of shoot damage (2.53, 4.13 and 3.33) during 2023, 2024 and the pooled analysis.
- xv. The treatment T₇ (Cartap hydrochloride 20% EC) had the minimum percent shoot damage (4.05, 7.22 and 5.63%), while treatment T₀ (Control) recorded the maximum percent shoot damage (25.69, 40.28 and 32.98%) during 2023, 2024 and the pooled analysis.

5.2 Yield parameters

- i. The highest number of fruits per plant (7.00, 6.67 and 6.83) was recorded in T₇ (Cartap hydrochloride 20% EC), whereas the lowest number of fruits per plant (4.13, 3.60 and 3.87) was observed in treatment T₀ (Control) in both years and the pooled analysis.
- ii. During both years and the pooled analysis, the maximum fruit length (14.20, 14.01 and 14.10 cm) was recorded in T₇ (Cartap hydrochloride 20% EC), while the minimum fruit length (8.59, 8.32 and 8.46 cm) was observed in treatment T₀ (Control), respectively.

- iii. The maximum fruit width (7.96, 7.82 and 7.89 cm) was observed in treatment T₇ (Cartap hydrochloride 20% EC), whereas the minimum (4.48, 4.27 and 4.38 cm) was recorded in treatment T₀ (Control) during both years and the pooled analysis, respectively.
- iv. The treatment T₇ (Cartap hydrochloride 20% EC) had the highest fruit yield per plant (0.98, 0.93 and 0.96 kg), while treatment T₀ (Control) recorded the lowest fruit yield per plant (0.57, 0.49 and 0.53 kg) in both years and the pooled analysis.
- v. The highest fruit yield per plot (29.44, 27.97 and 28.71 kg) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), whereas the lowest fruit yield per plot (17.01, 14.78 and 15.90 kg) was observed in treatment T₀ (Control) during 2023, 2024 and the pooled analysis.
- vi. The maximum yield per hectare (36.35, 34.53 and 35.44 t) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), while the minimum yield per hectare (21.00, 18.25 and 19.63 t) was recorded in treatment T₀ (Control) in both years and the pooled analysis.
- vii. During both years and the pooled analysis, the maximum yield increase over control per hectare (73.26, 89.71 and 81.48%) was recorded in treatment T₇ (Cartap hydrochloride 20% EC), while the minimum yield increase over control per hectare (10.32, 13.43 and 11.87%) was recorded in treatment T₈ (Carbofuran 3% CG), respectively.

5.3 Quality parameters

- i. During both years and the pooled analysis, the maximum total soluble solids (4.12, 3.79 and 3.96 °Brix) were recorded in treatment T₀ (Control), while the minimum total soluble solids (3.91, 3.34 and 3.62 °Brix) were observed in treatment T₂ (Triazophos 40% EC).
- ii. The highest titratable acidity (0.68, 0.58 and 0.63%) was recorded in treatment T₀ (Control), while the lowest titratable acidity (0.47, 0.26 and 0.37%) was observed in treatment T₂ (Triazophos 40% EC) during 2023, 2024 and the pooled analysis, respectively.
- iii. The treatment T₀ (Control) had the highest crude protein (1.62, 1.76 and 1.69%), while treatment T₂ (Triazophos 40% EC) recorded the lowest crude protein (1.34, 1.29 and 1.32%) in both years and the pooled analysis.

- iv. The maximum chlorophyll index of leaves (45.15 and 44.27) was recorded in T₀ (Control), while the minimum chlorophyll index of leaves (43.77 and 42.87) was observed in T₁ (Chlorpyrifos 20% EC) during 2023 and 2024, respectively. Similarly, in the pooled analysis, the highest chlorophyll index of leaves (44.71) was observed in treatment T₀ (Control), while the lowest (43.32) was recorded in T₁ (Chlorpyrifos 20% EC).

5.4 Residual studies of insecticides in brinjal fruits

- i. The initial deposits of chlorpyrifos 20% EC were 0.691 mg/kg in 2023, 0.736 mg/kg in 2024, and 0.714 mg/kg in the pooled analysis. Residues declined steadily over time, with reductions of 95.01% in 2023, 93.86% in 2024, and 94.44% in the pooled data by the 7th day after spraying. Residues fell below the detection limit by the 10th day during 2023, 2024 and the pooled analysis.
- ii. The initial triazophos 40% EC residues in brinjal were 1.391 mg/kg (2023), 1.242 mg/kg (2024), and 1.317 mg/kg (pooled). Residue levels declined significantly, with reductions of over 94.19% by the 7th day in 2023, 91.79% in 2024, and 92.99% in the pooled analysis. By the 10th day, residues were below the detection limit during 2023, 2024 and the pooled analysis.
- iii. Acetamiprid 20% SP residues in brinjal initially measured 1.139 mg/kg (2023), 1.213 mg/kg (2024) and 1.176 mg/kg (pooled). By the 5th day, residues declined over 91.64%, 93.72% and 92.68%, respectively. Residues fell below detectable levels by the 7th day during both years and in the pooled data.
- iv. Deltamethrin 2.8% EC showed initial residues of 0.482 mg/kg (2023), 0.530 mg/kg (2024), and 0.506 mg/kg (pooled). By the 5th day, residues declined with dissipation rates of 92.48%, 89.50%, and 90.99%, respectively. Residues dropped below detectable limits by the 7th day in both years and in the pooled analysis.
- v. In 2023, the initial residue of cartap hydrochloride 50% SP in brinjal fruits was 1.238 mg/kg, which declined to 0.152 mg/kg by the 5th day, with 87.46% dissipation. In 2024, the initial deposit was 1.248 mg/kg, reducing to 0.106 mg/kg (91.48% dissipation) by 5th day after spraying. Pooled analysis showed an initial deposit of 1.243 mg/kg, with residues decreasing to 0.129 mg/kg (89.47% dissipation). Residues were below detectable limits by the 7th day in both years and in pooled data.
- vi. Initial residues of carbofuran 3% CG were 0.332 mg/kg (2023), 0.393 mg/kg (2024), and 0.362 mg/kg (pooled). Residues declined progressively, reaching 89.18% (2023),

90.04% (2024), and 89.61% (pooled) dissipation by the 10th day. All residues fell below detectable limits by the 15th day after application in both years and pooled data.

5.5 Seasonal incidence of shoot and fruit borer

- i. During 2023, it was observed that the shoot damage caused by *Leucinodes orbonalis* was initially 6.78 per cent during the 5th week after transplanting (27th SMW). The damage gradually increased and peaked at 28.78 per cent. During 2024, shoot damage caused by *Leucinodes orbonalis* was initially 4.20 per cent during the 4th week after transplanting (26th SMW). The damage gradually increased and peaked at 32.68 per cent during the 35th SMW. In the pooled analysis, shoot damage was initially 2.10 per cent during the 4th week after transplanting (26th SMW). The damage gradually increased and peaked at 29.75 per cent.
- ii. During 2023, the fruit infestation levels ranged from 3.48 to 40.62 per cent. The maximum fruit infestation was observed at 40.62 per cent during the 37th SMW. The minimum fruit infestation was recorded at 3.48 per cent during the 31st SMW. During 2024, the infestation levels (number basis) ranged from 4.68 to 45.75 per cent. The maximum fruit infestation was observed at 45.75 per cent on 38th SMW. The minimum fruit infestation was recorded at 4.68 per cent on 31st SMW. In the pooled analysis, the infestation levels (number basis) ranged from 4.08 to 41.27 per cent. The maximum fruit infestation was observed at 41.27 per cent during the 38th SMW. The minimum fruit infestation was recorded at 4.08 per cent during the 31st SMW.
- iii. The fruit infestation levels (weight basis) ranged from 1.24 to 37.22 per cent. The maximum fruit infestation was observed at 37.22 per cent during the 37th SMW. The minimum fruit infestation was recorded at 1.24 per cent during the 31st SMW in 2023. During 2024, the infestation levels (weight basis) ranged from 1.64 to 42.78 per cent. The maximum fruit infestation was observed at 42.78 per cent on 38th SMW. The minimum fruit infestation was recorded at 1.64 per cent on 31st SMW. In the pooled analysis, the infestation levels ranged from 1.44 to 37.25 per cent. The maximum fruit infestation was observed at 37.25 per cent on 38th SMW. The minimum fruit infestation was recorded at 1.44 per cent during 31st SMW.
- iv. The correlation analysis between shoot infestation and various weather parameters revealed consistent trends during 2023, 2024 and the pooled analysis. Shoot infestation exhibited a highly significant positive correlation with morning and evening relative humidity during 2023, 2024 and the pooled analysis. In contrast, maximum temperature

showed a highly significant negative correlation, during 2024 and the pooled analysis, while it was non-significant in 2023. The minimum temperature, rainfall, and sunshine hours showed a non-significant correlation with shoot infestation during 2023, 2024 and the pooled analysis.

- v. The correlation analysis between fruit infestation on a number basis and weather parameters revealed that maximum temperature consistently showed a highly significant negative correlation during 2023, 2024 and the pooled analysis. Rainfall and minimum temperature also exhibited moderately significant to non-significant negative correlations during 2023, 2024 and the pooled analysis. In contrast, morning relative humidity showed a highly significant positive correlation throughout, indicating a strong association between higher humidity and increased fruit infestation. Evening relative humidity and sunshine hours showed non-significant to moderately significant positive correlations, reflecting a weaker or inconsistent influence on infestation levels during the both individual years and in the pooled analysis.
- vi. The correlation analysis between fruit infestation on a weight basis and weather parameters revealed the consistent trends during 2023, 2024 and the pooled analysis. Maximum temperature exhibited a highly to moderately significant negative correlation, while minimum temperature and rainfall showed moderately significant or non-significant negative correlations, indicating that lower temperatures and rainfall are generally associated with reduced infestation levels during 2023, 2024 and the pooled analysis. In contrast, morning relative humidity showed a highly significant positive correlation, while evening relative humidity and sunshine hours showed non-significant to moderately significant positive correlations during 2023, 2024 and the pooled analysis.

5.6 Efficacy of insecticides against shoot and fruit borer

- i. The minimum mean fruit infestation on a number basis (10.06, 12.07 and 11.06%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.64, 15.19 and 13.91%), while the maximum mean fruit infestation (38.00, 40.03 and 39.02%) was recorded in T₀ (Control), followed by T₈ (32.67, 33.91 and 33.29%) during 2023, 2024 and the pooled analysis. The overall findings of per cent fruit infestation on a number basis indicated that T₇ (Cartap hydrochloride 50% SP) was recorded to be the most effective insecticidal treatment against *Leucinodes orbonalis*. The order of efficacy of eight insecticides was cartap-hydrochloride 50% SP >

deltamethrin 2.8% EC > acetamiprid 20% SP > chlorpyrifos 20% EC > triazophos 40% EC > karanj oil 1% > neem oil 1% > carbofuran 3% CG. The untreated control was found to be the least effective against percent fruit infestation caused by shoot and fruit borer in brinjal.

- ii. The minimum mean fruit infestation on a weight basis (9.69, 10.82 and 10.26%) was recorded in treatment T₇ (Cartap hydrochloride 50% SP), followed by treatment T₆ (12.17, 13.94 and 13.06%), while the maximum mean fruit infestation (36.56, 38.79 and 37.67%) was recorded in T₀ (Control), followed by T₈ (31.44, 32.67 and 32.05%) during 2023, 2024 and the pooled analysis. The overall findings of per cent fruit infestation on a weight basis indicated that T₇ (Cartap hydrochloride 50% SP) was the most effective insecticidal treatment against *Leucinodes orbonalis*. The order of efficacy of eight insecticides was: Cartap-hydrochloride 50% SP > Deltamethrin 2.8% EC > Acetamiprid 20% SP > Chlorpyrifos 20% EC > Triazophos 40% EC > Karanj oil 1% > Neem oil 1% > Carbofuran 3% CG. The untreated control was found to be the least effective against percent fruit infestation on a weight basis caused by shoot and fruit borer in brinjal.

5.7 Economics of cultivation

- i. The highest total cost of cultivation (Rs. 1,79,323.50/ha) was observed in treatment T₄ (Neem oil 1%), whereas the lowest total cost of cultivation (Rs. 1,75,086.50/ha) was recorded in T₀ (Control).
- ii. The maximum gross returns (Rs. 4,36,171.85, 4,83,487.41 and 4,59,829.63) were observed in T₇ (Cartap hydrochloride 50% SP), while the minimum (Rs. 2,52,053.33, 2,55,484.44 and 2,53,768.89) were recorded in T₀ (Control) during 2023, 2024 and the pooled analysis.
- iii. The maximum net returns (Rs. 2,60,576.88, 3,07,892.44 and 2,84,234.66) were observed in T₇ (Cartap hydrochloride 50% SP), while the minimum (Rs. 76,966.83, 80,397.94 and 78,682.39) were recorded in T₀ (Control) during 2023, 2024 and the pooled analysis.
- iv. The highest benefit-cost (B:C) ratio (1.48, 1.75, 1.62) was observed in T₇ (Cartap hydrochloride 50% SP), while the lowest B:C ratio (0.44, 0.46, 0.45) was recorded in T₀ (Control) during 2023, 2024 and the pooled analysis.

CONCLUSION

Based on the results of present investigation, it is concluded that the optimized application of treatment T₇ (Cartap hydrochloride 50% SP) enhances growth and yield characteristics of brinjal while resulting in lower persistence of pesticide residues in the fruits of brinjal at harvest. The study further revealed that the application of recommended doses of insecticidal treatments had no significant impact or only minor alterations on quality attributes. From residue perspective, no detectable pesticide residues were found in the untreated control and botanical insecticide treatments. Two botanical treatments were included in the study in response to increasing public awareness and the growing demand for pesticide-free produce; however, their efficacy was significantly lower compared to the synthetic insecticides evaluated. The order of efficacy of the eight insecticides against shoot and fruit borer infestation was as follows: Cartap-hydrochloride 50% SP > Deltamethrin 2.8% EC > Acetamiprid 20% SP > Chlorpyrifos 20% EC > Triazophos 40% EC > Karanj oil 1% > Neem oil 1% > Carbofuran 3% CG. A waiting period of 7-10 days is recommended for all the synthetic insecticidal treatments, except for treatment T₈ (Carbofuran 3% CG), which requires 15 days waiting period before harvesting brinjal. The most effective treatment in terms of benefit-cost ratio was T₇ (Cartap-hydrochloride 50% SP) followed by treatment T₆ (Deltamethrin 2.8% EC), in comparison to the treatment T₀ (Control). It is recommended that farmers avoid the indiscriminate application of insecticides and adopt judicious use practices to enhance crop productivity while ensuring environmental safety and minimizing the risk of hazardous chemical residues.

FUTURE SCOPE OF RESEARCH

The investigation was focused to examine the “Residual studies of promising pesticides in Brinjal”. Therefore, present investigation consists immense scope of future research on brinjal crop improvement and further research may be undertaken on the following aspects-

- Multilocation trial could be conducted to confirm the efficacy of the treatments.
- Different varieties of brinjal can be evaluated to determine whether similar results can be achieved.
- The same treatments could be evaluated on other fruit vegetable crops that are consumed without peeling.
- Different insecticidal treatments from various pesticide groups should be evaluated to examine their impact on the plant surface and their mechanism of action within the plant.
- Evaluation of combination of synthetic and botanical insecticides should be conducted to reduce farmer’s dependence on chemical insecticides.
- The economics of insecticide application can be studied under different agroclimatic conditions.

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Analysis of variance (ANOVA) tables

1. Analysis of variance tables for the effect of various insecticidal treatments on plant height (cm) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.097			
Treatment	8	31.751	3.969	38.865	< 0.001
Error	16	1.634	0.102		
Total	26	33.482			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.061			
Treatment	8	62.452	7.807	10,364.974	< 0.001
Error	16	0.012	0.001		
Total	26	62.525			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Treatment	8	44.954	5.619	239.505	< 0.001
Error	16	0.375	0.023		
Total	26	45.355			

2. Analysis of variance tables for the effect of various insecticidal treatments on shoot length (cm) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.076			
Treatment	8	4.313	0.539	15.627	< 0.001
Error	16	0.552	0.035		
Total	26	4.941			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.011			
Treatment	8	12.038	1.505	100.359	< 0.001
Error	16	0.240	0.015		
Total	26	12.289			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	-0.016			
Treatment	8	7.560	0.945	73.648	< 0.001
Error	16	0.205	0.013		
Total	26	7.750			

3. Analysis of variance tables for the effect of various insecticidal treatments on root length (cm) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.203			
Treatment	8	13.698	1.712	13.036	< 0.001
Error	16	2.102	0.131		
Total	26	16.003			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.066			
Treatment	8	20.426	2.553	154.800	< 0.001
Error	16	0.264	0.016		
Total	26	20.756			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.013			
Treatment	8	16.202	2.025	87.286	< 0.001
Error	16	0.371	0.023		
Total	26	16.587			

4. Analysis of variance tables for the effect of various insecticidal treatments on number of leaves of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.532			
Treatment	8	338.696	42.337	145.551	< 0.001
Error	16	4.654	0.291		
Total	26	344.882			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.355			
Treatment	8	351.270	43.909	141.873	< 0.001
Error	16	4.952	0.309		
Total	26	358.577			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.870			
Treatment	8	344.735	43.092	247.733	< 0.001
Error	16	2.783	0.174		
Total	26	349.388			

5. Analysis of variance tables for the effect of various insecticidal treatments on number of branches of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.192			
Treatment	8	239.329	29.916	133.174	< 0.001
Error	16	3.594	0.225		
Total	26	243.116			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.187			
Treatment	8	234.213	29.277	141.679	< 0.001
Error	16	3.306	0.207		
Total	26	237.706			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.166			
Treatment	8	236.715	29.589	146.102	< 0.001
Error	16	3.240	0.203		
Total	26	240.121			

6. Analysis of variance tables for the effect of various insecticidal treatments on stem diameter (cm) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.004			
Treatment	8	3.673	0.459	330.028	< 0.001
Error	16	0.022	0.001		
Total	26	3.700			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.006			
Treatment	8	3.492	0.436	477.245	< 0.001
Error	16	0.015	0.001		
Total	26	3.512			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.005			
Treatment	8	3.579	0.447	628.427	< 0.001
Error	16	0.011	0.001		
Total	26	3.595			

7. Analysis of variance tables for the effect of various insecticidal treatments on days to flower initiation of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.392			
Treatment	8	5.075	0.634	0.596	0.767
Error	16	17.021	1.064		
Total	26	26.488			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.582			
Treatment	8	9.300	1.163	2.081	0.101
Error	16	8.937	0.559		
Total	26	20.819			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.919			
Treatment	8	6.682	0.835	1.468	0.244
Error	16	9.101	0.569		
Total	26	18.701			

8. Analysis of variance tables for the effect of various insecticidal treatments on days to 50% flowering of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.209			
Treatment	8	6.318	0.790	0.650	0.726
Error	16	19.431	1.214		
Total	26	30.958			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.238			
Treatment	8	6.480	0.810	0.755	0.645
Error	16	17.163	1.073		
Total	26	28.881			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.220			
Treatment	8	6.338	0.792	0.700	0.687
Error	16	18.107	1.132		
Total	26	29.665			

9. Analysis of variance tables for the effect of various insecticidal treatments on number of flowers per plant of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.249			
Treatment	8	53.333	6.667	91.595	< 0.001
Error	16	1.165	0.073		
Total	26	54.747			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.501			
Treatment	8	57.745	7.218	77.032	< 0.001
Error	16	1.499	0.094		
Total	26	59.745			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.357			
Treatment	8	55.421	6.928	104.890	< 0.001
Error	16	1.057	0.066		
Total	26	56.834			

10. Analysis of variance tables for the effect of various insecticidal treatments on days to fruit formation of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.209			
Treatment	8	6.317	0.790	0.650	0.726
Error	16	19.432	1.214		
Total	26	30.957			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.239			
Treatment	8	6.480	0.810	0.755	0.645
Error	16	17.162	1.073		
Total	26	28.881			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.237			
Treatment	8	6.352	0.794	0.702	8
Error	16	18.090	1.131		16
Total	26	29.679			

11. Analysis of variance tables for the effect of various insecticidal treatments on days to first harvesting of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.204			
Treatment	8	5.953	0.744	0.688	0.697
Error	16	17.307	1.082		
Total	26	28.465			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.113			
Treatment	8	6.372	0.796	0.823	0.594
Error	16	15.485	0.968		
Total	26	25.970			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.639			
Treatment	8	6.133	0.767	0.782	0.625
Error	16	15.676	0.980		
Total	26	26.449			

12. Analysis of variance tables for the effect of various insecticidal treatments on leaf area (cm²) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.134			
Treatment	8	317.178	39.647	232.465	< 0.001
Error	16	2.729	0.171		
Total	26	320.041			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.742			
Treatment	8	327.641	40.955	131.371	< 0.001
Error	16	4.988	0.312		
Total	26	334.371			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.497			
Treatment	8	320.375	40.047	257.503	< 0.001
Error	16	2.488	0.156		
Total	26	323.360			

13. Analysis of variance tables for the effect of various insecticidal treatments leaf area index of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.001			
Treatment	8	0.236	0.030	270.134	< 0.001
Error	16	0.002	0.000		
Total	26	0.239			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.001			
Treatment	8	0.230	0.029	205.312	< 0.001
Error	16	0.002	0.000		
Total	26	0.233			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.001			
Treatment	8	0.232	0.029	380.906	< 0.001
Error	16	0.001	0.000		
Total	26	0.234			

14. Analysis of variance tables for the effect of various insecticidal treatments on number of shoot damage of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.127			
Treatment	8	9.736	1.217	172.951	< 0.001
Error	16	0.113	0.007		
Total	26	9.976			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.199			
Treatment	8	20.954	2.619	136.022	< 0.001
Error	16	0.308	0.019		
Total	26	21.461			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.161			
Treatment	8	14.679	1.835	404.483	< 0.001
Error	16	0.073	0.005		
Total	26	14.912			

15. Analysis of variance tables for the effect of various insecticidal treatments on incidence of shoot borer (%) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.973			
Treatment	8	1,320.379	165.047	296.034	< 0.001
Error	16	8.920	0.558		
Total	26	1,334.272			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	12.440			
Treatment	8	2,873.539	359.192	270.114	< 0.001
Error	16	21.276	1.330		
Total	26	2,907.256			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.181			
Treatment	8	2,014.363	251.795	511.304	< 0.001
Error	16	7.879	0.492		
Total	26	2,030.423			

16. Analysis of variance tables for the effect of various insecticidal treatments on number of fruits per plant of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.483			
Treatment	8	22.536	2.817	80.908	< 0.001
Error	16	0.557	0.035		
Total	26	23.576			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.303			
Treatment	8	26.110	3.264	83.736	< 0.001
Error	16	0.624	0.039		
Total	26	27.036			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.386			
Treatment	8	24.200	3.025	111.031	< 0.001
Error	16	0.436	0.027		
Total	26	25.021			

17. Analysis of variance tables for the effect of various insecticidal treatments on fruit length (cm) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.816			
Treatment	8	83.346	10.418	107.825	< 0.001
Error	16	1.546	0.097		
Total	26	86.708			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.009			
Treatment	8	85.851	10.731	79.450	< 0.001
Error	16	2.161	0.135		
Total	26	90.021			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.910			
Treatment	8	84.578	10.572	95.457	< 0.001
Error	16	1.772	0.111		
Total	26	88.260			

18. Analysis of variance tables for the effect of various insecticidal treatments on fruit width (cm) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.145			
Treatment	8	33.547	4.193	94.915	< 0.001
Error	16	0.707	0.044		
Total	26	34.399			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.120			
Treatment	8	34.273	4.284	89.696	< 0.001
Error	16	0.764	0.048		
Total	26	35.158			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.129			
Treatment	8	33.850	4.231	94.842	< 0.001
Error	16	0.714	0.045		
Total	26	34.693			

19. Analysis of variance tables for the effect of various insecticidal treatments on fruit yield per plant (kg) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.010			
Treatment	8	0.469	0.059	87.505	< 0.001
Error	16	0.011	0.001		
Total	26	0.489			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.006			
Treatment	8	0.529	0.066	90.240	< 0.001
Error	16	0.012	0.001		
Total	26	0.547			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.007			
Treatment	8	0.504	0.063	129.943	< 0.001
Error	16	0.008	0.000		
Total	26	0.518			

20. Analysis of variance tables for the effect of various insecticidal treatments on fruit yield per plot (kg) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.729			
Treatment	8	423.791	52.974	88.071	< 0.001
Error	16	9.624	0.601		
Total	26	442.144			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.695			
Treatment	8	481.731	60.216	91.099	< 0.001
Error	16	10.576	0.661		
Total	26	498.002			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.061			
Treatment	8	450.542	56.318	121.242	< 0.001
Error	16	7.432	0.465		
Total	26	465.036			

21. Analysis of variance tables for the effect of various insecticidal treatments on yield per hectare (t) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	13.298			
Treatment	8	645.989	80.749	88.244	< 0.001
Error	16	14.641	0.915		
Total	26	673.928			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.658			
Treatment	8	734.308	91.788	90.856	< 0.001
Error	16	16.164	1.010		
Total	26	759.130			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	10.788			
Treatment	8	687.006	85.876	121.672	< 0.001
Error	16	11.293	0.706		
Total	26	709.087			

22. Analysis of variance tables for the effect of various insecticidal treatments on yield increase over control per hectare (%) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	606.521			
Treatment	8	14,680.822	1,835.103	85.214	< 0.001
Error	16	344.565	21.535		
Total	26	15,631.907			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	744.716			
Treatment	8	22,295.866	2,786.983	65.651	< 0.001
Error	16	679.220	42.451		
Total	26	23,719.802			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	60.922			
Treatment	8	18,227.022	2,278.378	111.280	< 0.001
Error	16	327.590	20.474		
Total	26	18,615.533			

23. Analysis of variance tables for the effect of various insecticidal treatments on total soluble solids (°Brix) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.055			
Treatment	8	0.129	0.016	1.480	0.240
Error	16	0.174	0.011		
Total	26	0.358			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.104			
Treatment	8	0.602	0.075	2.545	0.053
Error	16	0.473	0.030		
Total	26	1.179			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.071			
Treatment	8	0.214	0.027	1.910	0.129
Error	16	0.224	0.014		
Total	26	0.510			

24. Analysis of variance tables for the effect of various insecticidal treatments on titratable acidity (%) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.006			
Treatment	8	0.103	0.013	2.489	0.057
Error	16	0.083	0.005		
Total	26	0.192			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.041			
Treatment	8	0.346	0.043	2.567	0.052
Error	16	0.270	0.017		
Total	26	0.657			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.020			
Treatment	8	0.143	0.018	2.191	0.087
Error	16	0.130	0.008		
Total	26	0.293			

25. Analysis of variance tables for the effect of various insecticidal treatments on crude protein (%) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.028			
Treatment	8	0.196	0.025	1.446	0.252
Error	16	0.272	0.017		
Total	26	0.497			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.013			
Treatment	8	0.635	0.079	2.011	0.112
Error	16	0.632	0.039		
Total	26	1.280			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.021			
Treatment	8	0.318	0.040	1.808	0.149
Error	16	0.352	0.022		
Total	26	0.691			

26. Analysis of variance tables for the effect of various insecticidal treatments on chlorophyll index of leaves (SPAD-502) of brinjal during 2023, 2024 and the pooled analysis

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.275			
Treatment	8	4.676	0.585	0.577	0.783
Error	16	16.221	1.014		
Total	26	26.172			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.273			
Treatment	8	4.691	0.586	0.585	0.776
Error	16	16.026	1.002		
Total	26	23.990			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.716			
Treatment	8	3.993	0.499	0.692	0.694
Error	16	11.540	0.721		
Total	26	17.249			

27. Analysis of variance tables for the effect of various insecticidal treatments on fruit infestation of brinjal on number basis during 2023, 2024 and the pooled analysis

Spray-1

One day before spray

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.945			
Treatment	8	5.401	0.675	0.680	0.703
Error	16	15.875	0.992		
Total	26	26.221			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.188			
Treatment	8	4.720	0.590	0.562	0.794
Error	16	16.805	1.050		
Total	26	26.713			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.066			
Treatment	8	5.051	0.631	0.619	0.750
Error	16	16.320	1.020		
Total	26	26.437			

1 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	46.803			
Treatment	8	1,820.568	227.571	791.815	< 0.001
Error	16	4.598	0.287		
Total	26	1,871.970			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.256			
Treatment	8	1,114.140	139.267	114.990	< 0.001
Error	16	19.378	1.211		
Total	26	1,140.774			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.061			
Treatment	8	1,421.430	177.679	420.996	< 0.001
Error	16	6.753	0.422		
Total	26	1,433.244			

3 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	29.546			
Treatment	8	3,242.472	405.309	1,028.113	< 0.001
Error	16	6.308	0.394		
Total	26	3,278.326			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.002			
Treatment	8	1,944.319	243.040	592.986	< 0.001
Error	16	6.558	0.410		
Total	26	1,953.879			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	11.688			
Treatment	8	2,543.478	317.935	1,966.666	< 0.001
Error	16	2.587	0.162		
Total	26	2,557.753			

5 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.282			
Treatment	8	1,911.421	238.928	256.044	< 0.001
Error	16	14.930	0.933		
Total	26	1,927.633			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.282			
Treatment	8	1,911.421	238.928	256.044	< 0.001
Error	16	14.930	0.933		
Total	26	1,927.633			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.146			
Treatment	8	1,564.211	195.526	399.794	< 0.001
Error	16	7.825	0.489		
Total	26	1,572.182			

7 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.313			
Treatment	8	2,045.975	255.747	219.367	< 0.001
Error	16	18.653	1.166		
Total	26	2,065.941			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	41.716			
Treatment	8	1,942.170	242.771	122.754	< 0.001
Error	16	31.643	1.978		
Total	26	2,015.529			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.758			
Treatment	8	2,633.112	329.139	327.704	< 0.001
Error	16	16.070	1.004		
Total	26	2,652.940			

10 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	57.236			
Treatment	8	1,732.568	216.571	440.024	
Error	16	7.875	0.492		
Total	26	1,797.679			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	57.236			
Treatment	8	1,732.568	216.571	440.024	
Error	16	7.875	0.492		
Total	26	1,797.679			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	10.662			
Treatment	8	1,726.606	215.826	662.761	< 0.001
Error	16	5.210	0.326		
Total	26	1,742.478			

14 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.069			
Treatment	8	1,272.304	159.038	112.002	< 0.001
Error	16	22.719	1.420		
Total	26	1,298.093			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	38.756			
Treatment	8	1,575.974	196.997	319.453	< 0.001
Error	16	9.867	0.617		
Total	26	1,624.597			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	15.893			
Treatment	8	1,413.693	176.712	288.240	< 0.001
Error	16	9.809	0.613		
Total	26	1,439.396			

Spray-2
1DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.982			
Treatment	8	2,878.186	359.773	490.264	< 0.001
Error	16	11.741	0.734		
Total	26	2,896.909			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	45.793			
Treatment	8	2,574.249	321.781	37,195.617	
Error	16	0.138	0.009		
Total	26	2,620.181			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.255			
Treatment	8	2,698.211	337.276	1,774.018	< 0.001
Error	16	3.042	0.190		
Total	26	2,705.508			

3 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.270			
Treatment	8	3,763.549	470.444	389.589	< 0.001
Error	16	19.321	1.208		
Total	26	3,783.140			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	37.228			
Treatment	8	3,778.131	472.266	2,396.556	
Error	16	3.153	0.197		
Total	26	3,818.512			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	10.618			
Treatment	8	3,746.939	468.367	1,350.233	
Error	16	5.550	0.347		
Total	26	3,763.106			

5 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.696			
Treatment	8	2,361.835	295.229	276.948	< 0.001
Error	16	17.056	1.066		
Total	26	2,381.587			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	43.481			
Treatment	8	2,949.551	368.694	4,528.921	< 0.001
Error	16	1.303	0.081		
Total	26	2,994.334			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	16.801			
Treatment	8	2,608.256	326.032	1,249.585	< 0.001
Error	16	4.175	0.261		
Total	26	2,629.232			

7 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.357			
Treatment	8	2,400.694	300.087	271.294	< 0.001
Error	16	17.698	1.106		
Total	26	2,418.749			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	11.665			
Treatment	8	2,916.481	364.560	285.295	< 0.001
Error	16	20.445	1.278		
Total	26	2,948.592			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.758			
Treatment	8	2,633.112	329.139	327.704	< 0.001
Error	16	16.070	1.004		
Total	26	2,652.940			

10 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.146			
Treatment	8	2,515.054	314.382	220.027	< 0.001
Error	16	22.861	1.429		
Total	26	2,539.061			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	60.076			
Treatment	8	2,979.847	372.481	3,083.296	< 0.001
Error	16	1.933	0.121		
Total	26	3,041.856			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	11.386			
Treatment	8	2,730.778	341.347	1,040.388	< 0.001
Error	16	5.250	0.328		
Total	26	2,747.414			

14 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.154			
Treatment	8	2,551.160	318.895	265.208	< 0.001
Error	16	19.239	1.202		
Total	26	2,574.553			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	65.731			
Treatment	8	2,960.262	370.033	8,468.249	< 0.001
Error	16	0.699	0.044		
Total	26	3,026.691			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	9.434			
Treatment	8	2,736.846	342.106	1,041.755	< 0.001
Error	16	5.254	0.328		
Total	26	2,751.535			

28. Analysis of variance tables for the effect of various insecticidal treatments on fruit infestation of brinjal on weight basis during 2023, 2024 and the pooled analysis

Spray-1

One day before spray

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.931			
Treatment	8	5.315	0.664	0.621	0.748
Error	16	17.110	1.069		
Total	26	26.356			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.000			
Treatment	8	5.427	0.678	0.653	0.724
Error	16	16.633	1.040		
Total	26	26.060			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.964			
Treatment	8	5.364	0.670	0.636	0.737
Error	16	16.856	1.054		
Total	26	26.184			

1DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	75.644			
Treatment	8	1,127.490	140.936	5,320.151	
Error	16	0.424	0.026		
Total	26	1,203.558			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	72.205			
Treatment	8	1,742.466	217.808	2,198.994	
Error	16	1.585	0.099		
Total	26	1,816.255			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	73.818			
Treatment	8	1,397.192	174.649	6,159.641	
Error	16	0.454	0.028		
Total	26	1,471.464			

3 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	78.283			
Treatment	8	3,075.009	384.376	1,694.537	< 0.001
Error	16	3.629	0.227		
Total	26	3,156.920			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.198			
Treatment	8	1,943.967	242.996	155.942	< 0.001
Error	16	24.932	1.558		
Total	26	1,976.097			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	11.250			
Treatment	8	2,468.867	308.608	598.277	< 0.001
Error	16	8.253	0.516		
Total	26	2,488.370			

5 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	72.939			
Treatment	8	1,747.576	218.447	3,351.654	< 0.001
Error	16	1.043	0.065		
Total	26	1,821.558			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.524			
Treatment	8	1,280.918	160.115	76.601	< 0.001
Error	16	33.444	2.090		
Total	26	1,314.886			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	15.293			
Treatment	8	1,492.106	186.513	330.639	< 0.001
Error	16	9.026	0.564		
Total	26	1,516.425			

7 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	20.766			
Treatment	8	1,956.717	244.590	446.195	< 0.001
Error	16	8.771	0.548		
Total	26	1,986.254			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	74.102				
Treatment	2,005.453	250.682	3,665.347	< 0.001	2,005.453
Error	1.094	0.068			1.094
Total	2,080.650				

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.337			
Treatment	8	1,936.581	242.073	118.232	< 0.001
Error	16	32.759	2.047		
Total	26	1,969.677			

10 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	25.506			
Treatment	8	1,698.452	212.306	452.910	< 0.001
Error	16	7.500	0.469		
Total	26	1,731.458			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.214			
Treatment	8	1,736.733	217.092	115.233	< 0.001
Error	16	30.143	1.884		
Total	26	1,769.090			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	25.506			
Treatment	8	1,698.452	212.306	452.910	< 0.001
Error	16	7.500	0.469		
Total	26	1,731.458			

14 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	75.766			
Treatment	8	1,247.182	155.898	2,611.031	< 0.001
Error	16	0.955	0.060		
Total	26	1,323.904			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	35.664			
Treatment	8	1,593.338	199.167	1,369.877	< 0.001
Error	16	2.326	0.145		
Total	26	1,631.328			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.659			
Treatment	8	1,408.288	176.036	3,275.951	8
Error	16	0.860	0.054		16
Total	26	1,411.807			

Spray-2

1 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	27.417			
Treatment	8	2,802.737	350.342	291.367	< 0.001
Error	16	19.239	1.202		
Total	26	2,849.393			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.038			
Treatment	8	2,588.193	323.524	231.963	< 0.001
Error	16	22.316	1.395		
Total	26	2,612.546			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.874			
Treatment	8	2,665.943	333.243	375.884	< 0.001
Error	16	14.185	0.887		
Total	26	2,686.002			

3 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.416			
Treatment	8	3,575.351	446.919	149.659	< 0.001
Error	16	47.780	2.986		
Total	26	3,624.547			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.396			
Treatment	8	3,798.522	474.815	283.145	< 0.001
Error	16	26.831	1.677		
Total	26	3,828.748			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.226			
Treatment	8	3,661.034	457.629	1,318.587	8
Error	16	5.553	0.347		16
Total	26	3,668.813			

5 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.107			
Treatment	8	2,111.559	263.945	277.364	8
Error	16	15.226	0.952		16
Total	26	2,134.892			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.304			
Treatment	8	2,949.384	368.673	259.937	< 0.001
Error	16	22.693	1.418		
Total	26	2,973.381			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.627			
Treatment	8	2,483.761	310.470	469.618	8
Error	16	10.578	0.661		16
Total	26	2,497.966			

7 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.538			
Treatment	8	2,234.390	279.299	216.253	< 0.001
Error	16	20.665	1.292		
Total	26	2,255.592			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.827			
Treatment	8	2,916.588	364.574	224.091	< 0.001
Error	16	26.030	1.627		
Total	26	2,947.446			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.962			
Treatment	8	2,544.735	318.092	317.229	< 0.001
Error	16	16.044	1.003		
Total	26	2,562.740			

10 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	9.311			
Treatment	8	2,022.949	252.869	206.609	< 0.001
Error	16	19.582	1.224		
Total	26	2,051.843			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.835			
Treatment	8	2,995.046	374.381	161.625	< 0.001
Error	16	37.062	2.316		
Total	26	3,035.942			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.835			
Treatment	8	2,995.046	374.381	161.625	< 0.001
Error	16	37.062	2.316		
Total	26	3,035.942			

14 DAS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.195			
Treatment	8	2,632.240	329.030	815.196	< 0.001
Error	16	6.458	0.404		
Total	26	2,639.893			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.359			
Treatment	8	2,982.642	372.830	204.358	< 0.001
Error	16	29.190	1.824		
Total	26	3,018.192			

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.195			
Treatment	8	2,632.240	329.030	815.196	< 0.001
Error	16	6.458	0.404		
Total	26	2,639.893			

CURRICULUM VITAE

Title of Ph.D. Thesis: “Residual studies of promising pesticides in Brinjal”

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Academic Record

Examination	Name of Board/University	Subject	Year of Passing	Result
High School	CBSE	English, Hindi, Mathematics, Science, Social Science, IT	2014	First division (70%)
Intermediate	CBSE	English, Physical Education, Physics, Chemistry, Mathematics	2016	First division (61.40%)
B.Sc. Agriculture Honours	Chandigarh University, Mohali	Agriculture	2020	First division (75.10%)
M.Sc. Horticulture	Lovely Professional University, Phagwara	Vegetable Science	2022	First division (79.80%)

List of Publications

S. No.	Category	Title	Journal/publisher	Indexing	Status (Year)
Paper and Book Chapter					
1.	Research paper	Dissipation Dynamics of Various Insecticides and Their Impact on the Quality Attributes of Brinjal	Journal of food chemistry and Nanotechnology	Q4: Scopus	Published (2024)
2.	Research paper	Effect on the Physicochemical and Nutritional Properties of Cookies with the Incorporation of Beetroot Grown with the Application of Poultry Manure	Journal of food chemistry and Nanotechnology	Q4: Scopus	Published (2024)
3.	Research paper	Effect of Different Seed Priming Treatments on Seed Germination and Seedling Vigor of Okra (<i>Abelmoschus esculentus</i> L. var. Punjab Suhawani)	Journal of food chemistry and Nanotechnology	Q4: Scopus	Published (2024)
Presentation in International Conferences					
5.	Oral presentation	Impact of insecticide applications on yield and residual effects on biochemical properties of brinjal (<i>Solanum melongena</i> L.)	International Conference on Recent Trends in Smart and Sustainable Agriculture for Food and Nutritional Security	Lovely Professional University (LPU) in Punjab, India on September 27th and 28th, 2024	Delivered (2024)

6.	Oral presentation	Quantitative analysis of synthetic pesticides residues in soil sample from brinjal field using HPLC	7th International Conference on Advances in Agriculture Technology and Allied Sciences (ICAATAS 2024)	TNU-The Neotia University, West Bengal (ICAR ACCREDITED) on Sept 15-16, 2024	Delivered (2024)
Award					
7.	Oral Presentation Award	Effect of Different Seed Priming Treatments on Seed Germination and Seedling Vigor of Okra (<i>Abelmoschus esculentus</i> L. var. Punjab Suhawani)	International Conference on Recent Trends in Smart and Sustainable Agriculture for Food and Nutritional Security	Lovely Professional University (LPU) in Punjab, India on November 22nd and 23rd, 2023	Second Prize (2023)
Patent/Copyright					
8.	Copyright	Positive impact of seed priming on yield of Okra	Registration number: L-161489/2025 Lovely Professional University, Phagwara, Punjab - India -144411 (Granted)		

Work Experience:

- One month's work experience at the HPMC, Jarol, Mandi, (H.P.)
- Marketing and sales experience under Soga Enterprises Nurpur, Kangra (H.P.)

Declaration

I hereby declare that the information is true to the best of my knowledge.

Date and Place: 04-08-2025 & Jalandhar, Punjab

Vishal Thakur