

**DESIGNING SUSTAINABLE, ECO-FRIENDLY APPROACHES FOR
MANAGEMENT OF MAJOR ARTHROPOD PESTS OF BRINJAL
(*Solanum Melongena* L.) WITH EMPHASIS ON HOST PLANTS
INNATE AND INDUCED RESISTANCE**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

In

Entomology

By

Sonawane Bhushan Laxman

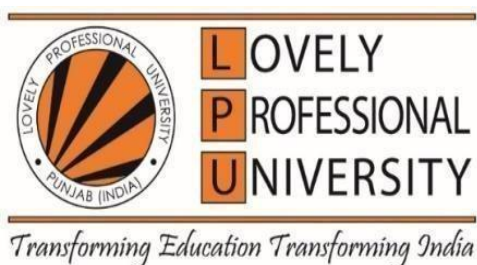
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DECLARATION

I, hereby declared that the presented work in the thesis entitled “**Designing sustainable, eco-friendly approaches for management of major arthropod pests of brinjal (*Solanum melongena* L.) with emphasis on host plants innate and induced resistance**” submitted for **DOCTOR OF PHILOSOPHY IN AGRICULTURE (ENTOMOLOGY)** to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.

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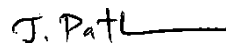
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CERTIFICATE I

This is to certify that the thesis entitled, “**Designing sustainable, eco-friendly approaches for management of major arthropod pests of brinjal (*Solanum melongena* L.) with emphasis on host plants innate and induced resistance**” submitted in fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **AGRICULTURE (ENTOMOLOGY)** embodies the results of a piece of bonafide research carried out by **Sonawane Bhushan Laxman (Registration No. 12008606)**, under my guidance and supervision. To the best of my knowledge, the present work is the result of original investigation and study. No part of this thesis has ever been submitted for any other degree, diploma or equivalent course.

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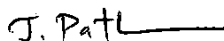
CERTIFICATE II

This is to certify that the thesis entitled “**Designing sustainable, eco-friendly approaches for management of major arthropod pests of brinjal (*Solanum melongena* L.) with emphasis on host plants innate and induced resistance**” submitted by **Sonawane Bhushan Laxman (Registration no. 12008606)** to Lovely Professional University, Phagwara, Punjab in partial fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **AGRICULTURAL (ENTOMOLOGY)** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an external examiner.



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LIST OF ABBREVIATIONS AND SYMBOLS USED

Abbreviated Form	Full Form	Abbreviated Form	Full Form
%	Percentage	Min. Temp.	Minimum Temperature
ANOVA	Analysis of Variance	Max. Temp.	Maximum Temperature
DAT	Day After Treatment	RH	Relative Humidity
Sp.	Species	RH (M)	Relative Humidity (Morning)
etc.	Et cetera	RH (E)	Relative Humidity (Evening)
Fig.	Figure	R	Rainfall
gm	Gram	SMW	Standard Meteorological Week
Sq.mt	Square Meter	SD	Standard Deviation of the mean
mg	milligram	ETL	Economic Threshold Level
ml	Milliliter	DMRT	Duncan's New Multiple Range Test
Kg	Kilo Gram	CRD	Completely Randomized Design
@	at the rate of	RBD	Randomized Block Design
±	Plus-Minus Sign	SPSS	Statistical Package for Social Sciences
°C	Degree Celsius		
<i>et al.</i> ,	and others		

LIST OF ANNEXURES

Annexure 1	Detailed data of weather forecasting <i>Rabi</i> season, 2022
Annexure 2	Detailed data of weather forecasting <i>Kharif</i> season, 2023

Abstract

Brinjal (*Solanum melongena* L.) is a valuable vegetable crop in subtropical and tropical areas of India and several insect pests are known to cause economic losses. To avoid losses, we focused on “Designing sustainable, eco-friendly approaches for management for major arthropods pests of brinjal (*Solanum melongena* L.) with emphasis on host plants innate and induced resistance” in 2020-21. The current study indicated that the NBH-214, Ajay, and MAHY-91 brinjal varieties were resistant to hadda beetle (*Henosepilachna vigintioctopunctata*), shoot and fruit borer (*Leucinodes orbonalis*), jassid (*Amrasca biguttula biguttula*), and whitefly (*Bemisia tabaci*). However, these varieties developed resistance because to the high levels of Phenol, Proline, Peroxidase, and PAL. Along with the morphological characteristics such as green color with white and purple stripes on the fruit, thorns on the leaf and calyx, and non-glandular trichomes were detected in the resistant variety.

During the *Rabi* and *Kharif* seasons, the foliar application of Spinosad 45% SC @ 0.4 l/lit resulted in the highest mortality of test insect pests, followed by NSKE 1% @ 2 ml/lit and *Metarhizium anisopliae* (1×10^8 conidia/ml) @ 10 ml/l. However, the application of salicylic acid @ 50mg/lit and Jasmonic acid @ 100 mg/lit was triggering the plant defensive mechanism and developed resistance against jassid and whitefly during both the seasons. However, Jasmonic acid @ 100 mg/lit and Panchagavya @ 5% solution also observed less population against shoot and fruit borer and hadda beetle during the both seasons. These elicitors significantly increased the amount of phenol content ranged between 98.06 to 105.56 mg/100g, proline content ranged between 3.81 to 4.89 μ M/g, Peroxidase content ranged between 1.21 to 1.31 μ M/min/g protein and PAL ranged between 31.74 to 38.79 μ M/ cinnamic acid/min/g. Therefore, the result obtained from the research will help to develop sustainable pest management module where selection of resistance variety like NBH-214, Ajay and MAHY-91, then apply the elicitor like Jasmonic acid @ 100 mg/lit and Panchagavya @ 5% solution and salicylic acid @ 50mg/lit for developing resistance and at last apply the biorational pesticides like NSKE 1% @ 2 ml/lit and *Metarhizium anisopliae* (1×10^8 conidia/ml) @ 10 ml/l and then Spinosad 45% SC @ 0.4 ml/lit to minimize pest population which include in integrated pest management strategy for brinjal pest.

Keywords: Arthropod Complex; HPR; Biopesticides, Elicitors, Pest Management and Brinjal

Brinjal, *Solanum melongena* L., referred as ‘eggplant’ or ‘aubergine’ is an important vegetable of both tropics and sub-tropics region. It is also referred as “King of Vegetables” due to its popularity in Indian cuisine (Choudhary and Gaur, 2009) belong to Solanaceous family (Gopalan *et al.*, 2007). However, China is leading for vegetable production followed by India. It’s a crop of Indo-Burmese origin as evidenced by the morphological and isoenzyme diversity in Indian germplasms and has been reported from India 4000 years ago (Issiki *et al.*, 1994; Ansari and Singh., 2014). Three sub varieties namely *esculentum* (large, round or egg-shaped fruits), *serpentinum* (slender, long fruits) and var. *depressum* (dwarf varieties) are commonly grown in all parts of India (Choudhury., 1976). Later it spread through trade and gained popularity in other Asian, African, European and American countries (Harish *et al.*, 2011; Channe *et al.*, 2013). This particular crop is well-suited for cultivation across all regions of India. In 2022, the cultivated area for brinjal production nationwide was 753 hectares, yielding a total production of 13,023 metric tons. Punjab, with a total area of 300.40 hectares dedicated to vegetable production, contributed significantly to the brinjal output, producing 5,971.46 metric tons. However, in terms of brinjal production, West Bengal emerged as the leading producer, with approximately 1.69 lakh hectares (4.18 lakh acres) under cultivation, while Punjab ranked 16th with a share ranging from 0.81% to 0.86% of the total brinjal cultivation area (Agricultural Statistics at a Glance., 2022).

Brinjal crop is damaged by numerous insects and pests from sowing till harvest including borers, sucking pest and non-insect pest. Numerous insects and pests are threat to brinjal cultivation from seedling to harvest and the quality and quantity will impact by insect-pest and diseases. The most damaging pests under Indian conditions include brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee); fruit borer (*Helicoverpa armigera* Hubner); leaf roller (*Antoba=Eublemma olivaceae* Walker); epilachna beetle (*Henosepilachna vigintipunctata* Fabricius); stem borer (*Euzophera pericella* Ragonotl); flea beetle (*Monolepta signata* Olive); leafhopper (*Amrasca biguttula biguttula* Ishida); thrips (*Thrips palmi*), aphids (*Aphis gossypii* Glover); lacewing bug (*Urentius hystricellus* Distant); white fly (*Bemisia tabaci* Gennadius); papaya mealybug

(*Paracoccus marginatus* Williams) and red spider mite (*Tetranychus macfarlanei* Baker) were found to be major pests under Indian conditions leading to an alarmingly high yield loss of 70-90 per cent if not managed (Subbaratnam and Butani, 1982; Jagginavar *et al.*, 2009; Chakraborti and Sarkar, 2011; Anjali *et al.*, 2012; Borkakati *et al.*, 2019). The range of insect pests affecting brinjal cultivation includes sucking pest having four species of insects as jassid, aphid, whitefly and tingid bugs. Additionally, brinjal is susceptible to infestation by the shoot and fruit borer as well as the hadda beetle. Despite these challenges, the brinjal ecosystem also hosts natural enemy complex, which includes green lacewing, *Chrysoperla carnea*; coccinellid beetles *Adalia bipunctata*, *Brumoides* spp., *Coccinella transversalis*, *Harmonia dimidiata* and *Cheilomenes propinqua*; syrphid fly, *Episyrphus balteatus*; spiders, *Oxyopes* sp., and parasitoids *Tetrastichus* sp. and *P. foveolatus* (Kumar *et al.*, 2018a; Borkakati *et al.*, 2019).

The occurrence of major pests of brinjal damaging at different infestation level was noted such as jassids (*Amrasca biguttula biguttula*) moderately at 37.55% damage, whiteflies (*Bemisia tabaci*) at 42.5%, and mealy bug (*Paracoccus marginatus*) at 47.5% high damage level while thrips (*Thrips palmi*) found with low 10% damage, aphids (*Aphis gossypii*) at high damage with 40% level, hadda beetle (*Epilachna vigintioctopunctata*) have 32.5% moderately damage and shoot and fruit borer (*Leucinodes orbonalis*) at high infestation with 49.95% level (Thokchom *et. al*, 2022). Among them *L. orbanalis* infestation occurred throughout the cropping period but the severity of infestation upto 95% yield loss during the rainy season (Abrol and Singh 2003; Kaur *et al.*, 2014) and sucking pests can lead upto 10-15 per cent yield loss based on severity of infestation (Munde *et al.*, 2011). This may even increase in endemic areas with risk of viral diseases, as hemipterans are efficient vectors in transmitting phytopathogens (Chatterjee *et al.*, 2018). Though brinjal is grown throughout the year in many places, understanding the severity of pests and population build up with regard to the existing climatic conditions is a crucial aspect of pest management. The population dynamics of insects is indeed shaped by a multitude of factors, including climatic conditions and host plant availability which are influenced by genotype and environmental factors. This understanding has been supported by several studies, including those by (Raina and Yadav, 2018; Bharat *et al.*, 2019).

The pest management practices totally depend on chemical applications due to easy availability and knockdown effect on pest. To reduce pest infestation farmers resort to constant application of synthetic pesticides which though may give a short-term relief but pose a significant threat to the environment as well as non-targets including natural enemies and pollinators, disrupting the ecological balance and reducing sustainability. The pesticide residues alarmingly contained pesticide 40-450 times than MRL in brinjal crop which reported for India and Bangladesh during study (Srinivasan, 2008; Latif *et al.*, 2010; Kariyanna *et al.*, 2020). Due to overused of pesticides, *Leucinodes orbanalis* has developed resistance in commonly used insecticides like flubendiamide, cyantraniliprole and chlorantraniliprole (Kodandaram *et al.*, 2017; Shirale *et al.*, 2017). Kodandaram *et al.*, (2015) reported the side effects of synthetic pesticides and emphasized the search and inclusion of newer, biorational and cheaper molecules in integrated pest management programs.

Biopesticides like Spinosad, neem seed kernel extract, and entomopathogenic fungi have demonstrated efficacy in managing pests in brinjal cultivation owing to their distinctive modes of action. Elicitors like Jasmonic acid, Salicylic acid, Panchagavya, Acetic acid and Vermicompost increase the production and accumulation of secondary metabolites or the generation of new substances in plants by promoting stress responses. Yang *et al.*, (2013) documented that treatment with jasmonic acid (JA) significantly prevented damaged of growth and development *Helicoverpa armigera*. Additionally, Bruessow *et al.*, (2010) reported that salicylic acid (SA) can accumulate at oviposition sites, with larval feeding further intensifying this accumulation, as observed by Lortzing *et al.*, (2019).

Furthermore, researchers observed repellent and deterrent feeding activity due to application of panchagavya against Diamond backmoth, Hadda beetle, Tobacco cutworm and Ground hopper with varying concentrations (Chandrashekharaiyah, *et al.*, 2015; Senthilkumar *et al.*, 2015; Sathya *et al.*, 2019). Arancon *et al.*, (2005) demonstrated that the application of vermicompost to soilless potting media reduced populations of aphids and mealybugs on peppers, as well as mealybugs on tomatoes.

Apart from using plant protection agents identifying the host plant's ability to resist pests and trying to use them as parent lines in breeding could help us tap the plants innate ability to resist pest and use these resistant varieties which can drastically reduce the requirement for insecticides. The lot of brinjal breeding programs are being carried out to address biotic and abiotic stress tolerance as well as improve consumer preference by improving the morphological and biochemical traits of the cultivars. Also screening eco-friendly molecules that can induce resistance by activating defense related pathways can help in designing effective, eco-friendly pest management approaches.

1.2 Objectives

1. To screen various brinjal cultivars for identification of cultivars resistant to major arthropod pests of brinjal and to study seasonal incidence of brinjal pests and their natural enemies.
2. To screen biorational pesticides for management of major pests of brinjal.
3. To evaluate the efficacy of exogenous application of eco-friendly molecules eliciting host plant resistance in managing major pests of brinjal.

The research literature relevant to the current study “**Designing sustainable, eco- friendly approaches for management of major arthropod pests of brinjal (*Solanum melongena* L.) with emphasis on host plants innate and induced resistance**” has been reviewed under following:

2.1 Development and Screening of resistant varieties against the major pests which affects brinjal

- 2.1.1 Development of resistance based on morphological characters
- 2.1.2 Development of resistance based on biochemical characters
- 2.1.3 Population dynamics of major pest and associated natural enemies and its relation with environmental factors

2.2 Impact of biorational pesticides for management of major pests of brinjal

- 2.2.1 Impact of Spinosad on pest and their natural enemies
 - 2.2.1.1 Mode of action of Spinosad
- 2.2.2 Impact of Entomopathogens on pest and their natural enemies
 - 2.2.2.1 Mode of action of entomopathogens
- 2.2.3 Impact of neem-based product on insect pest of brinjal
 - 2.2.3.1 Mode of action of neem

2.3 Impact of exogenous elicitors on plant in relation with insect pests

- 2.3.1 Salicylic Acid (SA)
 - 2.3.1.1 Mode of action of salicylic acid
- 2.3.2 Jasmonic Acid (JA)
 - 2.3.2.1 Mode of action of jasmonic acid
- 2.3.3 Acetic Acid (AA)
 - 2.3.3.1 Mode of action of acetic acid
- 2.3.4 Panchagavya
 - 2.3.4.1 Mode of action of panchagavya
- 2.3.5 Vermicompost
 - 2.3.5.1 Mode of action of vermicompost

2.1 Development and Screening of resistant varieties against the major pests which affects brinjal

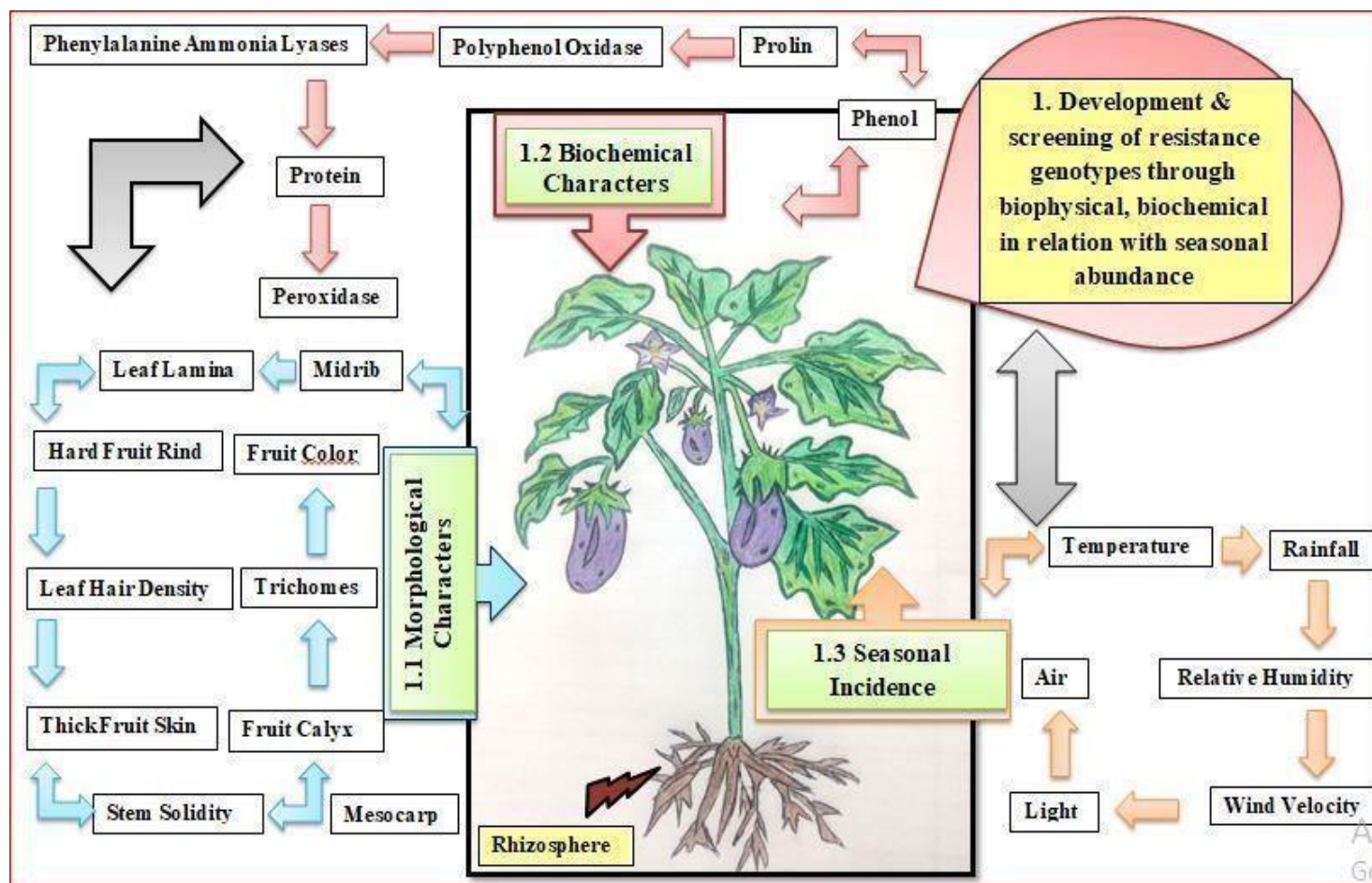


Fig. 1 Morphological and biochemical factor responsible for development of resistance

2.1.1 Development of resistance base on morphological characters

Utilizing resistant varieties is a critical component of bio-intensive pest management systems. Insect pests are drawn to, feed on, and lay their eggs on plant parts based on their morphological and physical characters due to its non-preference mechanism. The morphological characters like trichome type, length and density, color, shape and size of fruit, thorns on leaves, prickles on calyx and pedicel, leaf area are important traits in variety development programs. which help to develop resistance in the brinjal. These parameters will take in consideration while undertaking breeding program in development of resistance variety against insect pest.

Researchers studied the fruit characteristics of brinjal and found a linear relationship between the length of the seedless area and the periphery's seed rings and the level of fruit borer infection. When compared to light-colored varieties, varieties with dark purple or white color showed a greater sensitivity to the brinjal shoot and fruit borer (Jat and Pareek, 2003; Gupta and Kauntey, 2008).

In their distinct studies, researchers tested various brinjal genotypes against *L. orbonalis* and observed both direct and indirect effects of various traits related to growth and yield. Additionally, they concluded that length of fruit stalk, number of fruits per plant, color, and size should be prioritized during breeding program for varietal development (Khan and Singh, 2014; Netam *et al.*, 2018; Supriya and Mamocha, 2019).

In their individual trials, researchers divided types into resistant and highly resistant categories, where many genotypes were found to be optimal to control jassid, whitefly and thrips population by their morphological traits that display to sucking pest resistance (Rashid *et al.*, 2002; Elanchezhyan *et al.*, 2008; Jafir *et al.*, 2018). Previous reports noted associations between pest resistance and the physical traits of the brinjal plants, suggesting that the length and density of hairs on the leaf surface did not mainly control the resistance to jassid (*A. biguttula biguttula*) and trichomes on the leaf were found to have negative relation with jassid population (Amin *et al.*, 2015; Amin *et al.*, 2017) while longer and dense trichome also developed the resistant against jassid due to its non-preference behavior (Malini *et al.*, 2013).

The thickness of the leaf lamina exhibits a negative correlation with whitefly population, although this relationship is not statistically significant (Masood, 2011; Khan *et al.*, 2017). Hair density on the lamina, veins, and midrib region of leaves significantly and positively influences the population of whitefly (*Bemisia tabaci*), as demonstrated by (Chu *et al.*, 2003; Ashfaq *et al.*, 2010; Khan *et al.*, 2018).

2.1.2 Development of resistance based on biochemical parameters

Biochemical factors act as the host plant's defense mechanism against the pest complex that attacks the brinjal crop. These factors also serve as the precursor for defenses against biotic and abiotic stress, antixenosis, antibiosis, and tolerance functions, enabling the host plant to thrive in unfavorable conditions. Consequently, detailed information about biochemical traits is provided below by multiple researchers.

Peroxidases, polyphenol oxidases, superoxide dismutases, and phenylalanine ammonia lyases are essential oxidative enzymes that plants generate in response to pest damage. These enzymes have a variety of defense functions to the insect pest complex that attacks brinjal specially *L. orbanalis* (Doshi, 2004; Patil and Hole, 2021). Since the phenol-oxidizing enzyme POX important role in the manufacture of plant cell wall, and because of POX it turns the lignification and wall thickening, which provide defense responses in plants against pest. However, the quinones generated by phenol oxidation interact with the nucleophilic side chains of amino acids to decrease the availability of proteins to pests (Khorsheduzzaman *et al.*, 2010; Rameshkumar *et al.*, 2019).

Increased post-infectional phenomena including total phenol status, Peroxidase activity, induced hydroquinone, and an increase in the number of isozyme bands may make it possible to locate resistant sources. Proline plays crucial roles in various biological processes, including protein structure and synthesis, immunological function, and healing of wounds (War *et al.*, 2012). Polyphenol oxidase (PPO), an enzyme, catalyzes the conversion of phenolic chemicals into extremely reactive quinones. When a fruit is sliced or bruised after harvest, it browns due to the polymerization of quinones formed from polyphenol oxidases (PPOs). However, in intact and undamaged plant cells, PPOs are still present and serve as part of the plant's natural defense mechanisms.

PPO activity aids in the formation of melanin, which enhances the cell wall's defenses to diseases and insects. This activity often increases in response to stress, as highlighted by (Zhao *et al.*, (2009). An essential plant enzyme called phenylalanine ammonia-lyase removes ammonia from phenylalanine to create trans-cinnamic acid, which is a precursor to lignins, flavanoids, and coumarins. The initial stage in histidine breakdown is catalyzed by histidine ammonia-lyase, which also serves a crucial regulatory role in regulating the production of all phenylpropanoid compounds, aiding in pest resistance and in general, plants contain various biochemical constituents that confer a significant decrease of pest's population, their damaged and help to hindered them (Dar, 2017b).

The biochemical properties of host plants are crucial in determining their ability to resist different insect pests. Genotypes that exhibit higher resistance levels typically possess elevated levels of natural phenols. These substances are commonly linked to deterring feeding, hindering growth, and can even directly repel insect pests when present in higher concentrations, primarily due to their toxic effects (Dar *et al.*, 2017a).

When selecting cultivars resistance against *L. orbanalis*, it's important to consider not only yield but also the quantity of biochemical elements. Brinjal varieties with low sugar content and higher levels of phenolic compounds tend to exhibit significant resistance to various biotic stresses. Moreover, a range of biochemical components present in plants can contribute to resistance against insect pests, highlighting the importance of evaluating multiple factors beyond just yield performance (Kumari *et al.*, 2014; Prasad *et al.*, 2014; Dar, 2017b).

Additionally, one of the most crucial characteristics to lower the prevalence of fruit and shoot borer is phenol concentration which was essential factors in showing antixenosis, antibiosis and shown a clear variation as per crop age. There were few borer infestations if the phenol content is high (Reddy and Patel, 2014; Dar *et al.*, 2017a). This discovery is consistent with the findings of all other researchers, who discovered that genotypes with higher levels of the Solasodine, Phenols, and PPO activity are better to resist against (*L. orbonalis*) damage (Prasad *et al.*, 2014; Docimo *et al.*, 2016; Dar *et al.*, 2017a).

The presence of phenol is directly inhibiting the lepidopteron pest along with the fruit color (Amin *et al.*, 2014). In comparison with fruit color, violet (pink) was observed highly susceptible followed by light green. However, the flavonoids content was higher in fruit having white color which avoided damage of shoot and fruit borer (Kumari *et al.*, 2014). The phenol content rose with the crop age and varied with genotypes therefore there was a negative and substantial correlation between phenols and *L. orbonalis* infestation (Prasad *et al.*, 2014; Dar *et al.*, 2017a; Nagappan *et al.*, 2017; Rameshkumar *et al.*, 2019). The direct association between the contents of silica, polyphenol oxidase, phenylalanine ammonia lyase, peroxidase, glycoalkaloids, lignin and crude fat, the contents of amino acids, sugar (total and reducing sugars) and crude protein, the infestation of *L. orbonalis* was very unfavourable (Doshi, 2004; Khorsheduzzaman *et al.*, 2010; Patil and Hole, 2021).

Jasmonic acid (JA), ethylene, and salicylic acid (SA), as well as other phytohormones, are helpful in the development of herbivore-induced defenses (Smith *et al.*, 2009, Wu and Baldwin, 2009). Methyl jasmonate, cis-jasmone, and methyl salicylate, among others, are other similar chemicals that are now being tested to determine the induced resistance mechanism in plants (Matthes *et al.*, 2010; Venu *et al.*, 2010). By stimulating lignification of cells, facilitating wound healing, and synthesizing secondary metabolites, elevated peroxidase activity triggered by the application of jasmonic acid and salicylic acid, or by insect attacks, serves to shield plants against insect infestations, diseases, and various environmental stressors (Heng-Moss *et al.*, 2004; Rangasamy *et al.*, 2009). When subjected to challenges from jasmonic acid (JA), salicylic acid (SA), and insect invasion, the plants exhibited varying expressions of polyphenol oxidase (PPO) activity. This variability might stem from individual differences in the up-regulation sensitivity response to biotic stress. Typically, an increase in PPO activity occurs in response to stress, aiding in the production of melanin, which enhances the resistance of cell walls against infections and insect attacks (Zhao *et al.*, 2009). To diminish the accessibility of proteins to insect pests, quinones generated through phenols oxidation engages with amino acids (Zhang *et al.*, 2008; Bhonwong *et al.*, 2009).

Therefore, genotypes with high levels of phenols and low levels of sugar, protein, ash, and moisture may be chosen and used as the source for breeding new cultivars with resistance to the major pest of brinjal. Enzymes and other protective elements are in charge of the plant's defense to environmental stress and pest damage and brinjal with higher enzyme activity develop more resistant traits (War *et al.*, 2012).

Table 1. Morphological and biochemical factor responsible for development of resistance against major pest of brinjal

Sr. No.	Selected references	Target Pest	Relevant study with proposed research work	Remarks
2.1.1 Development of resistance base on Morphological characters				
1.	Chandrashekhar <i>et al.</i> 2008; Wagh <i>et al.</i> , 2012; Kassi <i>et al.</i> , 2019.	Brinjal shoot and fruit borer (<i>Leucinodes orbonalis</i>)	Round fruited varieties are more frequently attacked by shoot and fruit borer (<i>Leucinodes orbonalis</i>) than long fruited varieties due to variation in morphological characters such as fruit length and diameter, pericarp thickness, and fruit colour of brinjal genotypes and anatomical traits of fruit like fruit exhibits compact vascular bundles arranged in a thick layer with lignified cells and a relatively small pith area.	Long fruited genotypes found to be more resistance against brinjal pest
2.	Hossain <i>et al.</i> , 2002; Wagh <i>et al.</i> , 2012	Brinjal shoot and fruit borer (<i>L. orbonalis</i>)	The vascular tissue cells are densely packed and lignified, forming a compact arrangement, while the pith area is relatively small, stem's rigidity, tissue's thickness, thin pithy stem pointed unidirectionally are anatomical adaptations, structures to protect brinjal crop from <i>L. orbonalis</i> .	Anatomical factor also develop resistance against shoot and fruit borer

3.	Lit, 2009; Yousafi <i>et al.</i> , 2013; Dahal <i>et al.</i> , 2020	Jassid (<i>Amrasca biguttula biguttula</i>)	To combat jassid infestations, resistant varieties have been developed with specific physical traits. These include smooth-textured leaves rather than leathery ones or those with spines. Varieties resistant to jassid may also exhibit characteristics such as a favorable leaf area index, low hair density, reduced trichome density, smaller trichomes, and shorter trichome length.	Because of the texture and smoothness of the young leaves, the leaf structure has been proven to be robust.
4.	Khan <i>et al.</i> , 2010; Khan <i>et al.</i> , 2018	Whitefly (<i>Bemisia tabaci</i>)	Morphological traits like trichome density, length and breadth play an important role to minimize the whitefly infestation. It is also observed that the higher number of eggs were laid on cultivars with most hairs compared to less hair density and also hair length had negative impacted on the whitefly population.	Restrict the movement of whitefly due to presence of dense trichome.
5.	Wagh <i>et al.</i> , 2012; Barik <i>et al.</i> , 2020; Kroschel <i>et al.</i> , 2020).	Hadda beetle (<i>Henosepilachna vigintioctopuntata</i>)	In brinjal wild variety <i>Solanum sisymbriifolium</i> the spines were observed on leaf surface which developed non-preference to hadda beetle.	Smooth and healthy leaves were preferred by hadda beetle for feeding.
2.1.2 Development of resistance base on biochemical characters				

1.	Le Gall and Behmer, 2014; Khan <i>et al.</i> , 2015; Laichattiwat <i>et al.</i> , 2018; Shipa <i>et al.</i> 2021	Jassid (<i>Amrasca biguttula biguttula</i>)	Many reports mentioned different biochemical contents such as high moisture, chlorophyll level, proline content and sugar content of leaf of brinjal present in host plant which was selected by insects to feed and caused damage of jassid and other sucking insect pests of brinjal	Biochemical characteristics play a significant role in pest management as they have distinct effects on the pest's feeding behavior.
2.	Ibrahim <i>et al.</i> , 2016; Khan <i>et al.</i> , 2017; Khan <i>et al.</i> , 2018	Whitefly (<i>Bemisia tabaci</i>)	Some proteins promote population growth, while Cry genes, proline, peroxidase, polyphenol oxidase prevent the growth of the whitefly population. All these above components have variation in results as some are beneficial or others have harmful effect also	Protein makes pests more prone to damage, since it aids in the vigour, growth, and development of the damaged plants.

3.	Khorsheduzzaman <i>et al.</i>, 2010; Rameshkumar <i>et al.</i>, 2019	Shoot and fruit borer (<i>Leucinodes orbonalis</i>)	Brinjal genotypes with high polyphenol oxidase activity reacted defensively to borer attacks and there was a strong positive connection between Polyphenol oxidase activity and pest infestation	Phenol, Proline, Peroxidase are essential biochemicals for lignification and wall thickening of cell, which helps in plants to develop helps in plant defence mechanisms against pests.

2.1.3 Population dynamics of major pest and associated natural enemies and its relation with environmental factors

The response of each variety against the jassid varied in geographical location, pest guilt and presence of biochemical in leaf affect jassid population based on their characters varieties are categorized into susceptible, moderately tolerant and resistant (Abang *et al.*, 2016; Bilal *et al.*, 2017; Sultana *et al.*, 2017; Sowmya and Pradeep, 2020). A number of studies revealed that results of the brinjal varietal screening against jassid cannot be quite well compared among different studies because many scientists used different varieties under varied abiotic conditions (Sonali, 2008; Ramzan *et al.*, 2019; Naeem- Ullah *et al.*, 2020). The behavior of the jassid population exhibited variability in response to the levels of resistance found in different varieties or cultivars of brinjal across various localities. Sowmya and Pradeep, (2020) reported from Shimoga that screening of 34 cultivars against jassid was done and maximum number of jassids were noticed in variety hassiru udda badane and minimum in Kanakapura badane. Similar results, but for different cultivars, mentioned by Gautam *et al.*, (2019a) reporting the Local Deshi variety exhibited high susceptibility to jassid, followed by Green Star and Qayamat. On the other hand, Ananya showed lower susceptibility, followed by Kiran, BR-112, and Nano-38. Praveen *et al.*, (2018) found that IC-090050 displayed high resistance to *Amrasca devastans*, with a hopper burn intensity of 9.90 per cent, significantly lower compared to Bhagyamathi and Dommeru local, which recorded 1.41 and 2.74 times higher jassid intensity, respectively.

Gautam *et al.*, (2019a) conducted research in Gwalior, and noted that the Local Deshi variety exhibited high susceptibility to whitefly, with Green Star and Qayamat following suit. In contrast, Ananya displayed lower susceptibility, with Kiran, BR-112, and Nano-38 being even less susceptible to whitefly infestations. Praveen *et al.*, (2018) conducted their study in Andhra Pradesh and found that among various brinjal genotypes screened for whitefly infestation, genotype IC-127074 had the fewest whiteflies per three leaves per plant, while genotype IC-090050 had the highest population of whiteflies.

Salve *et al.*, (2020) reported that the variety JB-262 exhibited relatively lower infestation by *Bemisia tabaci* (whitefly), followed by the BH-2 variety. Conversely, variety JBH-3 showed higher infestation levels, with Pusa Upkar following suit.

These findings are consistent with earlier studies by Singh and Singh, (2002), noted that, not a single variety out of thirty-four brinjal cultivars was free from incidence or damaged of whitefly, the CO-2 variety displayed significantly lower populations of the pest.

According to researchers, whiteflies were predominantly present in January (2nd Southwest monsoon) and March (12th Southwest monsoon). This prevalence coincided with favourable mean relative humidity and total rainfall conditions. Conversely, whiteflies showed a strong non-significant relationship of temperatures as well as wind speed (Anjali *et al.*, 2012; Indirakumar *et al.*, 2016). Whiteflies increased as temperature and humidity increases, and vice versa, despite the wise versa record being reported as well. The number of rainy days had the most positive impact on the population of whiteflies, whereas the relative humidity at night had the greatest detrimental impact (Sahu, 2008; Mane and Kulkarni, 2011). In Bangalore, Chandrakumar *et al.*, (2008) recorded the two peaks for major sucking pest. The aphid peak was observed in 2nd week of December to January while whitefly and jassid observed in 3rd and 4th week of December. The populations of coccinellids beetles and lacewings peaked in the first and second weeks of December and January, respectively. However, maximum temperature and rainfall also had a negative correlation with the reducing pest population. The jassid population was found in the December 1st and 2nd week while whitefly reported in 4th week and borer observed when crop was 46 days old (Gayakwad, 2012). However, the major pest of brinjal became active in first week of April month (Deole, 2015). A polyphagous pest like *Aphis gossypii*, incidence was started from the month of April to the end of July while the aphid reached maximum number in the month of June during the season of *Rabi* and *Kharif* (Nonita *et al.*, (2007). The highest *L. orbanalis* population was seen on experiment plot that was undertaken in the *Rabi* and *Kharif* season when crop growth stages increased. However, humidity and sunshine hours had a significant relation with occurrence of borer attack in brinjal (Varma *et al.*, 2011; Kumar *et al.*, 2018a).

Praveen *et al.*, (2018) conducted research in Andhra Pradesh and found that among various brinjal varieties screened against the hadda beetle, the variety IC-127074 had the fewest hadda beetles per three leaves per plant, while the highest population was recorded in variety IC-112309-A.

Bhagat and Munshi, (2004) conducted a screening of six commercial cultivars of brinjal and in their findings Pusa Purple Long had highest average population of hadda beetles among the tested cultivars.

Beetle *H. vigintioctopunctata* activity is greatly influenced by various ecological factors, including the highest and lowest temperatures, wind speed, lowest and highest humidity with rainfall. The high infestation differs geographically, where variation is influenced by date of transplanting, variations in season, and pest biology variables. Many workers investigated connection of hadda beetles with abiotic factors significantly influencing the activity of beetles (Putta Raju, 2008; Varma and Anandhi, 2008; Haseeb *et al.*, 2009; Qamar *et al.*, 2009; Tiwari *et al.*, 2012). In extreme infestations of grub, plant parts like leaves, epidermis, parenchyma cells, and phloem cells are completely found damaged in eggplant (Varma and Anandhi, 2008; Mohanchander *et al.*, 2013). The recent hatched beetle in its adult stage exhibits a vivid yellowish appearance. As it matures, its color transitions to a copper-brown shade, characterized by a bronze-tinted mottling pattern with black spots (Kaur and Mavi, 2005; Varma and Anandi, 2008). Its spherical body is distinguished by an upper side having convex shape and a downside look flat, resembling the shape of the letter "D" when viewed from the side (Qamar *et al.*, 2009). Several species of coccinellid hadda beetle, including species *vigintioctopunctata* (Sharma & Tayde, 2017), *pustulosa* (Nakamura and Ohgushi, 1981), *niponica* (Ohgushi & Sawada, 1985), and *E. chiysomelina*, have been the focus of earlier investigations on population dynamics (Ali & Saeedy, 1986). *Henosepilachna* spp. can cost host plants like the brinjal a lot of money, depending on the season, location, and environmental conditions. Significantly lower agricultural yields were produced as a result of the crop's stages, adult chlorophyll content, and larval removal, along with damaged leaves, flowers, and fruits (Ghosh and Senapati, 2001b). Although *H. vigintioctopunctata* infestation seasons vary by location, the peak is often seen in July and August, according to an earlier version of this article (Venkatesha, 2006; Haseeb *et al.*, 2009; Khursheed and Desh, 2014; Sharma and Tayde, 2017).

Similar findings on brinjal crop revealed that the epilachna beetle was seen during the third and fourth weeks of December and had a positive correlation with the warmest temperatures. Additionally, it was discovered that epilachna beetle life stages had a

positive correlation with temperature (mean, minimum, and maximum) and a negative correlation with relative humidity (morning, evening, and mean) (Putta Raju, 2008; Kalaiyarasi *et al.*, 2017). Along with Varma and Anandhi, (2008) the epilachna beetle incidence in brinjal reached its peak in the third week of February in 2004–05, having first been noticed in the 20th week after transplanting (third week of January).

However, abiotic factors like temperature, rainfall, humidity and sunshine hours had a significant effect on biology of pest and their lifecycle which helps us to understand them and easily can be managed. So, an abiotic factor is important part of study which enlightens our knowledge about pest incidence at different stages and their growth and development.

2.1.3 Population dynamics of major pest and associated natural enemies and its relation with environmental factors

1.	Deole, 2015; Indirakumar <i>et al.</i> , 2016; Sharma and Tayde, 2017; Kumar <i>et al.</i> , 2019; Nelson <i>et al.</i> , 2020	Shoot and fruit borer (<i>Leucinodes</i> <i>orbonalis</i>)	At mean temperature and relative humidity of 26.5 ° C and 35 %, there were cases of the shoot and fruit borer, with an average infestation level of 0.64 % and a peak level of 5.21. Accordingly, crop maturity differs in different research trails, the average month from the beginning of February to the end of April had the highest levels of fruit and shoot infestation. The ecological variables temperature and humidity, respectively, had positive and negative impact on the larval population of pest.	The crop's vegetative phases progress and the form of the leaves and fruits favors borer population to increases.
2.	Varma <i>et al.</i> , 2011; Anjali <i>et al.</i> , 2012; Singh <i>et al.</i> , 2013	Jassid (<i>Amrasca</i> <i>biguttula</i> <i>biguttula</i>)	Season-based experiments on jassid incidence, which began with an average population of 1.2 jassid /plant, they observed a negative association between maximum and minimum temperatures while a positive correlation between total rainfall and mean relative humidity.	Environmental factors significantly influence the life cycle and proliferation of pests.

3.	Anjali <i>et al.</i> , 2012; Indirakumar <i>et al.</i> , 2016	White fly (<i>Bemisia tabaci</i>), BSFB (<i>L. orbonalis</i>)	The temperature, morning humidity, and daylight periods showed positive correlations with eggplant pest infestation. However, there was an inverse relationship between the rates of insect infestation and rainfall and evening relative humidity.	Rainfall has beneficial impact. Insect activity decreases when it rained, according to observations.
4.	Naik <i>et al.</i> , 2008; Patial and Mehta, 2008; Naik <i>et al.</i> , 2009; Birla, 2011	Aphid (<i>Aphis gossypii</i>), Jassid (<i>Amrasca biguttula biguttula</i>), white fly (<i>Bemisia tabaci</i>), Hadda beetle (<i>Henosepilachna vigintioctopunctata</i>)	The brinjal pest complex and its succession studying, a total of 27 pests damaging the eggplant throughout different cropping season were recorded with high infestation as crop stages grow and they discovered a harmful insect pest complex to brinjal with the appearance of pests like <i>A. gossypii</i> , <i>T. vaporariorum</i> , <i>A. biguttula biguttula</i> , <i>H. vigintioctopunctata</i> , <i>Mylloceris</i> spp., <i>C. insolita</i> , <i>A. devastans</i> and <i>B. tabaci</i> and coccinellid predatory beetles.	Brinjal pest complex was discovered to be more active at various vegetative stages as a result of how temperature and moisture affect an insect's body's metabolism and reduce there population.
5.	Kadam <i>et al.</i> , 2006; Shaik, 2012; Devi, 2013	Sucking pest and their natural enemies	The sucking pest like <i>A. biguttula biguttula</i> , <i>Bemisia tabaci</i> and <i>Aphis gossypii</i> incidence started from the month of April and reached peak in June an	High temperature favors the increase of sucking pest

			increase in the number of pest and coccinellid predators like <i>Menochilus sexmuculata</i> , <i>Cheilomenes sexmaculata</i> , <i>Coccinella septempunctata</i> , and <i>Brumoids suturalis</i> . However, the environmental factors like temperature, relative humidity and rainfall was observed with positive and negative relation with pest population.	populations in comparison to their natural enemies.
6.	Kaur and Singh, 2013; Kaur <i>et al.</i> , 2014; Kumar <i>et al.</i> , 2021	Brinjal shoot and fruit borer (<i>Leucinodes orbonalis</i>)	The maximum shoot infestation was observed during 43 rd SW while maximum damage of fruits were noted during 46 th SMW of <i>Kharif</i> season.	
7.	Meena <i>et al.</i> , 2017; Kumar <i>et al.</i> , 2021	Jassid (<i>Amrasca biguttula biguttula</i>)	Jassid population reached at peak during 39 th SMW in <i>Kharif</i> , while the minimum population was recorded in 48 th SMW in year 2019 and 2020 as both had observed similar incidence.	Variations in abiotic factors affect the activity of insects, which causes them to die.

8.	Meena <i>et al.</i> , 2017; Ajabe <i>et al.</i> , 2019; Berani and Patel, 2020	Whitefly (<i>Bemisia tabaci</i>)	Peak timing for incidence of whitefly started built-up during October in 44 th SMW and then population declined up to crop maturity	
9.	Latif <i>et al.</i> , 2009; Khursheed and Desh, 2014; Manikandan <i>et al.</i> , 2019	Hadda beetle (<i>Henosepilacha vigintioctopunc tata</i>)	Multiple researchers across various locations have mentioned that occurrence of beetle began on 34 th SMW of August and peaked during the 37 th and 38 th SMW weeks of September.	Environmental factors significantly influence the life cycle and proliferation of pests.

2.2 Impact of biorational pesticides for management of major pests of brinjal

A biorational pesticide is defined as "any sort of insecticide active against pest populations, but relatively harmless to non-target organisms and consequently non-disruptive to biological control. Spinosad damaged the neurological system of the insect, disturbed neuronal activity by stimulating motor neurons, and eventually caused paralysis and death by inducing uncontrollable muscle spasms (Dripps *et al.*, 2008; Sparks *et al.*, 2008). Neem leaf extract suppresses pests through various mechanisms. Firstly, it induces a higher mortality rate among younger stages of different pests when they feed on the treated leaves. Additionally, it reduces the survival and reproductive rates of the pests. Furthermore, neem leaf extract can cause mating disturbances among pests, further disrupting their lifecycle and population growth. These combined effects contribute to the effective control of pests using neem leaf extract (Lokanadhan *et al.*, 2012; Dela *et al.*, 2014). The fungus, *Beauveria bassiana*, generated airborne conidia and single-cell blastospores that germinate when they come into contact with an insect's upper skin layer and penetrate directly into the bodies of their hosts from the upper skin (Thurkathipana and Mikunthan, 2008). The fungus in the body swiftly spreads by producing poisons. The spores of the fungus *M. anisopliae* enter the insect's body by contact and kill the host (Jugno *et al.*, 2018). Along with cylindrical conidia, they also create subcylindrical phialides. Invading the bodily cavity, *Lecanicillium lecanii* spores germinate, produce hyphae, and begin to rapidly degrade tissue. The fungus enters the insect and releases blastospores. The fungi that infiltrate the insect cuticle eventually kill the insects within 7 to 10 days, and the insect body have white fungus hairs (cottony appearance, ranging from white to pale yellow (Sharma and Sharma, 2021).

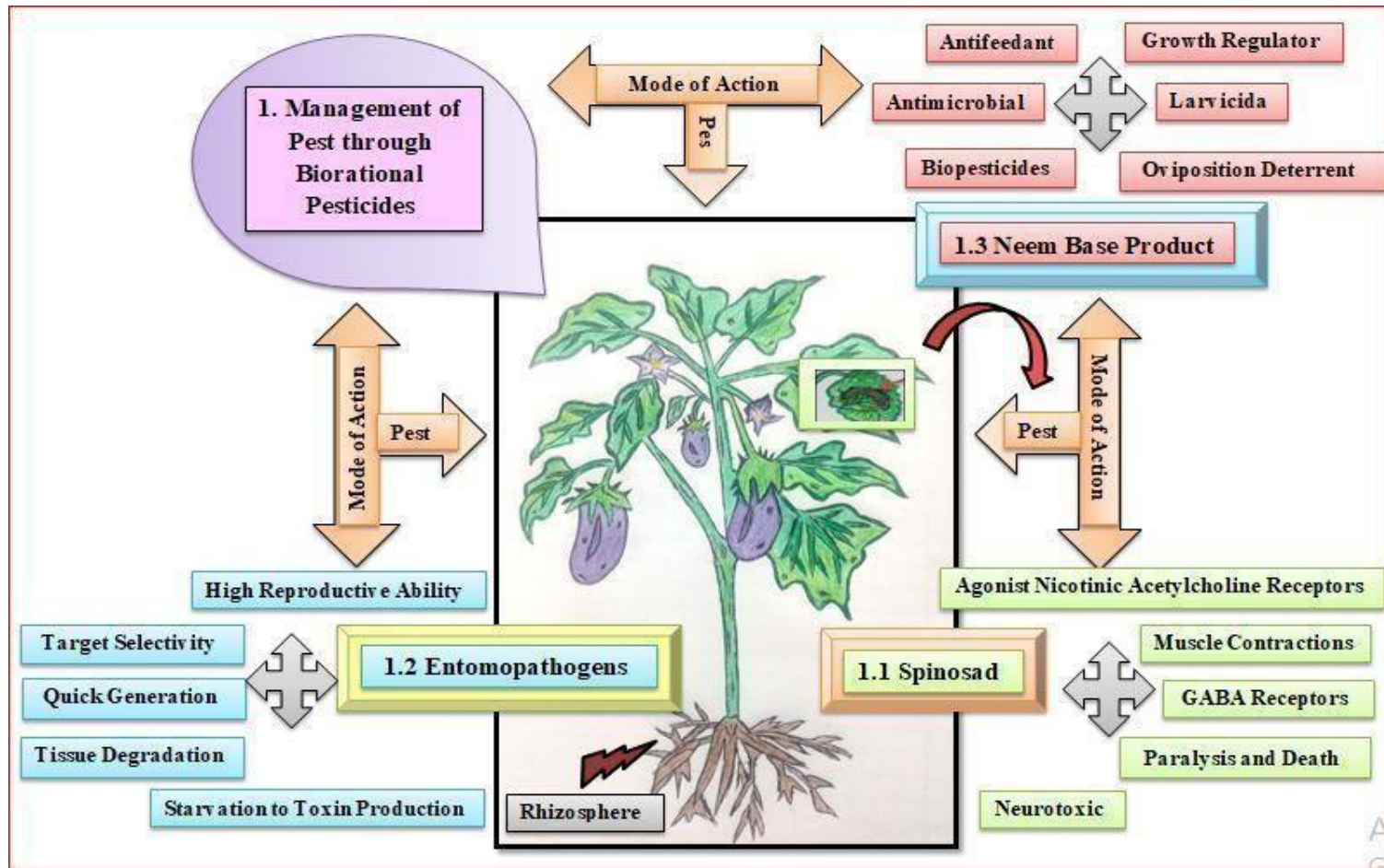


Fig. 2 Management of pest through biorational pesticides

Table 2. Impact of biorational pesticides for management of major pests of brinjal

Sr. No.	Selected references	Target Pest	Relevant study with proposed research work	Remarks
Impact of biorational pesticides for management of major pests of brinjal				
1.	Niranjan <i>et al.</i> , 2017; Reshma and Behera, 2018; Khare and Sneha, 2021; Singh <i>et al.</i> , 2021	Piercing and sucking pests and shoot and fruit borer (<i>L. orbonalis</i>)	Spinosad outperformed cypermethrin, emamectin benzoate, and neem extract in tests of its ability to control pests on brinjal, which included fruit and shoot borer, whiteflies, leafhoppers and aphids. Cyantranilprole, Flubendiamide, and Spinosad were new-generation insecticides that tested well for controlling <i>Leucinodes orbanalis</i> .	Insecticides of a new generation are more effective against brinjal pests.
2.	Alam <i>et al.</i> , 2003; Manzoni <i>et al.</i> , 2006; Kirst., 2010	Natural enemy complex of brinjal	Multiple studies have provided evidence that Spinosad, derived from <i>Saccharopolyspora spinosa</i> , is relatively safe for natural enemies. where list includes foliage dwelling predators viz., <i>Coccinella septempunctata</i> , <i>Chrysoperla carnea</i> , <i>Episyrphus balteatus</i> , ground dwelling predator,	Biorationals were not harmful to parasitic and predatory

			<i>Poecilus cupreus</i> and parasitoids <i>Trichramma atopovirilia</i> , <i>Trathala flavoorbitalis</i> an larval pupal parasitoid of BFSB	coccinellids.
3.	Rajendran, 2002; Thurkathipana and Mikunthan, 2008	Hadda beetle (<i>Eipilacna vigintioctopunctata</i>)	The white muscardine fungus, <i>Beauveria bassiana</i> , is one of the biopathogens that caused mortality in <i>Eipilacna vigintioctopunctata</i> . Beetle death becomes evident before the initial day following the application of the <i>B. bassiana</i> in the field. <i>M. anisopliae</i> , a green muscardine fungus, possesses the capability to inhibit the reproduction of both larvae and mature beetles.	High mortality is caused by biopathogens in hadda beetles.
4.	Jugno <i>et al.</i> , 2018	Brinjal aphids and jassid	Screening the bioefficacy of entomopathogens viz, <i>Bacillus thuringiensis</i> @ 1×10^8 spores and <i>Metarhizium anisopliae</i> @ 1×10^7 conidia causing mortality against brinjal aphids and leaf hoppers.	Biopesticides are highly effective and do not bioaccumulate.
5.	Prodhan <i>et al.</i> , 2018; Wahengbam <i>et al.</i> , 2021).	Lepidopterans, Brinjal shoot and fruit borer etc	Bt. endotoxins have been used extensively for insect pest control over years. It is used as foliar spray for pest management in various crops including brinjal. However transgenic brinjal carrying Bt. Cry genes is a best way for pest management	Cry toxins helpful for pest management.

6.	Mane and Kulkarni, 2010; Alzohairy, 2016	Sucking pest complex of brinjal crop	In addition to the azadirachtin compound found in neem plants, other active compounds such as neem oil, neemark, bioneem, nimbecidin, nimbin, mahmoodin and nimbolinin, among others, play a significant role in effectively controlling sucking pests like aphids, whiteflies, and jassids.	The sucking pest complex of brinjal is successfully combated by biological products.

2.2.1 Impact of Spinosad on pest and their natural enemies

Researchers found that the effectiveness of Spinosad and neem seed kernel extracts against the brinjal shoot and fruit borer (*Leucinodes orbonalis*), significantly reduced fruit infestation and increased yield in brinjal crop (Islam, 2013; Ali *et al.*, 2016; Khare and Sneha, 2021). Spinosad was found to be the most effective treatment compared to other options, when used alone or in combination with fertilizers, chemicals, biopesticides, etc. to combat *L. orbonalis* infestation of shoots and fruit and helpful in increasing brinjal fruit output (Kalawate and Dethé, 2012; Awal, 2012; Mamun *et al.*, 2014). As per previous reports, the pesticide that works the best on brinjal for management of insect pests was Spinosad 45 SC as it shows better result compared to others treatments. Carbosulfan 25 EC, the second-best pesticide in terms of fruit production, can be used to manage the *L. orbonalis* infestation in eggplant. Additionally, compared to the untreated control plots, Spinosad and Carbosulfan are thought to have produced the best yields. In order to manage the shoot and fruit borer in brinjal, Spinosad and Carbosulfan were found suitable (Deshmukh and Bhamare, 2006; Naik *et al.*, 2008; Sinha *et al.*, 2009; Sharma and Kaushik *et al.*, 2010; Mamun *et al.*, 2014).

Based on the research by Kalawate and Dethé (2012), Spinosad demonstrated moderate control over jassids, whiteflies, and aphids. However, it was notably more effective against BSFB (Brinjal Shoot and Fruit Borer). Although the yield obtained with spinosad and emamectin benzoate was statistically similar to that of cypermethrin (check treatment), the former yielded higher results (16.30 and 21.01 t ha⁻¹).

According to Nayak *et al.*, (2011), rynaxypyr resulted in the highest marketable fruit yield at 63.7 q/acre, followed closely by flubendiamide at 63.3 q/acre, and Spinosad at 63.2 q/acre. These treatments exhibited statistically comparable effectiveness. However, as stated by Kameshwaran and Kumar, (2015), the treatment with the highest yield was chlorantraniliprole 20 SC at 40 g a.i./ha, yielding 27.08 t/ha. This was followed by emamectin benzoate 25 WG at 11 g a.i./ha, with a yield of 23.61 t/ha, and spinosad 45 SC at 75 g a.i./ha, which yielded 20.83 t/ha.

2.2.1.1 Mode of action of Spinosad

Spinosad has specific mode of action which involves the alteration of nicotinic and GABA-gated ion channels in the insect nervous system. This alteration results in rapid

excitation of the nervous system, leading to involuntary muscle contractions, tremors, paralysis, and eventual death of the insect. Spinosad functions as an agonist of nicotinic acetylcholine receptors and also acts as an antagonist on receptors of gamma-aminobutyric acid in the nervous system (Dripps *et al.*, 2008; Sparks *et al.*, 2008).

2.2.2 Impact of Entomopathogens on pest and their natural enemies

Field tests evaluating the effectiveness of two neem formulations, neem seed kernal extract and nimbo bas, as well as 2 (*Bt.*)-based formulations, biolep and pusa *Bt.*, for the control *Leucinodes orbanalis* revealed that NSKE was the most effective treatment among those employed in the trials (Jayakrishnan and Madhuban, 2011; Raina and Yadav., 2018). Against shoot and fruit borer in brinjal, average shoot infestation at lowest level was observed due to application of *Bt.* with 13.31 per cent while 15.5 per cent shoot damaged was recorded in Neem oil (Tripura *et al.*, 2017; Gautam *et al.*, 2019b).

Thurkathipana and Mikunthan, (2008) reported the efficacy of *Beauveria bassiana* for epilachna beetle management in brinjal. The efficacy of entomopathogenic microbes viz., *Bacillus thuringiensis* @ 1 ml/L, *Metarhizium anisopliae* @ 10^7 spores/ml and *Beauveria bassiana* @ 10^7 spores/ml was compared along with Spinosad, azadirachtin, Malathion was used per litre at different concentration for managing brinjal pest complex and the results showed that *Bt.* and spinosad were effective against early larval instars of *Antoba olivacea* and *Leucinodes orbanalis* while Azadirachtin efficiently controlled *Epilachna* and *Selepa* while malathion was effective in controlling older instars of *Antoba olivacea* (Gowrish *et al.*, 2015).

2.2.2.1 Mode of action of Entomopathogens

The biological management of insect pests using Entomopathogenic Fungi (EPF) represents a desirable and effective approach that relies on natural microorganisms to control pest activity, offering a viable alternative to chemical insecticides. Various genera of EPF serve as pesticides across agricultural, greenhouse, forest, storage, and residential pest control applications. The action of entomopathogenic pesticides, as they employ diverse mechanisms to kill insects, ranging from inducing starvation to toxin production (Sharma and Sharma, 2021). EPF formed toxins of which plethora and extracellular enzymes, like chitinases and proteases, which aid in penetrating the host's physical defenses. Examples of EPF genera include *Beauveria*, *Metarhizium*, *Isaria*, *Lecanicillium*,

and *Hirsutella*. These fungi possess several biological characteristics crucial for effective biocontrol of insect pests, including target selectivity, high reproductive ability, rapid generation time, and prolonged survival in the environment (Sharma and Sharma, 2021).

Beauveria bassiana

The most well-known insect pathogen is *Beauveria bassiana* (Balsamo) Vuillemin (Hypocreales: Cordycipitaceae). *Cordyceps bassiana* has been the name of the teleomorph. Insects get sick by fungus called 'white muscardine' by the name of *Beauveria bassiana*. By germinating when they come into contact with an insect's upper skin layer and penetrating directly into the bodies of their hosts from the upper skin, this fungus produced airborne conidia and single-cell blastospores. The body's fungus quickly multiplies by creating poisons. *B. bassiana* and other fungus diseases can therefore infect people with merely a contact, unlike the bacterial and viral pathogens that affect insects. When fungus kills its host, it spreads outside of its immediate area by mildewing the insect (Kim *et al.*, 2011).

Metarhizium anisopliae

Metarhizium anisopliae (Metsch) as with yeastocidal agents, sorok (Ascomycota: Clavicipitaceae) typically multiply in their host in the form of blastospores or hyphae structures and spread to the body cavity with movement of the blood fluid. Asexual reproduction characterizes the mitosporic fungus *M. anisopliae*. These fungi's spores enter the body of the insect through touch and kill the host. They produce subcylindrical phialides as well as cylindrical conidia. Due to the presence of green spores produced by the fungus, the condition it induces is commonly referred to as "green muscardine disease," as noted by (Driver *et al.*, 2000). Fungi that are entomopathogenic to insects can invade plant roots as asymptomatic endophytes. *M. anisopliae* may colonize the roots of many different plants and is both an endophyte and an entomopathogen, which increases plant growth and resistance to pests and diseases (Sasan and Bidochka, 2012).

Verticillium lecanii

Verticillium lecanii affects insect pests by creating hyphae from spores that have penetrated an insect's cuticle or integument, it infects the insect. The fungus then destroys an insect's internal organs, which has the combined effects of chemical, mechanical, water

loss, and nutrient loss, which causes the insect to die. An entomopathogenic fungus species called *L. lecanii* was formerly known by the name *Verticillium lecanii*. On insects, *Lecanicillium lecanii* spores germinate, generate hyphae, and enter the body cavity where they quickly start to cause tissue degradation. Invading the insect, the fungus produces blastospores. The insects are then wiped out within 7–10 days by fungi that invade the insect cuticle. Insect corpses feature white fungus hairs (cottony appearance, ranging from white to pale yellow). The mycelium of the fungus is visible as dazzling white strands under a microscope (Upadhyay *et al.*, 2014; Alavo, 2015).

2.2.3 Impact of neem-based product on insect pest of brinjal

Sajjan, (2006) discovered that the greatest larval mortality on *P. xylostella* was observed five days after treatment with a combination of panchagavya (5%) and NSKE (5%). This was subsequently followed by treatments involving NSKE (5%) combined with cow urine (10%) and panchagavya (3%) combined with NSKE (5%).

Products made from neem greatly decreased jassid populations (*Amrasca devastans*). Additionally, it concurs with those who used neem, dhatura, neem liquid extract at 3% and neem oil at 2% to significantly reduce the amount of whitefly and jassids, among other sucking insect pests (Khattak *et al.*, 2006; Dutt, 2007; Bardin *et al.*, 2008). According to Murugesan and Murugesan (2008), botanicals with various active components of some plants like neem, crown flower, garlic, dhatura, tobacco, chrysanthemum, shrub verbena and chinese chaste tree which helps to lower the probability of resistance development and make them easily biodegradable in the environment, can control hadda beetle. Dela *et al.*, (2014) stated that neem leaf extract caused nymphal mortality during consumption and decreased the persistence and fecundity rate of the green peach aphid. To *M. persicae*, these extracts demonstrated intriguing aphicide capabilities, with dosage response relationships being highly linked.

Among various neem products, neem oil with a concentration of 13% was the most effective at reducing the epilachna beetle's population. The epilachna beetle's responses to neem oil treatment in terms of mortality, growth, and feeding also demonstrated that all larval instars were vulnerable. At third instar and lowest on first instar, respectively, the LC₅₀ values were higher. As larval age and oil concentration rise in proportion to each other, the LT₅₀ values of oil also rise (Anam *et al.*, 2006; Murugesan and Murugesan, 2008;

Podder *et al.*, 2013).

Neem has a lot of bioactive substances. Azadirachtin is the most crucial active component that accounts for the largest portion of neem. Instead of quickly killing insects, its active ingredient repels them, prevents them from feeding, and hinders their growth and reproduction. Neem has an active ingredient called azadirachtin, which has been shown to have typical insect growth-regulating (IGR) effects on insect larvae (Ashraf and Javaid, 2007; Koul, 2007; Elteraif and Hassanali, 2011; Muhammad and Kashere, 2020). Neem formulations have been shown to be effective by having properties like antifeedant, repellent and detrimental against a variety of insect pests, including grasshoppers, gall midges, gall folders, citrus blackflies, houseflies, bagworm moths, spiny bollworms, gall midges, grasshoppers, pulse beetles, and predatory spiders (Bardin *et al.*, 2008; Umamageswari *et al.*, 2008).

2.2.3.1 Mode of action of neem

In neem plant, compounds like salanin, melandriol and azadirachtin poses anti-peristaltic, non-preference, regulator of insect growth and mating disturbance activities against pest and these compounds also creates a sensation to vomiting, deterring the insect from feeding on the neem-treated surface. Additionally, neem inhibits the insect's ability to swallow effectively. Furthermore, neem serves as an oviposition deterrent, preventing females from depositing eggs. This property is particularly useful when coating stored seeds with neem kernel powder or neem oil. Neem also acts as an insect growth regulator, which have unique and interesting capability which harms or affects the insect's juvenile hormone (Morgan, 2009; Lokanadhan *et al.*, 2012).

2.3 Impact of exogenous elicitors on plant in relation with insect pests

Salicylic acid (SA) impacts various physiological processes in plants, including thermogenesis, stomatal dynamics, seed germination, cell proliferation, vegetative growth, flowering, photosynthesis, abiotic stress responses, and defense mechanisms against diseases and pests (Bideshki and Arvin., 2010; Carr *et al.*, 2010). By making systemic changes to how genes are transcribed and interacting with transcriptional cofactors of Non-expressor of Pathogenesis-Related (PR) genes, salicylic acid (SA) has the potential to increase the production of pathogenesis-related proteins possessing antimicrobial properties (NPR). Multiple investigations have demonstrated that

jasmonates (JAs), besides their role in stimulating plant growth and development, enhance plant resilience to stress by activating JA signaling pathways in response to various adverse environmental conditions (Miura and Tada., 2014; Shama *et al.*, 2016). In panchagavya, the inclusion of growth-regulating compounds like indole-3-acetic acid (IAA), gibberellic acid (GA), cytokinins, vital plant nutrients, beneficial microorganisms, and biofertilizers such as *Acetobacter*, *Azospirillum*, and *Phosphobacterium* has been reported (Somasundaram *et al.*, 2004).

Panchagavya is organic pesticide with combination of five cow products as cow dung, cow urine, milk, curd and ghee. Cow urine present in panchagavya acts as a repellent and deterring pest from feeding on plants due to its odor causing them to feed less on plants. By using it, dangerous synthetic fertilizers, herbicides, insecticides, and antibiotics are never used. Panchagavya aids in enhancing the root growth, stems, branches, and leaves, along with improving various associated parameters such as root length, stem length, number of branches, number of leaves, leaf area index, protein quantity, chlorophyll, oil quantity, and another characteristic, thereby increasing overall productivity (Pagar *et al.*, 2015; Ananda and Murthy 2017; Choudhary *et al.*, 2017). Vermicompost possesses the capacity to enhance soil fertility through physical, chemical, and biological means. Physically, vermicompost-amended soil exhibits improved aeration, porosity, bulk density, and water retention, as documented in studies by (Pathma and Sakthivel, 2012, 2013; Pathma *et al.*, 2019).

Apart from the innate immunity of host plant varieties to herbivore attack, induced resistance is also reported. When insects damage the plant tissue plant signalling pathways gets activated and plant produces secondary metabolites which offer protection against various biotic stress caused by pest and diseases. These secondary metabolites may act as insect pest repellents, ovipositional deterrents, anti-nutrients etc. which adversely affect insect physiology and reduce its rate of growth and survival. Wound signalling interconnects pathways allowing their cross talk and provides resistance to insect attack (War *et al.*, 2011; Lu *et al.*, 2014; Nikooei *et al.*, 2015). Exogenous application of salicylic and jasmonic acid, acetic acid etc., could activate plant defence against biotic stress by inducing systemic resistance in plants (Miura and Tada, 2014; Shama *et al.*, 2016).

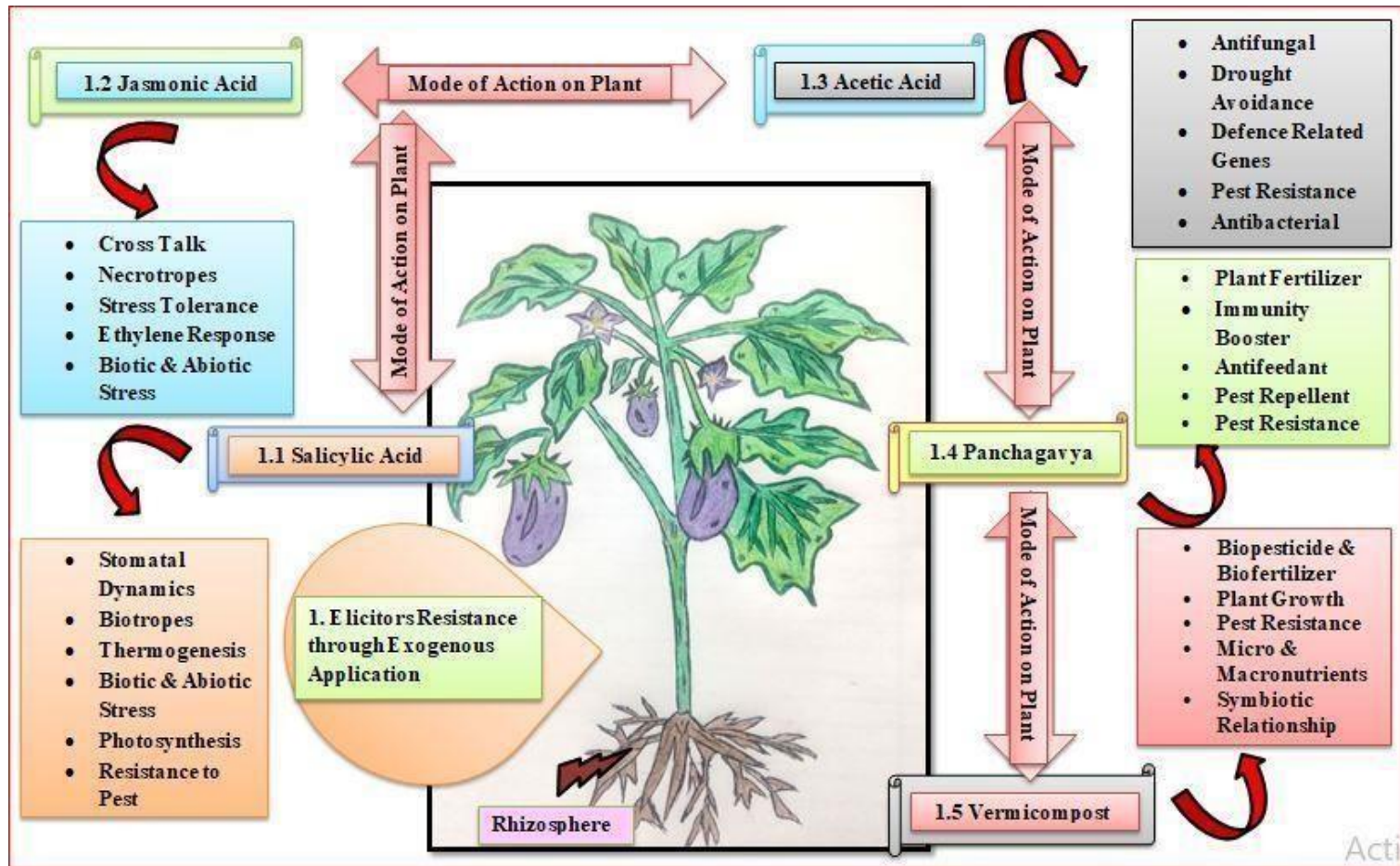


Fig. 3 Elicitors resistance through exogenous application

Table 3. Impact of exogenous elicitors on plant in relation with insect pests

Sr. No.	Selected references	Target Pest	Relevant study with proposed research work	Remarks
Impact of exogenous elicitors on plant in relation with insect pests				
1.	Bhasker <i>et al.</i> , 2020	Thrips (<i>Thrips tabaci</i>)	Data on role of SA in arthropod pest management is scanty. Onion plants that received SA application @ 250 mg ⁻¹ thrice showed drastic reduction in the thrips (<i>Thrips tabaci</i>) population as compared to other treatments	Salicylic acid works to counteract abiotic stressors, defend against diseases and pests, and restore biotrophs.
2.	Nouri-Ganbalani <i>et al.</i> , 2018	DBM (<i>Plutella xylostella</i>)	Exogenous application of jasmonic acid was evidenced to induce systemic defences in oilseed rape against <i>Plutella xylostella</i>	In the JA signalling system, jasmonic acid aids in the recovery of plants from necrosis and insect attack.
3.	Chen <i>et al.</i> , 2019	Tobacco cutworm (<i>Spodoptera litura</i>)	Exogenous application of acetic acid @ 10 mM concentration on tomato plants activated defense related genes to produce increased levels of plant metabolites including protease inhibitor, peroxidase, polyphenol oxidase etc., which induced	It is well known that polysaccharidic matrices produced by elicitors of resistance

			plants resistance to <i>Spodoptera litura</i>	and acetic acid play a role in microbial interactions.
4.	Khoshfarman-Borji <i>et al.</i> , 2020	Aphid (<i>Brevicornye brassicae</i>)	Combined application of SA with <i>Pseudomonas pudita</i> provided better resistance to canola plants against <i>Brevicornye brassicae</i> .	SA encourages a plant's cellular development, vegetative growth, blooming, photosynthetic responses to abiotic stressors, and defensive responses to diseases and pests.
5.	Sowmiya <i>et al.</i> , 2020	Shoot and fruit borer (<i>Leucinodes orbonalis</i>)	Efficacy of Panchagavya alone and in combination with botanicals in managing <i>Leucinodes orbonalis</i> under laboratory conditions. The antifeedant activity was found in CLE (5%) + panchagavya (3%), which is on par with OLE (5%) + panchagavya (3%), and followed by Neem oil (3%), while untreated control (3.89%) at 24 HAT.	The smell of urine in panchagavya serves as an antifeedant or insect repellent.

6.	Bharati, 2005; Sajjan, 2006; Pazhanisamy and Archunan (2019),	DBM (<i>Plutella xylostella</i>) Tobacco cutworm (<i>Spodoptera litura</i>)	The highest larval mortality of borers, Diamondback moth and Tobacco cutworm was observed on day 5 after treatment with a combination of panchagavya five per cent and neem seed kernel extract five percent, followed by NSKE combined with cow urine ten per cent, and three per cent panchagavya with neem seed kernel extract five percent.	Biorational combination with panchagavya demonstrates high insect pest mortality.
7..	Krishna Kumari <i>et al.</i> , 2003; Abbaszadeh <i>et al.</i> , 2014	Fruit borer (<i>Helicoverpa armigera</i>)	Certain chemicals in <i>C. infortunatum</i> extracts may be the reason why it has stronger antifeedant effects on <i>Helicoverpa armigera</i> . Neoclerodane diterpenoids, 3- epicaryoptin, and 15-hydroxyepicaryoptin are only a few of the chemicals that provide <i>C. infortunatum</i> its antifeedant properties. Additionally, it exhibits greater antifeedant potential against insect = pests when combined with panchagavya.	When mixed with panchagavya, <i>C. infortunatum</i> extracts have antifeedant potential against insect pests.
8.	Xiao <i>et al.</i> , 2016	Root-knot nematode	In tomato crop vermicompost has demonstrated efficacy in reducing root-knot nematode populations and enhancing host plant health.	Vermicompost is a good source of bioactive substances that make you resistant

				to nematodes but not roots.
9.	Arancon <i>et al.</i> , 2005	Aphids (<i>Macrosiphum euphorbiae</i>), mealy bugs (<i>Planococcus</i> spp.)	When incorporated into soilless potting media, vermicompost has been shown to decrease populations of aphids and mealybugs on pepper plants, as well as mealybugs on tomato plants.	Vermicompost possesses the potential to improve plant growth, yield, overall health, and resistance to pests by serving as a naturally occurring, slowly released reservoir of essential plant nutrients.

2.3.1 Salicylic Acid (SA)

Salicylic acid which is chemically (2-hydroxybenzoic acid), is an plant internal regulator for growth and development, which regulates numerous physiological process in plants including transpiration, stomatal closure, ion uptake, flower induction, biosynthesis inhibition of ethylene etc. (Khan *et al.*, 2003; Hayat *et al.*, 2010).

Exogenous foliar application of SA improves photosynthesis and plant water relations and improves the yield of brinjal (Gawade and Sirohi., 2011), garlic (Bideshki and Arvin., 2010) tomato (Habibi, 2012; Nazar *et al.*, 2015; Afsana *et al.*, 2017) and onion (Bhasker *et al.*, 2020). Foliar application of SA protects mustard (Nazar *et al.*, 2015), soybean (Razmi *et al.*, 2017) from drought stress and peach from cold stress (Zhang *et al.*, 2017). Bhasker *et al.*, (2020) reported that externally foliar induction of SA @ 250 mg⁻¹ three sprays 1st 30 DAS, 2nd 30 DAT and 3rd 60 DAT significantly improves growth and yield as well as sowed reduced pest and disease incidence resulting in profitable yield. Salicylic acid part in promoting resistance to phytopathogens in various crops by inducing both systemic and local defense is well studied and documented (Hayat *et al.*, 2010; Pandey and Gupta, 2012).

While pathogen defense is the area of SA that has received the most attention, responses can also be elicited by insects, especially sucking insects. The green peach aphid (*Myzus persicae*) feeds on Arabidopsis and causes the expression of genes associated to SA that are engaged in pathogen defense (Moran and Thompson, 2001). The Russian wheat aphid, *Diuraphis noxia* feeds on wheat and causes accumulation of SA, which contributes to resistance (Mohase and Westhuizen, 2002). The Mi-1 gene- mediated resistance of tomato against potato aphid also depends on SA and serves as a case study for similar plant defense responses to diseases and sucking insects (Li, 2006). Such reactions can also change how other plant defense pathways are activated. For example, the SA-related plant defenses are induced when the JA defense system is suppressed by the *B. tabaci* (type B), which feeds on Arabidopsis (Zarate *et al.*, 2007).

2.3.1.1 Mode of action of salicylic acid

Following its production, salicylic acid (SA) can exert various effects on plant physiology throughout all plant tissues. SA contributes significantly to plant thermogenesis, regulation of stomatal dynamics, promotion of seed germination,

facilitation of cell growth, enhancement of vegetative growth, regulation of flowering processes, optimization of photosynthesis, mediation of responses to abiotic stresses, and activation of defensive mechanisms against pests and pathogens (Janda *et al.*, 2014; Kumar *et al.*, 2015; Klessig *et al.*, 2018). Systemic acquired resistance (SAR) represents a crucial aspect of plant defense mechanisms, wherein plants can develop enduring resistance to microorganisms, even in areas not initially affected. This process relies on the accumulation of salicylic acid (SA), as highlighted (Durrant and Dong, 2004).

Salicylic acid (SA) interacts with transcriptional cofactors of Non-expressor of PR genes (NPR) to change transcriptional programming in a way that increases the expression of pathogenesis-related (PR) proteins with antimicrobial qualities. This mechanism has been supported by research from various studies including those by (Sudisha *et al.*, 2012; Ali *et al.*, 2018; Innes, 2018; Klessig *et al.*, 2018). Importantly, salicylic acid act as an essential compound in developing resistance. Rather, compounds like methyl salicylate, azelaic acid, pipecolic acid, and its derivative N-hydroxypipecolic acid, among others, function as volatile and/or mobile signals for surface plasmon resonance (SAR). This understanding is supported by research from various studies, including those by (Shah *et al.*, 2014; Bernsdorff *et al.*, 2016; Hartmann and Zeier, 2019).

2.3.2 Jasmonic Acid (JA)

Arabidopsis and tomato plants exposed to jasmonic acid and methyl jasmonate produced more trichomes (Traw and Bergelson, 2003; Boughton *et al.*, 2005). Herbivores are hampered in their ability to reach the leaf epidermis by the thick covering of trichomes, which also hinders insects and other arthropods from travelling freely across the plant's surface. The loss of trichomes increases the vulnerability of leaves to increased attack of pest (Agrawal *et al.*, 2009). There is substantial evidence indicating that the density of trichomes on plants increases in response to herbivory and/or application of elicitors, as supported by numerous studies such as (Traw and Dawson, 2002; Bjorkman and Ahrne (2005). Black mustard's trichome density increased as a result of *P. rapae* infestation (Traw and Dawson 2002). On the word of Bruinsma *et al.*, (2007), female *P. rapae* and *P. brassicae* decreased their oviposition on cabbage plants treated with JA. The cabbage moth is inhibited from laying eggs by Methyl salicylate (MeSA), suggesting that MeSA is also detectable by the attacking herbivores (Ulland *et al.*, 2008).

Jasmonic acid (JA) is another important phytohormone which accumulates at the site of pest infestation on plants and mediates plants defense response to arthropod attack. The signaling pathway mediated by jasmonates (JAs) is crucial for regulating plant responses to insect pests, as highlighted by research conducted by Erb and Reymond, (2019). However, several defense genes participate in the jasmonic acid (JA) pathway of signalling to combat whiteflies. These genes encompass terpenoid synthesis genes, which are known to be positively regulated by JA treatment (Li *et al.*, 2014; Shi *et al.*, 2017; Sun *et al.*, 2017).

Hussain *et al.*, (2014) showed that pre-treatment of sorghum plants with SA and JA brought a hike in activity of defense related enzymes such as polyphenol oxidase (PPO), peroxidase (POD), catalase (CAT), superoxide and secondary metabolites viz., malondialdehyde (MDA), hydrogen peroxide (H₂O₂), and total phenols which induced resistance to stem borer, *chilo partellus*. Awang *et al.*, (2015) reported that exogenous application of JA acid (0.5mM) two times in the cropping period in chilli reduced biotic stress and improved plant growth and yield. Treatment of paddy seeds with JA acid derivative namely Methly Jasmonate (MeJA) had evidenced to reduce damage by rice water weevil (RWW), *Lissorhoptrus oryzophilus* (Kraus and Stout, 2019). Puentes *et al.*, (2021) reported that MeJA was known to induce resistance to pine weevils, *Hylobius abietis* in Norway spruce.

2.3.2.1 Mode of action of Jasmonic acid

The JA biosynthesis pathway uses the enzymes lipoxygenase (LOX), allene oxide synthase (AOS), and allene oxide cyclase to transform to produce JA (Pattyn *et al.*, 2021). Different defense response mechanisms can be regulated by ET and JA individually, but there has also been evidence of their interaction (Wang *et al.*, 2002).

Numerous studies indicate that jasmonates can enhance plant stress resilience by activating JA signaling pathways, responding to diverse adverse environmental conditions, alongside their involvement in growth and development. A crucial element of JA signalling pathways is the conjugated complex JA-Ile, which is receptor-active (Lakehal and Bellini, 2019; Marquis *et al.*, 2020; Zander, 2021). Environmental cues are perceived as initiating signals by cell surface receptors, which then trigger the JA-Ile element. This promotes interactions with transcription factors downstream, leading to the

activation of specific defensive mechanisms in plants (Howe *et al.*, 2018).

2.3.3 Acetic Acid

One of the primary byproducts of lactic acid bacteria, which are genera in the order *Lactobacilliales*, is acetic acid, which naturally occurs in many fruits as a metabolic intermediary. Acetic acid comes in many different forms, but vinegar (4-18% acetic acid) is the most well-known. It is produced for use in industry through submerged oxidative fermentation, in which acetic acid bacteria (*Acetobacter*) turn ethanol into acetic acid while exposed to oxygen (Gullo *et al.*, 2014). Due to Acetic acid antifungal and antibacterial qualities, acetic acid has been widely employed in food preparation as a preservative and disinfectant (Pao *et al.*, 2008; Alawlaqi and Alharbi, 2014). Due to these qualities, researchers have been attempting to employ it for plant protection, including seed treatment (Szopinska, 2013; El-Saidy and El-Hai, 2016; Rioux *et al.*, 2016; Dorna *et al.*, 2018). As noted by Billard *et al.*, (2014), humic compounds produced from peat have also been identified by Savy *et al.*, (2020) as bio-stimulants in maize. According to Kim *et al.*, (2017), 10 days old maize seedlings grown in greenhouses were treated with acetic acid through the growth medium for 4 days. Water was then stopped for six days, and then it was watered again for five days. The administration of acetic acid resulted in significantly increased survival rates when compared to the control group.

Moreover, foliar acetic acid application combined with saline growth media irrigation was found by Rahman *et al.*, (2019) to significantly increase root biomass, root length, and leaf carbon assimilation rate in comparison to controls that received water spraying under the same saline growth media irrigation conditions. Similar to this, Utsumi *et al.*, (2019) showed that treating greenhouse-grown cassava with at certain acetic acid concentration for one-week increased drought tolerance over a later two-week water withholding period. Compared to control plants under drought stress, this improvement was demonstrated by less wilting, greater leaf relative water content (RWC), more chlorophyll, higher leaf temperature, and less transpiration. Furthermore, despite acetic acid's positive benefits, Utsumi *et al.*, (2019) pointed out that before it could be used as a bio-stimulant in commercial maize production, difficult dosage challenges needed to be resolved.

2.3.3.1 Mode of action of acetic acid

High acetic acid content works well as a pest deterrent, especially for more vulnerable insects like ants, spiders, and mosquitoes. Acetic acid bacteria (AAB) are able to proliferate and flourish in the digestive systems of insects because of the availability of sugars from their food, acidic pH levels, and aerobic settings. Furthermore, AAB bind closely to insect epithelial cells. It is known that these bacteria produce polysaccharidic matrices, such as cellulose, which is involved in the production of biofilms, multicellular behavior, adherence to insect cells, and stress tolerance in insect pathogens (Barak *et al.*, 2007).

2.3.4 Panchagavya

Panchagavya an organic portion made by fermenting a mixture of cow's milk, curd, ghee, urine, and dung is used a fertilizer since decades (Vallimayil and Sekar, 2012). However, reports show the efficiency of panchagavya in managing insect pest on many different plant species plants by either repelling pest attack or by killing pests (Senthilkumar *et al.*, 2015) along with panchagavya also showed antifeedant activity against different pest reported by Pazhanisamy and Archunan, (2019) against *E. vittella*, Sowmiya *et al.*, (2020) against (*Leucinodes orbonalis*), Senthilkumar *et al.*, (2015) against pest in (*Tectona grandis*).

Tharmaraj *et al.*, (2011) conducted experiments to assess the efficacy of panchagavya, a Vedic formulation known for its potential to enhance plant productivity and disease resistance, as a biofertilizer. Various pulses, including greengram, blackgram, cowpea and guar were tested in soil enriched with dried conventional and sea-weed depend panchagavya. The study also involved crops like *Lablab purpureus*, *Cicer arietinum*, and *Oryza sativa* var. *ponni*. Results indicated that panchagavya significantly enhanced pest and disease resistance, leading to increased overall yields. Sireesha, (2013) further noted that panchagavya exhibits characteristics of both biopesticides and fertilizers.

Rajesh *et al.*, (2013) carried out a field study aimed at assessing the impact of different concentrations of panchagavya on the growth, biochemical characteristics, and yield parameters of black gram. The concentrations tested ranged from control (0%) to 10%, with increments of 3% for each concentration level. The findings suggest that Panchagavya application, when appropriately diluted, can positively influence the growth

and yield of black gram, particularly at lower concentrations. Therefore, it is recommended to dilute Panchagavya for use as a spray, as this approach resulted in enhanced growth and yield outcomes for the herb.

Consistent with Vasumathi, (2001) and Sanjutha *et al.*, (2008), it is suggested that the growth enzymes present in Panchagavya may contribute to the enhanced growth characteristics and increased height observed in plants like *P. amarus* and *A. paniculata*. These enzymes likely promote rapid cell division and multiplication, leading to overall improved growth outcomes in these plant species.

Beaulah, (2001) reported that the presence of advantageous microorganisms from panchagavya in the rhizosphere environment of the root zone affects development or progress and yield. As stated by Gore and Srinivas, (2011) the *Lycopersicon esculentum* plant's height and root length significantly increased when the recommended fertilizer dose + beejamruth + panchagavya + jeevamruth were applied (Tomato). Panchagavya improved numerous crops, including rice, turmeric, sugarcane, gingelly, onion banana, vegetables, and curry leaf in aspects of wideness, pests and diseases defendant, in terms of maintaining the quality of leafy-vegetables and fruits (Somasundaram and Amanullah, 2007; Tharmaraj *et al.*, 2011).

Multiple studies have revealed that treating seeds or applying farmyard manure (FYM) at a rate of 15 t/ha along with a combination of NPK fertilizers, coupled with foliar spraying of 3% Panchagavya, has led to enhanced physiological growth in various crops. This treatment regimen has resulted in taller plant heights, higher dry matter production, enhanced nitrogen content, elevated chlorophyll content, increased leaf area index, improved yield, better yield attributes, and favorable economic returns across a range of crops. These crops include radish, ashwagandha, okra, black gram, chickpea, wheat, groundnut, and finger millet (Patil *et al.*, 2012; Pagar *et al.*, 2015; Ananda and Murthy 2017; Choudhary *et al.*, 2017).

Pigeonpea and tomato seeds treated with panchagavya after 15 DAS had longer roots and shoots, higher dried mass, leaf area, chlorophyll content, and photosynthetic activity (Gore and Sreenivasa, 2011; Leo Daniel Amalraj *et al.*, 2013). According to Jain *et al.*, (2014), application of Panchagavya demonstrates superior effects compared to farmyard manure (FYM) and vermicompost in several aspects. Panchagavya application

leads to increased germination percentage, germination index, root and shoot length, as well as higher fresh and dry weight of seedlings. Additionally, it contributes to enhanced plant height and chlorophyll content. Moreover, Panchagavya application influences the availability of macro and micronutrients such as zinc (Zn), copper (Cu), and manganese (Mn), and it also affects microbial activity in the soil.

Naik *et al.*, (2013) observed that the application of Panchagavya either as a foliar spray or in the growth medium resulted in superior growth and spike production in *Cymbidium* hybrids. Additionally, Subramaniam, (2005) found conventional utilization were panchagavya as a manure increased nodulation by approximately 18% to 62%. In a study by Vijayakumari *et al.*, (2012) stated about soybean, that seeds soaked in a solution containing 1% Panchagavya and 1% humic acid for 8 hours produced harvested seeds with higher protein content and ascorbic acid as mg/g tissue in comparison with another solutions.

The combination of Neem with Panchagavya, Tumbo with Panchagavya, VAM (Vesicular Arbuscular Mycorrhizae) with Panchagavya along with Amritpani, or simply applying Panchagavya spray at 3% concentration has consistently resulted in increased yields across various crops. These treatments have shown improvements in yield at different stages after sowing, including 30, 60, and 75 days, exhibiting higher percentages of oil and protein, increased oil and protein yields, and higher plant dry matter compared to other treatments. This positive effect has been observed in crops such as groundnut, cumin, maize, and buckwheat (Mahajan *et al.*, 2012; Vimalendran and Wahab 2013; Sakhubai *et al.*, 2014; Waghmode *et al.*, 2015).

Choudhary *et al.*, (2017) documented significantly higher levels of dry matter, leaf area index, number of pods, seed yield, straw and biological yield in black gram. Boraiah *et al.*, (2017) exhibited increased capsaicin concentration in capsicum. Results for okra (*Abelmoschus esculentus*) plants treated with panchagavya showed an increase in plant height, branch count, fruit count, and single fruit weight. It was brought on by a rise in photosynthetic activity brought on by an increase in chlorophyll content. When compared to the control, panchagavya application also raised the phenols, DPPH activity, carotenoids, and ascorbic acid (Swarnam *et al.*, 2016; Rakesh *et al.*, 2017).

2.3.4.1 Mode of action of panchagavya

Panchagavya is rich in various components including total reducing sugars such as glucose, as well as essential macronutrients like NPK along with micronutrients such as zinc, iron, copper, and manganese. Research by Papen *et al.*, (2002) suggests that the presence of chemolithotrophic and autotrophic nitrifiers (ammonifiers and nitrifiers) in Panchagavya contributes to enhanced ammonia absorption and overall nitrogen (N) supply. These microorganisms thrive in the leaves, aiding in the biological processes that support plant growth.

Panchagavya also contains effective microorganisms, which are a blend of naturally occurring beneficial microorganisms. These include lactic acid bacteria, actinomycetes, yeast, some fungi and photosynthetic bacteria. These microorganisms play crucial roles in various biological processes like cycling of nutrient, disease suppression, and improving soil health, thereby promoting overall plant growth and productivity (Xu, 2001; Swaminathan *et al.*, 2007). Panchagavya is a crop plant fertilizer used frequently in organic farming that is a combination of five different cow products. It is applied to soil, used as a foliar spray, and treated seeds. It can increase immunity and encourage growth (Tharmaraj *et al.*, 2011; Vallimayil and Sekar, 2012; Sireesha, 2013).

2.3.5 Vermicompost

Vermicompost is top-notch organic manure that is abundant in microbes that promote plant growth and act as biocontrol agents. It has been observed to protect plants from a different pathogen of plants and insect pests by using a variety of mechanisms that fortify the plant's resist to living and non-living parameters. Vermicompost can therefore be used as a biopesticide and a biofertilizer, and it will be crucial for sustainable agriculture (Pathma and Sakthivel, 2012 and 2013; Pathma *et al.*, 2019).

Nitrogen in the vermicast, which is produced by the decomposition of earthworm tissues and resulting in nitrogen mineralization with the aid of soil bacteria, may be to blame for the rise in N₂ concentration. Vermicomposted soil has a considerably higher nitrogen concentration than unvermicomposted soil, P₂O₅ is made up of 19.58% phosphorous and 7.37% nitrogen in worm's vermicast (Ananthakrishnasamy *et al.*, 2009; Chauhan and Joshi, 2010; Ansari and Ismail, 2012). Consistent with research by Ebrahimi *et al.*, (2021) vermicompost improves nutrients availability such has iron, potassium, and

phosphorus, as they are an organic source.

By adding 10 to 20% vermicompost to the soil, researchers saw 91 -100 % germination in their respective crops of trials compare to control plots which were conducted by them (Nadi *et al.*, 2011; Bhat and Limaye, 2012). As stated by Esakkiammal *et al.*, (2015) *Dolichous lablab* showed a similar tendency of increased height (shoot length), with plant height significantly rising over control. Worm castings in vermiwash and vermicompost can also be added to soil or other growing medium to boost yields, plant development, and pest resistance, according to studies (Pathma and Sakhtivel, 2012; Varghese and Prabha, 2014; Joshi *et al.*, 2015).

The advantages of vermicompost on plants and soil have been assessed in a number of review publications who mentioned that vermicompost, according to studies, increased the soil's quality, capacity to hold water, and porosity along with include hormones, mucus, vitamins, numerous macro and micronutrients, enzymes, proteins and a various bacterium (Joshi *et al.*, 2015; Datta *et al.*, 2016; Durak *et al.*, 2017). Karimi *et al.*, (2017) said that vermicompost helps to improved pathogens from cow dung waste and waste water and helps to improve soil. The effect of organic fertilizer on cucumber had a 22.6% increase in plant length while okra plant development was enhanced by the vermicompost increased soil porosity, fertility and water gaining capacity of soil (Ghasem *et al.*, 2014; Gupta *et al.*, 2018).

Vermicompost, as opposed to conventional composting, is a soil amendment devoid of pathogens and with nutrient forms that are easier for plants to absorb (Lim *et al.*, 2015). Consistent with Hussain, (2016) municipal wastewater, heavy metal rehabilitation of contaminated areas, and agricultural and industrial waste streams have all been identified as applications for vermicompost technology) earthworms are effective at restoring depleted agricultural soils of nutrients and improving plant growth, yield, health, and pest resistance. The extensive body of research on the advantages of vermicompost suggests that using it could potentially be a practical solution to these issues (Joshi *et al.*, 2015; Datta *et al.*, 2016).

Plant species and vermicompost concentration appear to have an impact on the type of effect that vermicompost has. The genotype of plants has a significant impact on seed germination, which is fundamentally an internally controlled process. But

environmental variables including temperature, humidity, sun exposure, soil moisture, and the presence of specific chemical compounds can also influence this process by either promoting it or inhibiting it. All of these elements interact with one another and are aided by numerous hormones that communicate to either encourage or hinder seed germination (Kucera *et al.*, 2005; Najar *et al.*, 2015).

In latest research by (Hussain *et al.*, 2016; 2017; 2018) it was discovered that vermicompost derived from parthenium, salvinia, ipomoea and lantana increase the seed germination rate according to numerous additional reports, the improved beneficial nutrient rate in the vermicompost amended soil/media are increased plant growth and its output (Sujatha and Bhat, 2016; Tombion *et al.*, 2016; Das *et al.*, 2017).

Numerous research has been done to determine how applying vermicompost to crops affects their growth and development (Lazcano and Dominguez, 2011). For instance, it has been demonstrated that vermicompost improved plant growth yield for Maize (*Zea mays*) by fostering favorable conditions for plant feeding (Joshi *et al.*, 2015; Liu *et al.*, 2019). Additionally, vermicompost is said to typically include more nutrients than organic matter obtained from plants, and helps to acquired essential elements to plants. Vermicompost is rich in plant growth regulators and has significant levels of microbial and enzymatic activity in respective crops as per trials conducted by researchers (Mahmud *et al.*, 2018; Pierre-Louis *et al.*, 2021).

Suitable use of vermicompost, it is feasible to improve soil management and increase organic carbon storage, media grows, the quantity of elements such as (zn, ca, and n) in plant-parts substantially increases (Cruz *et al.*, 2018). Treatment with vermicompost considerably boosted morphological features such root length, stem length, and the number of leaves in chickpea and pea (Hosseinzadeh *et al.*, 2016; Paczka *et al.*, 2021).

2.3.5.1 Mode of action of Vermicompost

An essential vermicompost product that is readily accessible to plant roots is vermiwash. It is a vermicompost-draining solution that is rich in earthworms. It has a high concentration of CF together with other bioactive substances that work in harmony with earthworms, including proteins, mucus, hormones, vitamins, enzymes, and decomposer bacteria (Aghamohammadi *et al.*, 2016; Nadana *et al.*, 2020; Gudeta *et al.*, 2021).

However, vermicompost is equally good in suppressing diseases and controlling pests because it contains bioactive components such as earthworm coelomic fluid (CF), which has antifungal and insecticidal characteristics. Because of its antibacterial qualities, CF is expelled via the dorsal pores as mucus, which serves as a defense mechanism (Nadana *et al.*, 2020). Through an evolutionary process, earthworms were able to generate bioactive chemicals that enable them to protect against soil diseases. These compounds are made unique by different chains of amino acids (Gupta and Yadav, 2016; Gudeta *et al.*, 2021).

Vermicompost has the potential to be a naturally occurring, gradually released source of plant nutrients that enhances plant health, development, yield, and resistance to pests. As a result, certain plant growth that promoted the nutrients in the vermicompost made outstanding development feasible.

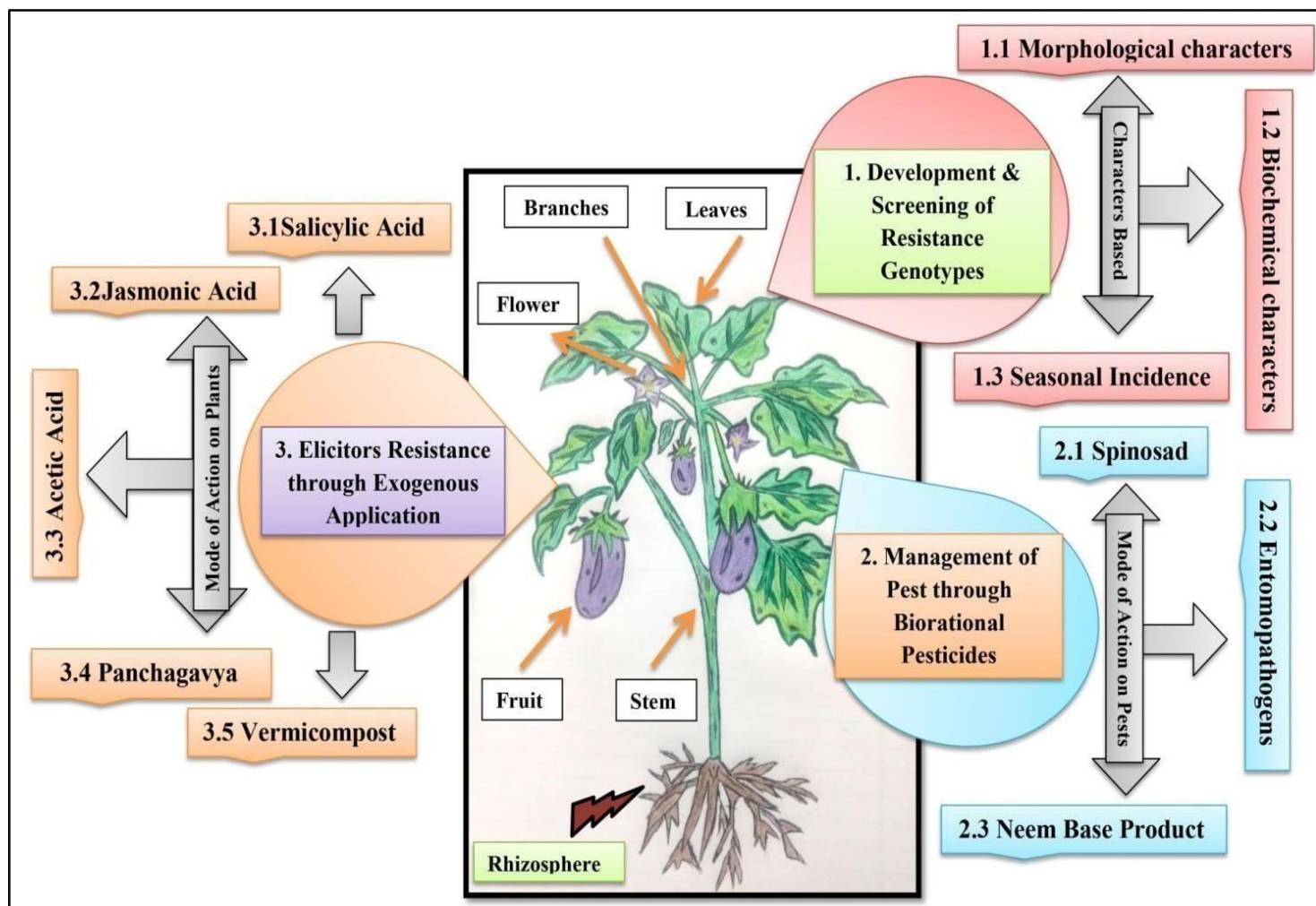


Fig. 4 Developing eco-friendly management strategies for major pests of brinjal

3.1 Experimental site, geography and climatic conditions

The field trials on the studies entitled “Designing sustainable, eco-friendly approaches for management of major arthropod pests of brinjal (*Solanum melongena* L.) with emphasis on host plants innate and induced resistance”. were carried out in Entomology Research Area, School of Agriculture of Lovely Professional University, Phagwara, Punjab during years 2020 to 2023. The farm is situated at latitude 31.250 ° N, altitude of 232 meter above mean sea level and longitude 75° E. Punjab has semi-arid, tropical and subtropical monsoon type of climate (Kumar, 2021).

3.2 Weather and climate conditions

The meteorological data was obtained from Meteorological observatory located on the LPU’s research farm. Phagwara experiences a climate that combines features of both humid subtropical and semi-arid conditions, marked by notable temperature extremes in both summer and winter seasons. Summers, spanning from April to June, are characterized by hot and dry conditions, while July to September brings hot and humid weather. Winters, from November to January, are cold, followed by milder temperatures in February and March. In the summer months, temperatures soar with maximums reaching up to 48°C and minimums around 25°C. Conversely, during winter, maximum temperatures hover around 19°C, with minimums dropping to as low as -1°C. The region receives an average annual rainfall ranging from 500 to 750 mm, with the majority occurring between July and September due to the influence of the South-West monsoon (Kumar, 2021).

3.3 Experimental layout, crop cultivation and data recording

Seeds of the selected cultivars/hybrids were purchased from the Punjab Agriculture University and local market. Seedlings were raised in the polyhouse and 45 days old seedlings were transplanted in the field with a spacing of 60 × 45 cm. For all the field trials Randomized Block Design (RBD) was adopted. For each trial an area of 450 sq.mt was utilized. All the cultivation practices except crop protection were carried out as per recommendation. Regular monitoring of the field was done. Observations were made on five randomly selected plants at weekly intervals as per the standard procedures and data was recorded as to suit the need as detailed under each section.

3.3.1 To screen various brinjal cultivars for identification of cultivar resistant to major arthropod pests of brinjal and to study seasonal incidence of brinjal pests and their natural enemies."

3.3.1.1 Experimental details

Details of the experiment:

Experimental design: Randomized Block Design (RBD)

Treatment: Eight

No. of replications: Three

Crop: Brinjal,

Method of sowing: Transplanting

Spacing: 60 × 45 cm

Plot size: 3.6 × 4.8 sq.mt

Experimental Season (s): *Rabi* and *Kharif* seasons

Varieties:

T₁- Manjushree.

T₂- NBH-1214

T₃- Ajay

T₄- Punjab Bharpur

T₅- MAHY-91

T₆-Navkiran,

T₇- Nishant

T₈- VNR 51C

Border Space	R ₁	Irrigation channel	R ₂	Irrigation channel	R ₃	Border Space
1 mt	4.8 m			1 m		
	T ₁ R ₁		T ₈ R ₂		T ₅ R ₃	
	T ₂ R ₁		T ₇ R ₂		T ₄ R ₃	
	T ₃ R ₁		T ₆ R ₂		T ₈ R ₃	
3.6 m	T ₄ R ₁		T ₁ R ₂		T ₃ R ₃	3.6 m
	T ₅ R ₁		T ₂ R ₂		T ₇ R ₃	
	T ₆ R ₁		T ₃ R ₂		T ₁ R ₃	
	T ₇ R ₁		T ₄ R ₂		T ₂ R ₃	
	T ₈ R ₁		T ₅ R ₂		T ₆ R ₃	
	4.8 m			1 m		

	Trial plots
	Irrigation channel
	Border space around the layout

Fig 5. Field layout for varietal screening of different brinjal varieties against major pest of brinjal

Different brinjal varieties suitable for season were purchased from Punjab Agriculture University and local market which was planted in LPU experimental farm land. Brinjal was grown with a spacing of 60×45 cm in Randomized block design (RBD) and the size of the plot was 17.28 m^2 (4.8×3.6 Sq.mt). All the cultivation practices were followed as per recommendation except insect control. Seedlings were raised in the hi-tech polyhouse facility in LPU and were transplanted on main field at 45 days after sowing (DAS).

3.3.1.2 Data Collection

I) Data of pest occurrence on all screened brinjal varieties

Weekly observations were conducted to evaluate the prevalence of insect pests and their natural predators or enemies across various brinjal varieties. Observations were conducted on five randomly chosen plants from each plot at weekly intervals to monitor the presence of jassid, whitefly, brinjal shoot and fruit borer and hadda beetle. Data was systematically recorded to fulfill the specific requirements outlined for each section of observation.

The grade index for relative tolerance or resistance category was determined based on the number of pest insects per five plants for shoot borer and five leaves per plant for jassid. Fruit infestation was assessed by counting the number of damaged fruits and calculating the damage percentage according to the resistance category provided by (Subbaratnam and Butani, 1981; Mishra *et al.*, 1988; Mukhopadhyay and Mandal, 1994; Kavishetty and Rani, 2018). According to Barik *et al.*, (2020), the estimation of Hadda beetle plant damage was carried out by selecting three leaves from the top, middle, and bottom sections of the plant at random. The mean was calculated, and the scoring was based on the extent of damage to the leaf area.

Category	Jassid	Shoot damage	Fruit damage	References
Tolerant	< 10.0	< 2.0	< 15.0 %	Subbaratnam and Butani, 1981; Mukhopadhyay and Mandal, 1994; Mishra <i>et al.</i> , (1988); Kavishetty and Rani (2018).
Moderately tolerant	11.0 - 19.0	2.1-3.0	16.0 - 25.0 %	
Susceptible	23.0 - 30.0	3.1-5.0	26. 0 - 40.0 %	
Highly susceptible	> 30.0	> 5.0	> 40 %	
Category	Hadda Beetle Plant Infestation (%)			References
Highly resistant	0-1 = 25 %	1. Approximately up to 1/4th of leaf area infested		Barik <i>et al.</i> , (2020).
Resistant	1-2 = 50 %	2. Approximately up to 1/2 of leaf area infested		
Susceptible	2-3 = 75 %	3. Approximately up to 3/4th of leaf area infested		
Highly susceptible	3-4 = > 75 %	4. Approximately more than 3/4th of leaf area infested		

a) Jassid and Whitefly

Weekly observations were conducted to determine the occurrence of pest as combine data of Jassid (nymph and adult) and Whitefly (adult) were taken for each pest (population of per five leaves) on five randomly selected plants from each plot. These observations were carried out during the evening time.

b) Brinjal shoot and fruit borer

Data for brinjal shoot borer damage and fruit borer damage (larval) population

were recorded at weekly interval where the number of infested shoots from the five randomly selected plants was recorded in each treatment refer as pest data for shoot infestation. During harvesting, brinjal fruits from each plot were separated as infested and healthy fruits at each picking. The healthy and unhealthy fruits were counted separately in which fruits showing exit holes of pest were considered as infested fruits. Total yield of healthy and unhealthy was noted and expressed in kg per hectare. The fruit infestation percentage was counted by through formula

$$\% \text{ Fruit Infestation} = \frac{\text{Infested Fruit}}{\text{Total fruit}} \times 100$$

c) Hadda Beetle

On field, combine data of hadda beetle (grub and adult) observation were made at weekly intervals to assess the incidence of pests on different brinjal varieties from five randomly selected plants and damaged plant from each plot were noted during evening time.

II) Weather data correlation with pest data of all brinjal screened varieties

Moreover, weather data including maximum temperature (°C), minimum temperature (°C), morning relative humidity (%), evening relative humidity (%), and total rainfall (mm) were collected from the meteorological laboratory situated within the experimental farm (LPU). These weather parameters were then correlated with recorded pest data to ascertain the impact of weather conditions on brinjal pests.

3.3.1.3 Morphological characteristics of different brinjal varieties

Morphological characters such as – 1) Plant - Plant growth habit. 2) Leaf morphology - a. Leaf blade length, b. Leaf blade width, c. Leaf blade thickness, d. Leaf blade lobing, e. Leaf blade color, f. Leaf blade tip angle, g. Leaf prickles, h. Petiole length and diameter, i. Petiole color. 3) Flower - a. Corolla color, b. Flower petiole diameter, c. Flowers inflorescence. 4) Fruit - a. Fruit calyx length, b. Fruit calyx prickles, c. Fruit pedicel length, d. Fruit pedicel thickness, e. Fruit pedicel prickles, f. Fruit Broadness, g. Fruit color @ commercial ripeness, h. Fruit curvature, i. Fruit apex shape, j. Fruit cluster of different brinjal varieties were studied. In order to understand the effect of plant

morphology on incidence of pests, the morphological characters of different brinjal varieties viz., popular brinjal hybrids T₁ - Manjushree, T₂ - NBH-1214, T₃ - Ajay, T₄ - Punjab Bharpur, T₅ - MAHY-91, T₆ - Navkiran, T₇ - Nishant, T₈ - VNR 51C were closely observed.

Trichome length from three selected trichome and diameter of one trichome from 1 cm leaf area was measured on FESEM analysis instrument (Company - JEOL JSM- 7610F PLUS), where difference was seen in all varieties trichomes length and diameter.

3.3.1.4 Biochemical analysis of brinjal leaves

Laboratory experiments were carried out to analyze the variations in the biochemical constituents of different brinjal varieties used. Healthy leaves of brinjal different varieties were analyzed for Phenols, Protein, Proline, Peroxidase (PO) and Phenylalanine Ammonia Lyase (PAL). Phenol activity was analyzed as per the standard protocol and catechol was used as standard (Zieslin and Ben-Zaken, 1993) while protein estimation was done as per the standard protocol Lowrys method (Lowry *et al.*, 1951). Peroxidase (PO) activity was also analyzed as described (Hammerschmidt *et al.*, 1982). Phenylalanine Ammonia Lyase (PAL) activity was analyzed through (Brueske, 1980) method. Proline was also estimated through Isatin paper assay method (Chinard, 1952).

3.3.1.5 Statistical analysis

Laboratory experiments were carried out in completely randomized block design (CRD). All the data obtained was subjected to an analysis of variance (ANOVA). To determine the relationship between major pest's density and abiotic factors such as temperature, rainfall and relative humidity, Pearson correlation was used. DMRT were used for mean separation (Gomez and Gomez, 1984). SPSS version 22.0 was used.

3.3.2 Testing the efficacy of bio rational insecticides against major pests of brinjal

Field trials were conducted in the experimental farm of LPU to assess the effectiveness of bio-rational insecticides in controlling the primary pests of brinjal. Each plot had a size of 17.28 m² (4.8×3.6 sq. meters), and the experiment was structured using a randomized block design with six treatments and three replications. Treatments were applied once the pest population exceeded the Economic Threshold Levels (ETL).

In *Rabbi* season of 2021 and 2022 only, single spray was required as pest

population was not exceeded above ETL level after 14 days and in *Kharif* season of 2022, due to more rain pest population was not exceed after first spray so only single spray was done but Kharif season of 2023 required second spray after 21 days as pest population were increased again and cause damage, so second spray were taken. Low volume of spray was utilized as six treatment and four replications was there. Commercial formulations NEEM GREEN, BEAUVE GREEN, META GREEN and VERTI GREEN are used of company Green Tech Agro Products, At Post - karendi Kheba, Tal - Bhor Dist – Pune, Maharashtra.

Details of the experiment:

Experimental design: Randomized Block Design (RBD)

Treatment: Six

Replications: Four

Crop and Variety: Brinjal VNR - 51C

Spacing: 60 × 45 cm

Plot size: 3.6 × 4.8 sq.mt

Experimental Season (s): *Rabi* and *Kharif* season

Treatments:

T₁ – TRACER (Spinosad 45 % SC @ 0.4ml/l)

T₂ – NEEM GREEN (NSKE 1% @ 2ml/l)

T₃ – BEAUVE GREEN (*Beauveria bassiana* 1x 10⁸ conidia/ml @ 10ml/l)

T₄ – META GREEN (*Metarhizium anisopliae* 1x 10⁸ conidia/ml @ 10ml/l)

T₅ – VERTI GREEN (*Verticillium lecanii* 1x10⁸ conidia/ml @ 10ml/l)

T₆ - Control

1m			4.8m				1 m
	T4R1	T2R1	T6R1	T1R1	T3R1	T5R1	
3.6 m	T1R2	T3R2	T4R2	T5R2	T6R2	T2R2	3.6 m
	T5R3	T6R3	T2R3	T3R3	T4R3	T1R3	
0.75m							0.75m
	T2R4	T4R4	T1R4	T6R4	T5R4	T3R4	

	Trial plots
	Irrigation channels
	Border space around the layout

Fig. 6 Field layout for testing the efficacy of biorational insecticides against major pest of brinjal

3.3.2.1 Experimental layout, crop cultivation and data recording

Seedlings were brought from local growers which of 45 days old and was transplanted in the field with a spacing of 60 x 45 cm. For all the field trials Randomized Block Design (RBD) was adopted. For each trial an area 450 sq.mt was utilized. All the cultivation practices were carried out as per recommendation.

3.3.2.2 Data Collection

Regular monitoring of the field was done. Observations were made on five randomly selected plants at one day intervals as per the standard procedures and data was recorded as to suit the need as detailed under each section. Formula used for transforming data was same for all insects' pests except natural enemies.

$$\text{Overall Reduction Percentage} = C - T \div C \times 100$$

Where, C represents - Control plot population and T represents - Treatment plot population

a) Jassid and Whitefly

The treatments were imposed once the pest crosses the ETL levels and observation was made at one day intervals for the incidence of Jassid (nymph and adult) and Whitefly (adult) combine data of nymph and adult were taken for each pest (population per five leaves) on five randomly selected plants from each plot during evening time.

b) Brinjal shoot and fruit borer

Data for brinjal shoot borer damaged and fruit borer damaged (larva) population was recorded at one day interval where the number of infested shoots from the five randomly selected plants was recorded in each treatment refer as pest data for shoot infestation. During harvesting, brinjal fruits from each plot were separated as infested and healthy fruits at each picking. The healthy and unhealthy fruits were counted separately in which fruits showing exit holes of pest were considered as infested fruits.

Total yield of healthy and unhealthy fruits was noted and expressed in kg per hectare.

$$\% \text{ Fruit Infestation} = \frac{\text{Infested Fruit}}{\text{Total fruit!}} \times 100$$

C) Coccinellids

Hadda beetle (grub and adult) combine data observations were made on five randomly selected plants at one day intervals from each plot in the evening. For predatory coccinellids regular monitoring of the field was done. Observations were made on five randomly selected plants at one day intervals as per the standard procedures and data was recorded as to suit the need as detailed under each section. Just natural enemies' data of larval and adult was expressed with below formula.

$$\text{Mean density} = \sum X_i \div N$$

Where, X_i = Number of natural enemies in i^{th} sample

N = Total numbers of plants sampled.

3.3.2.3 Statistical analysis

All collected data underwent analysis of variance (ANOVA). Mean values were separated using Duncan's New Multiple Range Test (DMRT) according to the method outlined by Gomez and Gomez (1984). SPSS version 22.0 was employed for all statistical analyses.

3.3.3 Exogenous application of elicitors inducing host plant resistance in managing major pests of brinjal

Field trials were conducted in experimental farm of LPU to evaluate efficacy of exogenous application of various compounds eliciting immune response in plants against insect herbivore. RBD was used and treatments were carried out in plot size 17.28 m² (4.8×3.6 sq.mt). The treatments were imposed once the pest crosses the ETL levels.

In *Rabbi* season of 2021 and 2022 only, single spray was required as pest population was not exceeded above ETL level after 14 days and in *Kharif* season of 2022, due to more rain pest population was not exceed after first spray so only single spray was done but *Kharif* season of 2023 required second spray after 21 days as pest population were increased again and cause damage, so second spray were taken. Low volume of spray was utilized as six treatment and four replications was there.

Details of the experiment:

Experimental design: Randomized Block Design (RBD)

No. of Treatments: Six

No. of replications: Four

Crop and Variety: Brinjal, Navkiran F1 hybrid

Spacing: 60 × 45 cm

Plot size: 3.6 × 4.8 sq.mt

Experimental period: *Kharif* and *Rabi* season(s).

Treatments:

T₁ - Salicylic acid @ 50 mg/l

T₂ - Jasmonic acid @ 395 mg/l

T₃ - Acetic acid @ 0.6ml/l

T₄ - Panchagavya 5 % solution/l

T₅ - Vermicompost @ 5 tonnes / hectare

T₆ - Control

1 m			4.8 m				1 m
	T4R1	T2R1	T6R1	T1R1	T3R1	T5R1	
3.6 m	T1R2	T3R2	T4R2	T5R2	T6R2	T2R2	3.6 m
	T5R3	T6R3	T2R3	T3R3	T4R3	T1R3	
0.75 m							0.75 m
	T2R4	T4R4	T1R4	T6R4	T5R4	T3R4	
			4.8 m				

	Trial plots
	Irrigation channels
	Border space around the layout

Fig. 7 Field layout for screening eco-friendly elicitors inducing host plant resistance against major pest of brinjal

3.3.3.1 Data Collection

Regular monitoring of the field was done. Observations were made on five randomly selected plants at one day intervals as per the standard procedures and data was recorded as to suit the need as detailed under each section. Data of different insect-pests and natural enemies on brinjal plants was collected as per mentioned in previous experiment. Formula used for transforming data was same for all insects' pests except natural enemies.

$$\text{Overall Reduction Percentage} = \frac{C - T}{C} \times 100$$

Where, C represents - Control plot population and T represents - Treatment plot population

a) Jassid and Whitefly

The treatments were applied once the pest populations exceeded the Economic Threshold Levels (ETL), and observations were conducted at one-day intervals to assess the incidence of Jassid (nymph and adult) and whitefly (adult) were taken for each pest (population per five leaves) on five randomly selected plants from each plot during the evening time.

b) Brinjal shoot and fruit borer

Data for brinjal shoot borer damage and fruit borer damage (larval) population was recorded at one day interval where the number of infested shoots received from the five randomly selected plants was recorded in each treatment refer as pest data for shoot infestation. During harvesting, brinjal fruits from each plot were separated as infested and healthy fruits at each picking. The healthy and unhealthy fruits were counted separately in which fruits showing exit holes of pest were considered as infested fruits. Total yield of healthy and unhealthy fruits was noted and expressed in kg per hectare.

$$\% \text{ Fruit Infestation} = \frac{\text{Infested Fruit}}{\text{Total fruit}} \times 100$$

c) Coccinellids

Hadda beetle (grub and adult) combine data observations were made on five randomly selected plants at one day intervals from each plot in the evening. Regular

monitoring of the field was done. An observation was made on five randomly selected plants at weekly intervals as per the standard procedures and data was recorded as to suit the need as detailed under each section. Just natural enemies' data of larval and adult was expressed with below formula.

$$\text{Mean density} = \sum X_i \div N$$

Where, X_i = Number of natural enemies in i^{th} sample

N = Total numbers of plants sampled.

3.3.3.2 Biochemical analysis of brinjal leaves

Laboratory experiments are carried out to analyze the variations in the biochemical constituents of different brinjal varieties used. Healthy leaves of brinjal different varieties was analyzed for phenols, peroxidase (PO), polyphenol oxidase (PPO), phenylalanine ammonia lyase (PAL). Similar analysis was carried in plant samples from spray trials where exogenous application of immune elicitors and modulators was done. Phenol activity was analyzed as per the standard protocol and catechol was used as standard (Zieslin and Ben-Zaken 1993) while protein estimation was done as per the standard protocol Lowrys method (Lowry *et al.*, 1951). Peroxidase (PO) activity was analyzed as described (Hammerschmidt *et al.*, 1982). Phenylalanine Ammonia Lyase (PAL) activity was analyzed by (Brueske, 1980). Proline was also estimated through Isatin paper assay method (Chinard, 1952).

3.3.3.3 Statistical analysis

Laboratory experiments were conducted using a completely randomized block design (CRD). Subsequently, all collected data was undergone analysis of variance (ANOVA). Mean values was separated using Duncan's New Multiple Range Test (DMRT) according to the method described by Gomez and Gomez (1984). Additionally, for statistical analysis, correlation, and regression analysis, SPSS version 22.0 was utilized.

4.1. To screen various brinjal cultivars for identification of cultivars resistant to major arthropod pest of brinjal and to study seasonal incidence of brinjal pests and their natural enemies.

4.1.1 Jassid (*Amrasca biguttula biguttula*)

The mean population of jassid (nymph and adult) varied significantly among different varieties (Table 4). The initial population of jassid ranged between 8.93 to 22.35 per plant and 9.79 to 21.97 per plant observed during *Rabi* 2022 and *Kharif* 2023 season respectively. All the varieties showed highly significant difference responses against the jassid ($df_{(8,3)}$; $F = 697.204$; $P < 0.001$ in *Rabi* 2022 and ($df_{(8,3)}$; $F = 353.907$; $P < 0.001$) during *Kharif* 2023 respectively (Table 4). The jassid population was maximum in variety VNR-51C (22.35 ± 0.57 and 21.97 ± 0.65) followed by Navkiran (21.59 ± 0.29 and 21.23 ± 0.19) while minimum jassid population was observed in Ajay (10.21 ± 0.13 and 9.79 ± 0.25) followed by NBH-1214 (8.93 ± 0.15 and 9.80 ± 0.31) during *Rabi* 2022 and *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1A)

The mean incidence of jassid (nymph and adult) population in all varieties was noted as per resistance category in which the highest incidence was noted in VNR-51C, Navkiran and Nishant were found susceptible with jassid population whereas, Manjushree, Punjab Bharpur and MAHY-91 reacted as moderately tolerant varieties while lowest mean population was noted in tolerant varieties like Ajay and NBH-1214 during the both seasons respectively (Table 4; Fig. 8; Plate 1A). The mean incidence of jassid (nymph and adult) population from maximum to minimum sequence of all varieties was observed like VNR-51C > Navkiran > Nishant > Manjushree > Punjab Bharpur > MAHY-91 > Ajay > NBH-1214 (Table 4; Fig. 8; Plate 1A).

Varieties exhibit varying responses to jassids based on geographical location, pest pressure, and the presence of biochemical compounds in leaves, all of which influence jassid population dynamics. Varieties are categorized as highly resistant or resistant based on these characteristics (Abang *et al.*, 2016; Bilal *et al.*, 2017; Sultana *et al.*, 2017; Sowmya and Pradeep, 2020). The abiotic parameters have important role in the dividing pest

population on crops like brinjal. A number of studies revealed that results of the brinjal varietal screening against jassid cannot be quite well compared among different studies because various researchers used different cultivars under varied environmental conditions (Mahmood *et al.*, 2002; Sonali, 2008; Ramzan *et al.*, 2019; Naeem-Ullah *et al.*, 2020).

The behavior of the jassid population exhibited variability in response to the levels of resistance found in different varieties or cultivars of brinjal across various localities like Sowmya and Pradeep, (2020) reported from Shimoga that screening of thirty-four varieties of brinjal were done against jassid, maximum number of jassid was noticed in hassiru udda badane and minimum in Kanakapura badane. Similar results, but for different cultivars, mentioned by According to Gautam *et al.*, (2019a), who conducted their study in Gwalior, Madhya Pradesh, the variety "Local Deshi" was identified as highly susceptible to jassids. Following this, "Green Star" and "Qayamat" were observed to be relatively less susceptible to jassid infestation. Less susceptible variety noted (Ananya next Kiran, BR-112 and Nano-38). Praveen *et al.*, (2018) conducted a study in Andhra Pradesh, where they found that IC-090050 exhibited high resistance to *A. devastans*, with a hopper burn intensity of 9.90 percent. This intensity was notably lower compared to Bhagyamathi and Dommeru local varieties, which recorded 1.41 and 2.74 times higher percent jassid intensity, respectively.

Mahmood *et al.*, (2002) reported similar findings from Nepal, indicating that different varieties of brinjal showed consistent differences in jassid population. Specifically, they found that Violetta Lunga and Prospara varieties consistently had higher jassid populations, while Nepali and Purple Long varieties had lower populations. Jafir *et al.*, (2018) done a experiment in Faisalabad, Pakistan, where they assessed thirteen different genotypes of brinjal for their resistance to jassid. They observed that the genotype AB-317, which was susceptible, had the highest population of jassid. In contrast, the genotype Twinkle Star, which exhibited resistance to jassid (*Amrasca devastans*), had the lowest population of jassid. Murtaza *et al.*, (2020) reported from Beijing, China that jassid population density was lowest in December on all varieties while maximum in November such as Bemisal and Dilnasheen varieties had significantly higher jassid population per leaf as compared to Nirala variety on different sampling dates. Many researchers had reported the similar result that jassid population varies according to brinjal varieties. The variety Black Beauty

consistently had the higher and Nirala had the lower population reported from Pakistan (Yousafi *et al.*, 2013).

Salve *et al.*, (2020) recorded varieties (JKJEH-6012, Utkal keshri, Pusa Upkar) with considerably less damaged, more susceptible cultivar (JBH-3); Shaikh *et al.*, (2013) mentioned (low damaged- AB-09-1, JBGR 1) and (high loss-AB 09-14) cultivars against jassids. Reddy and Srinivasa, (2001) conducted a study where they monitored jassid infestation at fifteen days interval ranging in thirty and ninety days afterwards transplanting. They observed that during the *Kharif* season, jassid populations were abundant on varieties such as Green Long, Arka Neelkant, and Arka Sheel. In contrast, they found lower populations of jassid on varieties such as MHB 10, Pusa Purple Round, Pusa Purple Long, and Arka Shirish. Dahatonde *et al.*, (2014), reported that genotypes of brinjal, AB-8/5 resistant to jassids which was significant with the varieties AB-9/1, JBG- 6/7, JBG-8/6 and JBR-8/8 respectively.

4.1.2. Whitefly (*Bemisia tabaci*)

The mean population of whitefly (adult) varied significantly among different varieties (Table 4; Fig. 8; Plate 1B). The initial population of whitefly (adult) ranged between 8.82 to 22.82 per plant and 9.33 to 23.15 per plant observed during *Rabi* 2022 and *Kharif* 2023 season respectively. All the varieties showed highly significant difference responses against the whitefly ($df_{(8,3)}$; $F = 194.826$; $P < 0.001$ in *Rabi* 2022 and ($df_{(8,3)}$; $F = 222.726$; $P < 0.001$) during *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1B). The whitefly population was maximum in variety VNR-51C (22.82 ± 1.18 and 23.15 ± 0.62) followed by Navkiran (21.37 ± 1.18 and 22.05 ± 0.36) while minimum whitefly population was observed in NBH-1214 (9.49 ± 0.09 and 10.15 ± 0.34) followed by Ajay (8.82 ± 0.03 and 9.45 ± 0.25) during *Rabi* 2022 and *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1B).

The mean incidence of whitefly (adult) population in all varieties was noted as per resistance scale in which the highest incidence was noted in VNR-51C, Navkiran and Nishant was found susceptible with whitefly population whereas, Punjab Bharpur and Manjushree reacted as moderately tolerant varieties while lowest mean population was noted in tolerant varieties like MAHY-91, NBH-1214 and Ajay during both the seasons

respectively (Table 4; Fig. 8; Plate 1B). The mean incidence of whitefly (adult) population from maximum to minimum sequence of all varieties was observed like VNR-51C > Navkiran > Nishant > Punjab Bharpur > Manjushree > MAHY-91 > NBH-1214 > Ajay (Table 4; Fig. 8; Plate 1B).

Peak population of whitefly was recorded higher during 5th week of October (44th SMW) reported by Berani and Patel, (2020). Various researchers noted whitefly incidence or population on different cultivars of brinjal at varied geographical regions like Jafir *et al.*, 2018 reported from Faisalabad, Pakistan that incidence of whitefly notes as (higher on cultivar- Galine F1 and lower on three cultivars as Dill > Advanta-314 > Twinkle star consider as resistance genotypes) continued with finding of Gautam *et al.*, (2019a) reported from Gwalior, Madhya Pradesh that eggplant varieties (highest prone - Qayamat, Green star, Local deshi and less prone - Ananya, Kiran, BR-112, Nano-38). Praveen *et al.*, (2018) reported from Andhra Pradesh, population of whiteflies on eggplant genotype has (least- IC-127074 and highest on -IC090050); Salve *et al.*, (2020) observed (least on - JB-262, BH-2 and highest - JBH-3, Pusa Upkar); Singh and Singh, (2002) mentioned (less on - CO-2 genotype); Shaikh *et al.*, (2013). (lower on -AB- 09-1, NDB 18 and higher on - AB 09-14). Dahatonde *et al.*, (2014), stated as resistant varieties-AB-8/6 to whiteflies which differ highly with JBG - 8/6, JBR - 8/8, JBIL- 10/23, AB - 8/5, AB - 9/1, AB -10/14 and AB - 8/4.

4.1.3. Hadda beetle (*Henosepilachna vigintioctopunctata*)

The mean population of hadda beetle (grub and adult) varied significantly among different varieties (Table 4; Fig. 8; Plate 1C and 2). The initial population of hadda beetle (grub and adult) ranged between 2.93 to 8.04 per plant and 2.52 to 7.93 per plant observed during *Rabi* 2022 and *Kharif* 2023 season respectively. All the varieties showed highly significant difference responses against the hadda beetle (df_(8,3); F = 65.073; P = 0.000 in *Rabi* 2022 and (df_(8,3); F = 56.438; P = 0.000) during *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1C and 2). Hadda beetle (grub and adult) population was maximum in variety VNR-51C (8.04 ± 0.26 and 7.93 ± 0.40) followed by Navkiran (7.07 ± 0.33 and 6.77 ± 0.80) while minimum hadda beetle population was observed in Ajay (3.54 ± 0.20 and 2.72 ± 0.27) followed by NBH- 1214 (2.93 ± 0.09 and 2.52 ± 0.22) during *Rabi* 2022 and *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1C and 2).

The mean incidence of hadda beetle (grub and adult) population in all varieties was noted as per resistance scale in which the mean population and percent plant infestation was highest in VNR-51C, Navkiran and Nishant was found highly susceptible with hadda beetle population and percent plant infestation whereas, Manjushree and Punjab Bharpur reacted as susceptible varieties while lowest mean population was noted in resistance varieties like MAHY-91, Ajay and NBH-1214 during both the seasons respectively (Table 4; Fig. 8; Plate 1C and 2). The mean incidence and percent plant infestation of hadda beetle population from maximum to minimum sequence of all varieties was observed like VNR-51C > Navkiran > Nishant > Manjushree > Punjab Bharpur > MAHY-91 > Ajay > NBH-1214 (Table 4; Fig. 8; Plate 1C and 2).

Hadda beetle population was higher during March - April but declined thereafter. It was positively associated with maximum temperature (Muthukumar and Kalyanasundaram, 2003). Anandhi *et al.*, (2008) revealed that incidence first noticed from the 20th week after transplanting (third week of January) with a mean incidence of hadda beetle started earlier, i.e., first week of November. As per our study similar kind of studies was found on hadda beetle incidence as Bharadiya and Patel (2005) reported that incidence of hadda beetle on eggplant was recorded from the 4th week of August onwards and reached the peak in the 3rd week of September.

Praveen *et al.*, (2018) from Andhra Pradesh stated as varieties of aubergine cultivars screened against hadda beetle, found (least population on -IC-127074 and highest on- IC-112309-A); Bhagat and Munshi (2004) used 6 marketable germplasm of brinjal they found highest mean population of hadda beetle was recorded in the cultivar Pusa Purple Long.

4.1.4. Shoot and fruit borer (*Leucinodes orbonalis*)

The mean larval population of shoot infestation varied significantly among different varieties (Table 4; Fig. 8; Plate 1D and 3). The initial population of shoot infestation ranged between 0.73 to 5.09 per plant and 0.82 to 5.21 per plant observed during *Rabi* 2022 and *Kharif* 2023 season respectively. All the varieties showed highly significant difference responses against the shoot infestation ($df_{(8,3)}$; $F = 388.990$; $P = 0.000$ in *Rabi* 2022 and ($df_{(8,3)}$; $F = 175.021$; $P = 0.000$) during *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1D and 3). Shoot infestation population was maximum in variety VNR-51C (5.09 ± 0.22 and

5.21 $\pm$ 0.11) followed by Navkiran (4.46 $\pm$ 0.12 and 4.79 $\pm$ 0.45) while minimum shoot borer infestation population was observed in Ajay (0.87 $\pm$ 0.18 and 0.97 $\pm$ 0.22) followed by NBH-1214 (0.73 $\pm$ 0.07 and 0.82 $\pm$ 0.12) during *Rabi* 2022 and *Kharif* 2023 respectively (Table 4; Fig. 8; Plate 1C and 3).

The mean damaged of shoot infestation in all varieties was noted as per resistance scale in which the mean population, shoot infestation and percent fruit infestation was highest in VNR-51C found highly susceptible while Navkiran and Nishant was found susceptible with shoot and fruit borer population whereas, Punjab Bharpur reacted moderately tolerant variety while Manjushree found has tolerant variety while lowest mean population was noted in tolerant varieties like MAHY-91, Ajay and NBH-1214 during both the seasons respectively (Table 4; Fig. 8; Plate 1C and 3). The mean incidence for shoot damaged and per cent fruit damaged as maximum to minimum sequence of all varieties was observed like VNR-51C > Navkiran > Nishant > Punjab Bharpur > Manjushree > MAHY-91 > Ajay > NBH-1214 (Table 4; Fig. 8; Plate 1C and 3).

Similar research revealed that, out of the thirty-one brinjal cultivars described by Mandal *et al.*, (2005), none of the wild or cultivated species of brinjal were found to be resistant to *L. orbonalis*. Just 20 accessions were used in another screening programmed, and none of them showed signs of notable resistance (Hossain *et al.*, 2002b). According to Netam *et al.*, (2018) from Raipur, the evaluation of 106 brinjal germplasm lines, two of them-IGB-92 and IGB-93-were found to be somewhat tolerant, 24 were found to be susceptible, the remaining 80 germplasm lines were found to be highly susceptible, and no brinjal germplasm was found to be unaffected to the fruit and shoot borer. According to Kassi *et al.*, (2019), the Round Brinjal 86602 cultivar exhibited the lowest larvae population and was shown to be somewhat resistant to the pest, whereas the Short Purple cultivar showed the highest larval population, followed by Round White Brinjal.

In another study, Malik *et al.*, (2013) found that out of forty brinjal germplasm lines, whereas fruit infestation ranged from 14.18 to 53.19 percent and shoot infestation ranged from 0 to 20 percent. The information on fruit infestation is also consistent with the results of other studies who observed varying infestation ranges from 3.00 to 677.71 percent fruit damage and average losses of 25.33% against *L. orbonalis* (Devi *et al.*, 2015; Sharma *et al.*, 2015; Javed *et al.*, 2017; Gautam *et al.*, 2019a; Kassi *et al.*, 2019; Praveen

et al., 2020).

Gokulapriya *et al.*, (2021) observed a comparable outcome, as indicated by their findings from the screening process. They reported that out of thirty-nine varieties, only six types of brinjal were classified as moderately resistant, exhibiting an average fruit damage ranging from 11% to 20%. Additionally, twelve varieties were identified as tolerant, with damage intensity ranging from 21% to 30%, while the remaining twelve accessions fell into the susceptible category, with fruit damage ranging from 31% to 40%. Singh *et al.*, (2016) screened thirty brinjal varieties and reported that maximum infestation on fruits was recorded in Swarna Mani and BR-112. According to Khan and Singh (2014), out of 192 genotypes of brinjal that were evaluated, two cultivars were found to be immune to the fruit and shoot borer, three cultivars or genotypes were found to be resistant, 21 cultivars were found to be reasonably resistant, 38 tolerant, 52 cultivars were susceptible, and the other 76 cultivars were found to be very vulnerable. According to Praveen *et al.*, (2020), out of the fourteen brinjal genotypes, Arka anand, 71-19 × RB-2, and BRBL-02 × BRBL-07 had the lowest percentage of shoot and fruit infestation (number and weight basis), while Muktakeshi × Swarnmani and Pusa hybrid- 9 had the highest percentage. Reports on damage of *Leucinodes orbonalis* in eggplant varieties having resistant and susceptible characters matches with previous workers research (Javed *et al.*, 2011; Singh *et al.*, 2016; Vethamoni and Praneetha, 2016).

Thapa *et al.*, (2009) found that there were no significant differences in the severity of *L. orbonalis* infestation among the 10 tested genotypes in terms of fruit weight and quantity during a field screening of different brinjal genotypes. According to Raina and Yadav (2018), the brinjal cultivars Pusa Kranti and Nurki were shown to be superior to the native landraces and had less infestation than Pusa Purple Long. According to Kavishetti and Lekha Rani (2018), there was minimal infestation of shoot and fruit borer in the hybrids Wardha local × Palakurthi local, Swetha × Vellayani local, and Neelima. Bhandurge (2012), also noted a decreased average of shoot and fruit borer in the BH-2 cultivar in comparison to JKJEH-691.

According to Salve *et al.*, (2020), BH-2 and Pusa Upkar varieties demonstrated notably lower infestation levels across nearly all monitored periods, followed by VR-2 and JBH-3. The average percentage of fruit infestation revealed that BH-2 had

significantly lower levels compared to all other cultivars, except JBH-3, which exhibited the highest fruit infestation rates. Rishi *et al.*, (2018) discovered that the infestation of *L. orbonalis* occurred during the 43rd week, specifically between October 18th and 24th. This infestation varied in terms of both shoot and fruit infestation percentages.

Following thorough investigations on the screening of brinjal cultivars, it was concluded that comparing screening studies is challenging due to use of different varieties and varying environmental conditions across studies (Mahmood *et al.*, 2002; Rashid *et al.*, 2002; Sonali, 2008).



Plate 1A
Amrasca biguttula biguttula



Plate 1B
Bemisia tabaci



Plate 1C
Epilachna vigintioctopunctata



Plate 1D
Leucinodes orbonalis



Plate 1E
Coccinella septempunctata



Plate 1F
Brumoides suturalis



Plate 1G
Menochilus sexmaculatus



Plate 1H Adult
Hippodamia variegat

Plate 1. Brinjal Pests and Natural Enemies



Plate 2A Egg



Plate 2B Larvae



Plate 2C Pupal formation



Plate 2D Adult

Plate 2. Hadda Beetle (*Henosepilachna vigintioctopunctata*) infestation on brinjal



Plate 3A Egg



Plate 3B Larvae



Fruit infestation



Plate 3C Pupal formation



Plate 3D Adult

Plate 3. Shoot and Fruit Borer (*Leucinodes orbonalis*) infestation on brinjal

Table 4. Screening of various brinjal cultivars for identification of cultivars resistant to major arthropod pest of brinjal

Varieties	Rabi 2022	Kharif 2023	Mean	Categ ory	Rabi 2022	Kharif 2023	Mean	Rabi 2022	Kharif 2023	Mean	% Plant infes tatio n	Categ ory	Rabi 2022	Kharif 2023	Mea n	Sho ot infe stat ion	% Fruit infes tatio n	Cate gor y
	<i>Amrasca biguttula biguttula</i>				<i>Bemisia tabaci</i>			<i>Henosepilachna vigintioctopuncta</i> <i>ta</i>					<i>Leucinodes orbonalis</i>					
	Nymph & Adult				Adult			Grub & Adult					Shoot damage					
Manjushree	17.07 ± 0.41 ^d	15.16 ± 0.28 ^c	16.11	MT	14.56 ± 0.21 ^e	16.05 ± 0.21 ^d	15.30	5.71 ± 0.17 ^c	5.05 ± 0.45 ^c	5.38	56.67	S	1.03 ± 0.22 ^e	1.32 ± 0.16 ^e	1.17	T	18.46	MT
NBH-214	8.93 ± 0.15 ^h	9.80 ± 0.31 ^f	9.36	T	9.49 ± 0.09 ^{fg}	10.15 ± 0.34 ^e	9.82	2.93 ± 0.09 ^e	2.52 ± 0.22 ^d	2.72	34.67	R	0.73 ± 0.07 ^f	0.82 ± 0.12 ^f	0.77	T	8.99	T
Ajay	10.21 ± 0.13 ^g	9.79 ± 0.25 ^f	10.00	T	8.82 ± 0.03 ^g	9.45 ± 0.25 ^e	9.13	3.54 ± 0.20 ^{de}	2.72 ± 0.27 ^d	3.13	38.00	R	0.87 ± 0.18 ^{ef}	0.97 ± 0.22 ^{ef}	0.92	T	11.52	T
Punjab Bharpur	15.71 ± 0.32 ^e	13.78 ± 0.45 ^d	14.74	MT	16.81 ± 0.62 ^d	17.23 ± 0.91 ^c	17.02	5.25 ± 0.71 ^c	4.24 ± 0.47 ^c	4.74	66.67	S	2.09 ± 0.06 ^d	3.03 ± 0.14 ^d	2.56	MT	17.50	MT
MAHY-91	11.89 ± 0.31 ^f	10.91 ± 0.10 ^e	11.40	MT	10.57 ± 0.28 ^f	9.33 ± 0.48 ^e	9.95	3.72 ± 0.26 ^d	2.89 ± 0.05 ^d	3.30	44.66	R	0.96± 0.16 ^{ef}	1.03 ± 0.16 ^{ef}	0.99	T	9.50	T
Navkiran	21.59 ± 0.29 ^b	21.23 ± 0.19 ^{ab}	21.41	S	21.37 ± 1.18 ^b	22.05 ± 0.36 ^a	21.71	7.07 ± 0.33 ^b	6.77 ± 0.80 ^b	6.92	82.00	HS	4.46 ± 0.12 ^b	4.79 ± 0.45 ^b	4.62	S	57.00	HS
Nishant	20.71 ± 0.38 ^c	20.67 ± 0.97 ^b	20.69	S	18.96 ± 0.59 ^c	19.15 ± 1.26 ^b	19.05	6.61 ± 0.65 ^b	7.11 ± 0.80 ^{ab}	6.86	78.00	HS	3.83 ± 0.15 ^c	4.28 ± 0.37 ^c	4.05	S	46.50	HS
VNR-51C	22.35 ± 0.57 ^a	21.97 ± 0.65 ^a	22.16	S	22.82 ± 1.18 ^a	23.15 ± 0.62 ^a	22.98	8.04 ± 0.26 ^a	7.93 ± 0.40 ^a	7.98	84.66	HS	5.09 ± 0.22 ^a	5.21 ± 0.11 ^a	5.15	HS	63.50	HS
P value	0.000**	0.000**			0.000**	0.000**		0.000**	0.000* *				0.000**	0.000**				
F value	697.204	353.907			194.826	222.726		65.073	56.438				388.990	175.021				

- * Mean of three replicates (were counted on 5 randomly selected plants per replication and was expressed as no. of pest per plant)
- Categories - R (Resistance), T (Tolerant), MT (Moderately Tolerant), S (Susceptible), HS (Highly Susceptible)
- P Value- Probability, F Value - Ratio of two variances, ± Standard Deviation Values,
- *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant

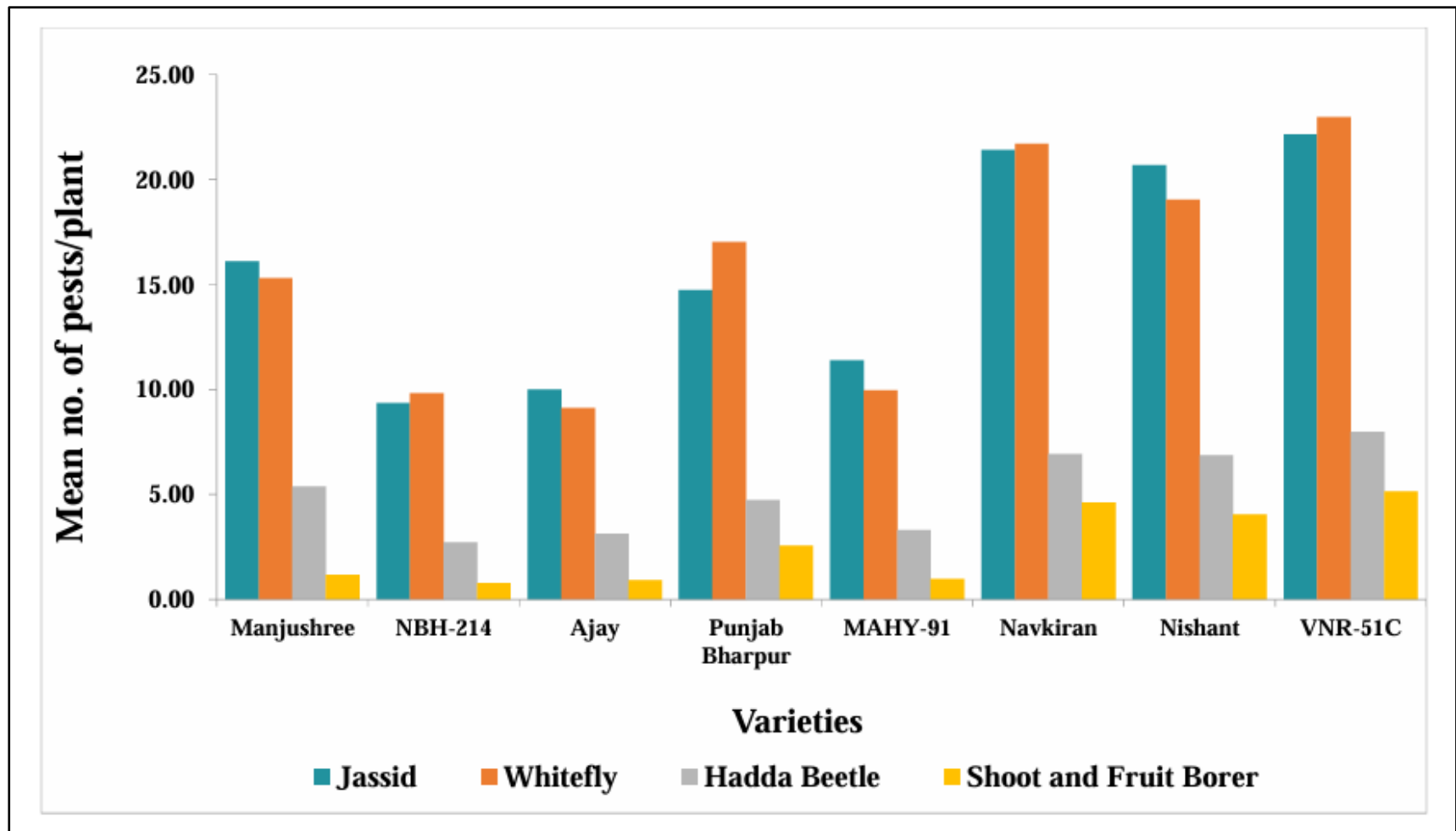


Fig. 8 Screening of various brinjal cultivars against major arthropod pest of brinjal

4.1.2. Yield of different brinjal cultivars against major arthropod pest of brinjal during *Rabi* 2022 and *Kharif* 2023.

In *Rabi* season 2022 and *Kharif* 2023, all the treatments had significant difference in yield. All the treatments showed significant impact on yield at 1st picking ($df_{(8,3)}$; $F = 3.115$; $P = 0.028$; $df_{(8,3)}$; $F = 3.139$; $P = 0.028$), 2nd picking ($df_{(8,3)}$; $F = 3.559$; $P = 0.017$; $df_{(8,3)}$; $F = 2.854$; $P = 0.039$), 3rd picking ($df_{(8,3)}$; $F = 2.867$; $P = 0.038$; $df_{(8,3)}$; $F = 3.184$; $P = 0.026$), 4th picking ($df_{(8,3)}$; $F = 3.561$; $P = 0.017$; $df_{(8,3)}$; $F = 3.957$; $P = 0.011$), 5th picking ($df_{(8,3)}$; $F = 4.592$; $P = 0.006$; $df_{(8,3)}$; $F = 2.776$; $P = 0.043$) and 6th picking ($df_{(8,3)}$; $F = 4.916$; $P = 0.004$; $df_{(8,3)}$; $F = 4.947$; $P = 0.004$) during *Rabi* season 2022 and *Kharif* 2023 (Table 5 and 6, Fig. 9).

The maximum fruit yield was obtained from varieties NBH-1214 (17228.00 and 17550.15 kg ha⁻¹) followed by MAHY-91 (16263.50 and 17228.00 kg ha⁻¹) compare to all treatments less yield was obtained from was Navkiran having (12727.62 and 13435.57 kg ha⁻¹) and VNR-51C (11377.31 and 12854.93 kg ha⁻¹) during *Rabi* season 2022 and *Kharif* 2023 (Table 2 and 3). As per yield obtained from varieties as highest to lowest sequence were NBH-1214 > MAHY-91 > Ajay > Punjab Bharpur > Manjushree > Nishant > Navkiran > VNR-51C (Table 5 and 6, Fig. 9).

Numerous studies have investigated the yield of different brinjal varieties, with findings varying among researchers. For instance, Ali *et al.*, (2017a) conducted research to assess various brinjal cultivars' performance against the hadda beetle. They observed that the Blue Pearl cultivar yielded the highest average of 1.84 kg per plant, a significant difference compared to other cultivars examined. In a study conducted by Kassi *et al.*, (2019), five varieties of brinjal were screened, revealing that Round Brinjal 86602 exhibited the highest yield of 0.944 kg per plant, whereas Brinjal Long 6275 had the lowest fruit yield at 0.497 kg per plant. Furthermore, Rani *et al.*, (2018) reported that the genotype BRBL-01, characterized by oblong stripe green fruits, demonstrated the least infestation by fruit borers both in terms of number and weight, resulting in maximum marketable yield. The study identified genotypes BRBL-01, Pusa Purple Cluster, and BRBL-02 as high-yielding varieties with minimal fruit borer infestation. Shaikh *et al.* (2013) noted that genotype AB-09-01 exhibited significantly higher fruit yields compared to genotype AB-09-14, which recorded significantly lower fruit yields. Similarly, according to Patel *et*

al., (2015), the highest percentage of marketable fruits was obtained from the pata kanta variety, followed by L-13, while the muktakeshi variety had the lowest percentage of marketable fruits, particularly against whitefly infestation.

The epilachna beetle, a dangerous pest of brinjal whose grubs and adults feed on the leaves, the leaf become skeletonized were yield losses are anticipated to be up to 10-15% in normal years, but in exceptionally bad years, crop output is significantly reduced to 20-30%. Total disaster is also a possibility when things are truly awful (Ghosh and Chakraborty, 2012; Jackson, 2016; Kroschel *et al.*, 2020).

Table 5. Yield of different brinjal varieties against major arthropod pest of brinjal in *Rabi* season 2022

Varieties	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Manjushree	8.66 ± 0.30 ^{abc}	10.00 ± 0.52 ^{abc}	14.65 ± 0.61 ^{abc}	16.65 ± 0.30 ^{abcd}	13.00 ± 0.72 ^{abc}	11.00 ± 0.40 ^{ab}	73.96	14266.97	14.26
NBH-214	11.33 ± 0.46 ^a	12.33 ± 0.50 ^{ab}	16.66 ± 0.41 ^{ab}	19.66 ± 0.61 ^a	16.33 ± 0.11 ^a	13.00 ± 0.34 ^a	89.31	17228.00	17.22
Ajay	10.33 ± 0.30 ^{ab}	11.66 ± 0.41 ^{ab}	18.30 ± 0.30 ^a	18.66 ± 0.23 ^{ab}	14.33 ± 0.23 ^{ab}	12.66 ± 0.30 ^a	85.94	16577.93	16.57
Punjab Bharpur	9.66 ± 0.30 ^{ab}	12.00 ± 0.20 ^{ab}	16.30 ± 0.11 ^{ab}	16.66 ± 0.30 ^{abcd}	11.66 ± 0.41 ^{bcd}	13.66 ± 0.30 ^a	79.94	15420.52	15.42
MAHY-91	10.00 ± 0.20 ^{ab}	12.66 ± 0.23 ^a	16.66 ± 0.50 ^{ab}	17.66 ± 0.41 ^{abc}	14.33 ± 0.23 ^{ab}	13.00 ± 0.34 ^a	84.31	16263.50	16.26
Navkiran	7.33 ± 0.11 ^{bc}	9.66 ± 0.11 ^{abc}	13.33 ± 0.50 ^{bc}	14.00 ± 0.20 ^d	12.66 ± 0.46 ^{bcd}	9.00 ± 0.20 ^b	65.98	12727.62	12.72
Nishant	8.00 ± 0.20 ^{bc}	9.33 ± 0.23 ^{bc}	15.65 ± 0.41 ^{abc}	14.33 ± 0.41 ^{cd}	10.33 ± 0.23 ^{cd}	10.66 ± 0.30 ^{ab}	68.30	13175.15	13.17
VNR-51C	6.33 ± 0.60 ^c	8.00 ± 0.23 ^c	11.66 ± 0.41 ^c	15.33 ± 0.30 ^{bcd}	9.33 ± 0.11 ^d	8.33 ± 0.23 ^b	58.98	11377.31	11.37
P value	0.028*	0.017*	0.038*	0.017*	0.006*	0.004*			
F value	3.115	3.559	2.867	3.561	4.592	4.916			

- Yield was expressed in kg per hectare
- P Value- Probability, F Value - Ratio of two variances, ± Standard Deviation Values
- *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant

Table 6. Yield of different brinjal varieties against major arthropod pest of brinjal in *Kharif* season 2023

Varieties	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Manjushree	9.00 ± 0.20 ^{abc}	10.33 ± 0.11 ^{abc}	13.66 ± 0.41 ^c	17.00 ± 0.20 ^{bc}	13.33 ± 0.50 ^{abc}	9.00 ± 0.20 ^d	72.32	13950.61	13.95
NBH-214	11.66 ± 0.41 ^{ab}	13.00 ± 0.40 ^a	17.33 ± 0.41 ^a	20.00 ± 0.20 ^a	15.66 ± 0.50 ^a	13.33 ± 0.23 ^{ab}	90.98	17550.15	17.55
Ajay	12.33 ± 0.30 ^a	11.33 ± 0.50 ^{abc}	16.66 ± 0.30 ^{ab}	19.33 ± 0.23 ^{ab}	14.66 ± 0.23 ^{ab}	13.00 ± 0.20 ^{ab}	87.31	16842.20	16.84
Punjab Bharpur	11.00 ± 0.40 ^{ab}	11.00 ± 0.20 ^{abc}	15.66 ± 0.11 ^{abc}	17.33 ± 0.41 ^{abc}	13.00 ± 0.52 ^{abc}	12.00 ± 0.20 ^{abc}	79.99	15430.16	15.43
MAHY-91	12.33 ± 0.64 ^a	12.66 ± 0.23 ^{ab}	17.00 ± 0.20 ^a	18.66 ± 0.61 ^{ab}	15.00 ± 0.20 ^a	13.66 ± 0.30 ^a	89.31	17228.00	17.22
Navkiran	8.66 ± 0.30 ^{bc}	10.00 ± 0.20 ^{bc}	14.00 ± 0.40 ^{bc}	15.00 ± 0.20 ^c	11.33 ± 0.30 ^{bc}	10.66 ± 0.11 ^{cd}	69.65	13435.57	13.43
Nishant	9.00 ± 0.20 ^{abc}	10.66 ± 0.11 ^{abc}	15.00 ± 0.20 ^{abc}	16.66 ± 0.11 ^{bc}	13.00 ± 0.34 ^{abc}	12.33 ± 0.30 ^{abc}	76.65	14785.87	14.78
VNR-51C	7.33 ± 0.30 ^c	8.66 ± 0.30 ^c	13.33 ± 0.23 ^c	15.66 ± 0.11 ^c	10.33 ± 0.23 ^c	11.33 ± 0.30 ^{bc}	66.64	12854.93	12.85
P value	0.028*	0.039*	0.026*	0.011*	0.043*	0.004*			
F value	3.139	2.854	3.184	3.957	2.776	4.947			

- Yield was expressed in kg per hectare
- P Value- Probability, F Value - Ratio of two variances, ± Standard Deviation Values
- *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non-Significant

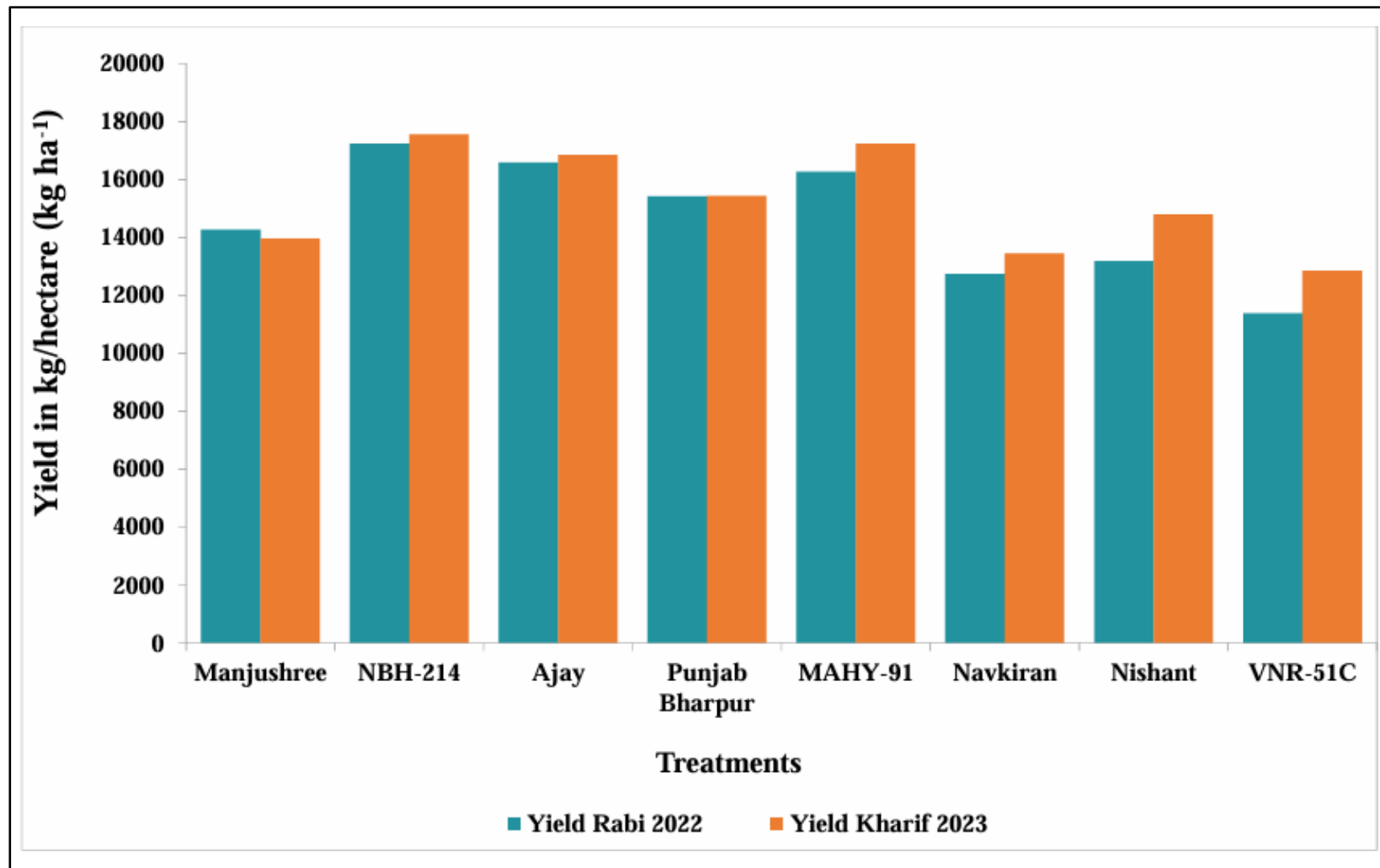


Fig. 9 Yield of varietal screening in *Rabi* season 2022 and *Kharif* Season 2023

4.1.3 Correlation of abiotic factors against major pest of brinjal in relation with different brinjal cultivars

In present investigation, all the varieties effect on major pest's population of brinjal and their relation with abiotic factors such as jassid, whitefly, hadda beetle and shoot and fruit borer incidence of all pests in all the varieties was observed from 51st to 8th SMW in *Rabi* season 2022 and 23rd to 32nd SMW in *Kharif* season 2023 with varied fluctuations in populations.

4.1.3.1 Jassid (*Amrasca biguttula biguttula*)

Jassid (nymph and adult) population on all varieties showed positive relation with temperature except Navkiran and VNR-51C which had negative relation. Negative relation with relative humidity and rainfall was observed except in Manjushree, Navkiran and VNR-51C had positive relation with relative humidity during *Rabi* season 2022. While maximum temperature was observed with positive relation and minimum temperature, morning- evening relative humidity and rainfall had negative relation except Navkiran had positive relation with evening relative humidity in *Kharif* season 2023 (Table 7).

Kadgonkar *et al.*, (2018), who reported that maximum population of jassid during month of January in (1st SMW). Patel *et al.*, (2015) observed that the jassid population began in the third week of February and reached its highest point during the first week of May. Similarly, the population of whitefly peaked around the last week of April, while aphid populations reached their peak around the second week of May. Omprakash *et al.*, (2013) found that jassids reached their peak population in the last week of October during the year 2010-11 and 2011-12. Kapil *et al.*, (2022) observed that the peak activity of jassid occurred during the 44th Standard Meteorological Week (SMW), coinciding with maximum and minimum temperatures of 30.4°C and 9.8°C, respectively, along with morning and evening relative humidity levels of 85.4% and 24.0%, respectively. They also noted that the peak population of jassid was observed during the 39th SMW in the *Kharif* season. Conversely, Meena *et al.*, (2017) and Kumar *et al.*, (2021) reported that the minimum population of jassids was recorded during the 48th SMW in the years 2019 and 2020, with both years showing similar incidence levels.

The study found a notable and positive correlation between the population buildup of

jassids and morning relative humidity. However, there was no significant correlation, either positive or negative, observed between jassid population and maximum and minimum temperatures or rainfall (Yadav *et al.*, 2016; Lal *et al.*, 2019; Kapil *et al.*, 2022).

4.1.3.2 Whitefly (*Bemisia tabaci*)

All varieties showed positive relation with maximum temperature on whitefly (adult) population except Ajay, Navkiran and VNR-51C also minimum temperature showed positive relation except varieties like Navkiran, Nishant and VNR-51C. While morning- evening relative humidity and rainfall had negative relation except Navkiran, Nishant and VNR-51C found with positive relation in humidity on whitefly population during *Rabi* season 2022. In the *Kharif* season of 2023, all varieties exhibited a positive relationship with maximum temperature regarding whitefly population, except for Manjushree and Nishant, which displayed a negative relationship. Conversely, minimum temperature, morning-evening relative humidity, and rainfall showed a negative relationship with all varieties of whitefly population during this season, as indicated in (Table 8).

The current study aligns with previous research findings, indicating a significant positive correlation between whitefly population and maximum temperature, while showing a significant negative correlation with morning and evening relative humidity. This observation is consistent with reports by (Yadav *et al.*, 2016; Humane *et al.*, 2021; Kapil *et al.*, 2022). Additionally, Lal *et al.*, (2019) also reported a significant positive correlation between the population buildup of whitefly and morning relative humidity.

The current studies align with the findings of Kadgonkar *et al.*, (2018), who observed the highest population of whitefly (*Bemisia tabaci*) during the first Standard Meteorological Week (SMW) of January. Furthermore, Kumar *et al.*, (2021) reported that the minimum population of whitefly was recorded during the 52nd SMW of 2019 and 2020, while the maximum population of whitefly reached its peak during the 40th SMW recorded during the *Kharif* seasons of 2019 and 2020.

4.1.3.3 Hadda beetle (*Henosepilachna vigintioctopunctata*)

In *Rabi* season 2022, all varieties showed a negative relation with temperature and rainfall while humidity had positive relation with all varieties on hadda beetle (grub and adult) population. While in *Kharif* season 2023, all the varieties showed positive relation

with temperature on hadda beetle population except Nishant and VNR-51C had negative relation while minimum temperature, morning-evening relative humidity and rainfall had negative relation with all varieties (Table 9).

The peak period of infestation indeed shows variability across regions, influenced by factors such as planting dates, environmental variations, and pest life cycle parameters. Several studies have examined the relationship between beetles and abiotic parameters, highlighting the significant role of environmental factors in beetle activity and researchers including (Haseeb *et al.*, 2009; Qamar *et al.*, 2009; Tiwari *et al.*, 2012; Nithish, 2020) have recorded beetles and studied their correlation with environmental factors. These studies collectively underscore the importance of considering environmental conditions when analyzing beetle activity and infestation patterns.

Our results align with previous research findings regarding the correlation between hadda beetle population and environmental factors. Specifically, Haseeb *et al.*, (2009) and Ali *et al.* (2017a) observed a significant negative correlation between hadda beetle population and maximum temperature, as well as a significant positive correlation with relative humidity. However, there appears to be some variation in results across different studies, which could be attributed to environmental factors. For example, Tushar *et al.*, (2014) reported a positive correlation between temperatures and hadda beetle population growth, with only minimum temperature significantly influencing population growth. On the other hand, Qamar and Haseeb, (2019) found that weather parameters such as temperature, relative humidity, and rainfall were favorable for hadda beetle to reach peak density on all tested host plants. Additionally, Saljoqi and Khan, (2007) observed that minimum relative humidity had a negative effect on the incidence of the beetle, while maximum relative humidity showed a positive correlation with beetle incidence.

These variations highlight the complex interplay between environmental factors and beetle population dynamics, underscoring the importance of considering multiple variables when studying pest behavior and developing effective pest management strategies. Our results align with those reported by Kumar *et al.*, (2021), indicating that the highest incidence of hadda beetle per plant occurred during the 43rd Standard Meteorological Week (SMW) of the *Kharif* season, while the minimum incidence was recorded during the 49th SMW of *Kharif* in 2019 and 2020. Moreover, previous studies

have also noted variations in the period of infestation of hadda beetle across regions, but the peak infestation is generally observed in July- August. Venkatesha, (2006) and Sharma and Tayde, (2017) reported that the population of *H. vigintioctopunctata* was notable on the 30th SMW of July, with the population reaching its peak during the 35th SMW of August. This consistency in findings across different studies underscores the seasonal variability and regional patterns in hadda beetle infestation dynamics.

Various researchers in different locations have reported on the incidence of *Epilachna vigintioctopunctata*, noting that it typically begins around the 34th Standard Meteorological Week (SMW) of August and reaches its peak during the 37th and 38th SMW of September. This observation has been documented by (Bharadiya and Patel, 2005; Latif *et al.*, 2009; Khursheed and Desh 2014; Manikandan *et al.*, 2019), highlighting the consistency of this pattern across diverse geographical regions. Additionally, Haseeb *et al.*, (2009) observed the initial incidence of *H. vigintioctopunctata* during the third week of January 2009 in Aligarh, Uttar Pradesh. This observation highlights the variability in the timing of hadda beetle incidence across different regions and seasons. Moreover, as noted by Nithish, (2020), various ecological variables such as sunlight, rainfall, wind speed, relative humidity, temperature, and sunshine duration significantly influence hadda beetle activity. This underscores the multifaceted nature of factors influencing pest behavior and population dynamics, emphasizing the importance of considering a wide range of environmental variables in pest management strategies.

4.1.3.4 Shoot and fruit borer (*Leucinodes orbonalis*)

All the varieties showed positive relation with temperature while negative relation with humidity and rainfall on shoot borer (larva) infestation in *Rabi* season 2022. In *Kharif* season 2023, all varieties showed positive relation with maximum temperature on shoot and fruit borer population while minimum temperature, relative humidity and rainfall had negative relation with all varieties (Table 10).

The present findings align with previous research results regarding the activity and population dynamics of the brinjal shoot infestation. Lodhi, (2005) reported that brinjal fruit borer activity peaked during the last week of March, coinciding with an average temperature of 26.5°C and relative humidity of 35%. Similarly, Varma *et al.*, (2011)

observed the highest population of brinjal shoot borer infestation in Allahabad, Uttar Pradesh, during the second week of December in both years of their study. Additionally, Anjali *et al.*, (2012) noted that the incidence of shoot borer infestation was observed primarily during November-December, with peak infestation occurring in February, specifically during the 6th and 7th Standard Meteorological Weeks (SMW). These consistent findings across different studies emphasize the seasonal patterns in the activity and population dynamics of the brinjal shoot borer infestation, providing valuable insights for pest management strategies and interventions. The maximum shoot infestation was observed during the 43rd Standard Week (SW), while the maximum fruit infestation occurred during the 46th SW. This consistency across multiple studies suggests a recurring seasonal pattern in pest activity and infestation dynamics during the *Kharif* season (Shukla and Khatri, 2010; Kaur and Singh, 2013; Kaur *et al.*, 2014; Kumar *et al.*, 2021).

Our findings align with those of Kumar *et al.*, (2017b), who investigated the impact of weather parameters on shoot borer infestation. They observed that temperature, humidity, and sunshine hours exhibited a positive correlation with the incidence of both shoot and fruit infestation by the pest. Conversely, rainfall and evening relative humidity displayed a negative correlation. Additionally, Mahesh and Men, (2007) noted that shoot and fruit borer activity typically initiated in August and peaked in mid-October. During this period, a significant positive association was observed between *L. orbonalis* infestation and maximum temperature as well as sunshine.

Nayak, (2014) noted that temperature had a positive impact, while relative humidity had a negative influence on the fluctuations in larval population patterns of shoot and fruit borer. Deole, (2015) research revealed a significant negative correlation between the percentage of fruit damage caused by fruit borers and minimum temperature, as well as a noteworthy positive correlation with maximum relative humidity. Singh *et al.*, (2011) observed that abiotic factors such as maximum temperature, evaporation, and sunshine hours exhibited some positive association with borer incidence, whereas minimum temperature showed a negative association. Varma *et al.*, (2011) reported contrary results, noting that brinjal shoot borer incidence exhibited a positive correlation with maximum relative humidity, rainfall, wind speed, and sunshine hours.

Table 7. Correlation of abiotic factors against jassid in relation with different brinjal varieties of *Rabi* 2022 and *Kharif* season 2023

<i>Amrasca biguttula biguttula</i> (Nymph and Adult)										
<i>Rabi</i> 2022						<i>Kharif</i> 2023				
Varieties	Max. Temp	Min. Temp.	Morn. RH	Even. RH	Rainfall	Max. Temp	Min. Temp	Morn. RH	Even. RH	Rainfall
Manjushree	0.147 ^{NS}	0.339 ^{NS}	0.094 ^{NS}	-0.183 ^{NS}	-0.605 ^{NS}	0.547 ^{NS}	-0.560 ^{NS}	-0.885 ^{**}	-0.806 ^{**}	-0.315 ^{NS}
NBH-214	0.529 ^{NS}	0.686 [*]	-0.484 ^{NS}	-0.721 [*]	-0.349 ^{NS}	0.574 ^{NS}	-0.503 ^{NS}	-0.880 ^{**}	-0.801 ^{**}	-0.368 ^{NS}
Ajay	0.430 ^{NS}	0.556 ^{NS}	-0.457 ^{NS}	-0.654 [*]	-0.322 ^{NS}	0.440 ^{NS}	-0.428 ^{NS}	-0.812 ^{**}	-0.690 [*]	-0.340 ^{NS}
Punjab Bharpur	0.552 ^{NS}	0.458 ^{NS}	-0.481 ^{NS}	-0.568 ^{NS}	-0.646 [*]	0.590 ^{NS}	-0.593 ^{NS}	-0.879 ^{**}	-0.845 ^{**}	-0.305 ^{NS}
MAHY-91	0.527 ^{NS}	0.564 ^{NS}	-0.324 ^{NS}	-0.562 ^{NS}	-0.435 ^{NS}	0.484 ^{NS}	-0.507 ^{NS}	-0.853 ^{**}	-0.755 [*]	-0.151 ^{NS}
Navkiran	-0.162 ^{NS}	-0.027 ^{NS}	0.207 ^{NS}	0.065 ^{NS}	-0.575 ^{NS}	0.301 ^{NS}	-0.516 ^{NS}	-0.698 [*]	0.607 ^{NS}	-0.416 ^{NS}
Nishant	0.034 ^{NS}	0.096 ^{NS}	-0.175 ^{NS}	-0.246 ^{NS}	-0.653 [*]	0.311 ^{NS}	-0.541 ^{NS}	-0.684 [*]	-0.571 ^{NS}	-0.230 ^{NS}
VNR-51C	-0.130 ^{NS}	-0.034 ^{NS}	0.041 ^{NS}	0.003 ^{NS}	-0.618 ^{NS}	0.402 ^{NS}	-0.652 [*]	-0.773 ^{**}	-0.704 [*]	-0.290 ^{NS}

Table 8. Correlation of abiotic factors against whitefly in relation with different brinjal varieties of *Rabi* 2022 and *Kharif* season 2023

<i>Bemisia tabaci</i> (Adult)										
<i>Rabi</i> 2022						<i>Kharif</i> 2023				
Varieties	Max. Temp	Min. Temp.	Morn. RH	Even. RH	Rainfall	Max. Temp	Min. Temp	Morn. RH	Even. RH	Rainfall
Manjushree	0.448 ^{NS}	0.558 ^{NS}	-0.345 ^{NS}	-0.620 ^{NS}	-0.416 ^{NS}	-0.211 ^{NS}	-0.388 ^{NS}	-0.166 ^{NS}	-0.133 ^{NS}	-0.298 ^{NS}
NBH-214	0.072 ^{NS}	0.291 ^{NS}	-0.200 ^{NS}	-0.433 ^{NS}	-0.216 ^{NS}	0.499 ^{NS}	-0.491 ^{NS}	-0.641 [*]	-0.677 [*]	-0.690 [*]
Ajay	-0.050 ^{NS}	0.207 ^{NS}	-0.116 ^{NS}	-0.312 ^{NS}	-0.395 ^{NS}	0.589 ^{NS}	-0.476 ^{NS}	-0.650 [*]	-0.708 [*]	-0.746 [*]
Punjab Bharpur	0.364 ^{NS}	0.469 ^{NS}	-0.448 ^{NS}	-0.693 [*]	-0.192 ^{NS}	0.316 ^{NS}	-0.399 ^{NS}	-0.537 ^{NS}	-0.518 ^{NS}	-0.737 [*]
MAHY-91	0.028 ^{NS}	0.287 ^{NS}	-0.246 ^{NS}	-0.433 ^{NS}	-0.205 ^{NS}	0.660 [*]	-0.468 ^{NS}	-0.707 [*]	-0.750 [*]	-0.712 [*]
Navkiran	-0.429 ^{NS}	-0.466 ^{NS}	0.553 ^{NS}	0.605 ^{NS}	-0.465 ^{NS}	0.144 ^{NS}	-0.440 ^{NS}	-0.448 ^{NS}	-0.411 ^{NS}	-0.596 ^{NS}
Nishant	0.055 ^{NS}	-0.019 ^{NS}	0.245 ^{NS}	0.247 ^{NS}	-0.305 ^{NS}	-0.001 ^{NS}	-0.359 ^{NS}	-0.368 ^{NS}	-0.297 ^{NS}	-0.568 ^{NS}
VNR-51C	-0.369 ^{NS}	-0.514 ^{NS}	0.496 ^{NS}	0.665 [*]	-0.302 ^{NS}	0.197 ^{NS}	-0.636 [*]	-0.447 ^{NS}	-0.543 ^{NS}	-0.547 ^{NS}

*Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant

Table 9. Correlation of abiotic factors against hadda beetle in relation with different brinjal varieties of *Rabi* 2022 and *Kharif* season 2023

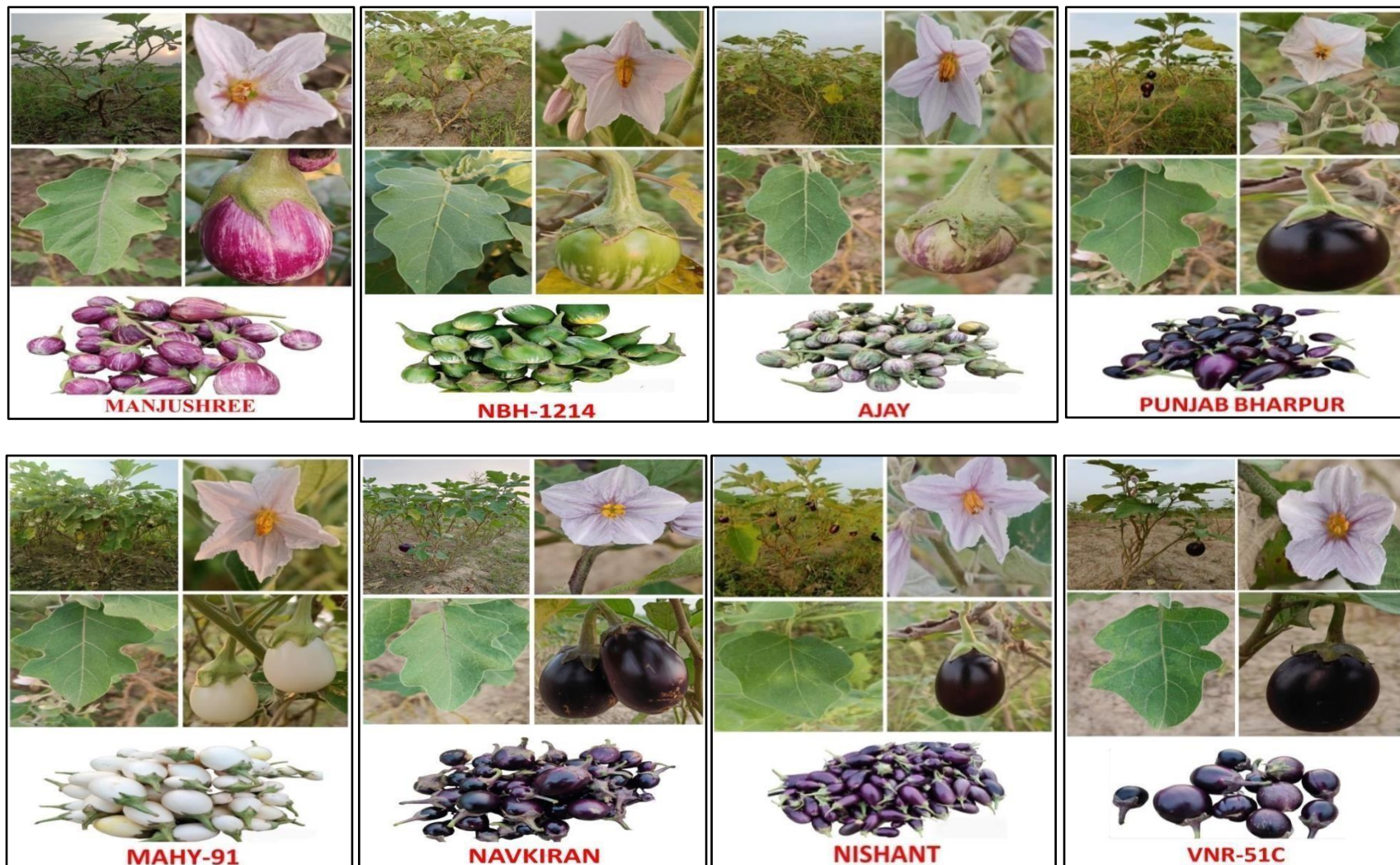
<i>Henosepilachna vigintioctopunctata</i> (Grub and Adult)										
<i>Rabi</i> 2022						<i>Kharif</i> 2023				
Varieties	Max. Temp	Min. Temp.	Morn. RH	Even. RH	Rainfall	Max. Temp	Min. Temp	Morn. RH	Even. RH	Rainfall
Manjushree	-0.631 ^{NS}	-0.648*	0.408 ^{NS}	0.703*	-0.434 ^{NS}	0.403 ^{NS}	-0.613 ^{NS}	-0.720*	-0.704*	-0.502 ^{NS}
NBH-214	-0.712*	-0.713*	0.244 ^{NS}	0.543 ^{NS}	-0.091 ^{NS}	0.471 ^{NS}	-0.558 ^{NS}	-0.775**	-0.729*	-0.488 ^{NS}
Ajay	-0.578 ^{NS}	-0.604 ^{NS}	0.152 ^{NS}	0.503 ^{NS}	-0.315 ^{NS}	0.396 ^{NS}	-0.518 ^{NS}	-0.680*	-0.650*	-0.565 ^{NS}
Punjab Bharpur	-0.629 ^{NS}	-0.583 ^{NS}	0.323 ^{NS}	0.559 ^{NS}	-0.110 ^{NS}	0.435 ^{NS}	-0.582 ^{NS}	-0.689*	-0.703*	-0.603 ^{NS}
MAHY-91	-0.610 ^{NS}	-0.438 ^{NS}	0.563 ^{NS}	0.638*	-0.567 ^{NS}	0.363 ^{NS}	-0.575 ^{NS}	-0.670*	-0.652*	-0.549 ^{NS}
Navkiran	-0.535 ^{NS}	-0.666*	0.240 ^{NS}	0.637*	-0.159 ^{NS}	0.083 ^{NS}	-0.434 ^{NS}	-0.510 ^{NS}	-0.421 ^{NS}	-0.436 ^{NS}
Nishant	-0.652*	-0.766**	0.156 ^{NS}	0.572 ^{NS}	-0.206 ^{NS}	-0.018 ^{NS}	-0.266 ^{NS}	-0.330 ^{NS}	-0.225 ^{NS}	-0.569 ^{NS}
VNR-51C	-0.338 ^{NS}	-0.514 ^{NS}	0.437 ^{NS}	0.732*	-0.386 ^{NS}	-0.006 ^{NS}	-0.514 ^{NS}	-0.304 ^{NS}	-0.333 ^{NS}	-0.391 ^{NS}

Table 10. Correlation of abiotic factors against shoot and fruit borer in relation with different brinjal varieties of *Rabi* 2022 and *Kharif* season 2023

<i>Leucinodes orbonalis</i> (Shoot damage Larva)										
<i>Rabi</i> 2022						<i>Kharif</i> 2023				
Varieties	Max. Temp	Min. Temp.	Morn. RH	Even. RH	Rainfall	Max. Temp	Min. Temp	Morn. RH	Even. RH	Rainfall
Manjushree	0.003 ^{NS}	0.214 ^{NS}	-0.266 ^{NS}	-0.430 ^{NS}	-0.318 ^{NS}	0.728*	-0.447 ^{NS}	-0.706*	-0.760*	-0.770**
NBH-214	0.031 ^{NS}	0.221 ^{NS}	-0.231 ^{NS}	-0.390 ^{NS}	-0.403 ^{NS}	0.674*	-0.463 ^{NS}	-0.695*	-0.751*	-0.716*
Ajay	0.142 ^{NS}	0.313 ^{NS}	-0.219 ^{NS}	-0.457 ^{NS}	-0.364 ^{NS}	0.718*	-0.455 ^{NS}	-0.769**	-0.790**	-0.687*
Punjab Bharpur	0.686*	0.722*	-0.616 ^{NS}	-0.759*	-0.337 ^{NS}	0.481 ^{NS}	-0.632 ^{NS}	-0.610 ^{NS}	0.705*	-0.550 ^{NS}
MAHY-91	0.038 ^{NS}	0.203 ^{NS}	-0.398 ^{NS}	-0.495 ^{NS}	-0.408 ^{NS}	0.644*	-0.501 ^{NS}	-0.753*	-0.796**	-0.575 ^{NS}
Navkiran	0.426 ^{NS}	0.412 ^{NS}	-0.645*	-0.743*	-0.381 ^{NS}	0.395 ^{NS}	-0.534 ^{NS}	-0.566 ^{NS}	-0.613 ^{NS}	-0.537 ^{NS}
Nishant	0.657*	0.611 ^{NS}	-0.486 ^{NS}	-0.664*	-0.498 ^{NS}	0.343 ^{NS}	-0.431 ^{NS}	-0.487 ^{NS}	-0.509 ^{NS}	-0.619 ^{NS}
VNR-51C	0.394 ^{NS}	0.409 ^{NS}	-0.268 ^{NS}	-0.414 ^{NS}	-0.554 ^{NS}	0.563 ^{NS}	-0.527 ^{NS}	-0.679*	-0.706*	-0.533 ^{NS}

*Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant

4.1.4. Morphometric characterization of brinjal varieties based on vegetative characters



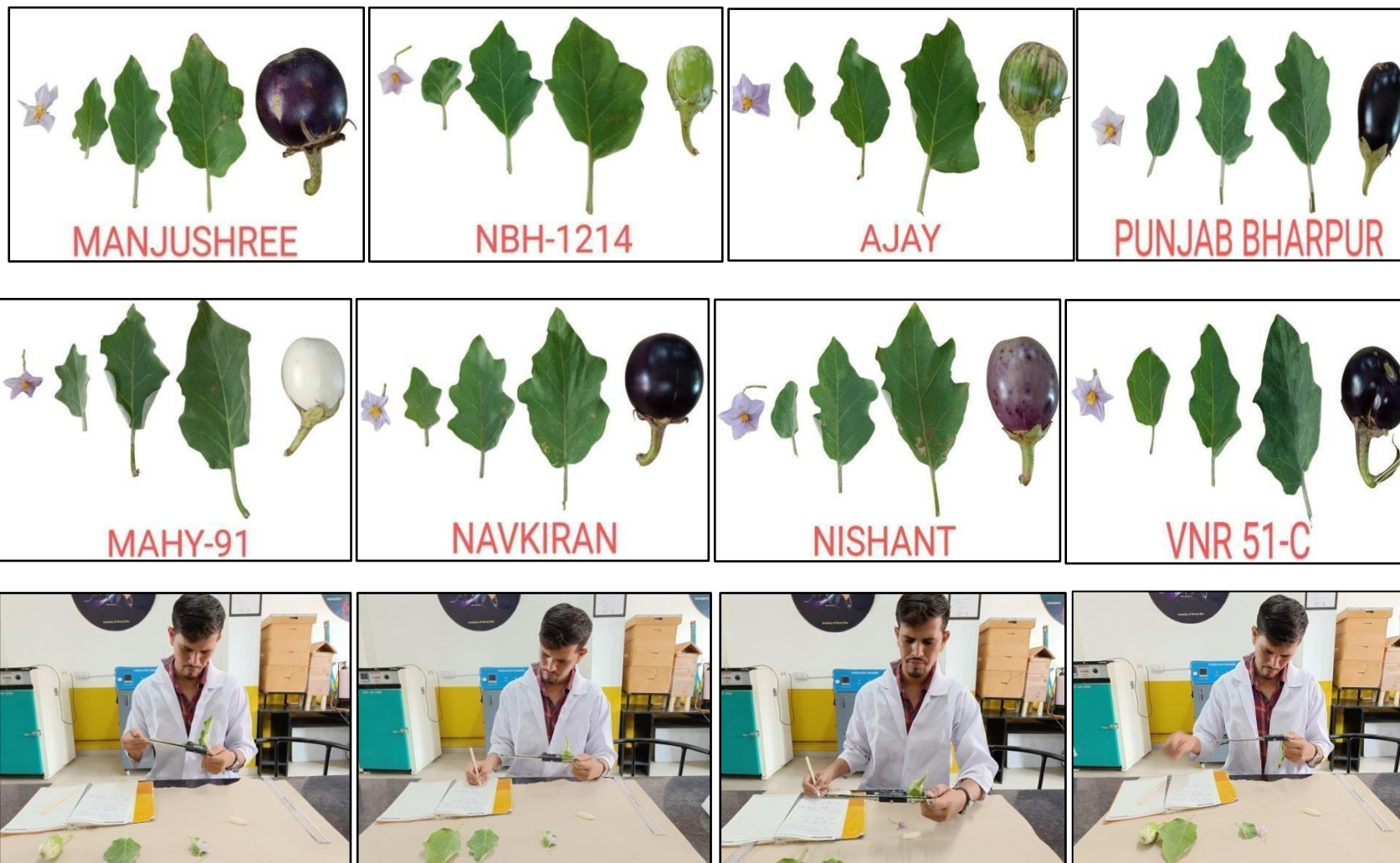


Plate 4. Morphometric characterization of brinjal varieties

4.1.4.1. Plant Height (Centimeters)

a) Plant growth habit in length

The average height per plant in length varied from between 39.67 to 60.33 cm. Varieties observed with significantly maximum height were NBH-1214 (60.33 ± 10.21) followed by VNR-51C (60.00 ± 9.64 cm) while prostrate varieties with minimum per plant height in length was recorded in Punjab Bharpur (40.00 ± 7.00 cm) followed by Manjushree (39.67 ± 6.43 cm). The sequence of all varieties from minimum to maximum height per plant in length was Manjushree < Punjab Bharpur < MAHY-91 < Ajay < Nishant < Navkiran < VNR-51C < NBH-1214 (Table 11; Plate 4).

b) Plant growth habit in width

The average width per plant varied from 53.50 between 81.67 cm. Varieties recorded with significantly maximum width are NBH-1214 (81.67 ± 13.87 cm) followed by MAHY-91 (81.00 ± 24.39 cm) and narrow varieties with minimum width per plant was observed in VNR-51C (67.33 ± 3.21 cm) and Punjab Bharpur (53.50 ± 8.05 cm). The sequence of all varieties from minimum to maximum width per plant was Punjab Bharpur < VNR-51C < Manjushree < Navkiran < Ajay < Nishant < MAHY-91 < NBH-1214 (Table 11.1; Plate 4).

4.4.1.2. Leaf morphological characters

a. Leaf blade length (Centimeters)

The average leaf blade length per plant varied from 6.87 to 12.60 cm. Varieties with maximum leaf blade length per leaf were Ajay (12.60 ± 1.85 cm) followed by VNR-51C (10.67 ± 5.03 cm) and narrow variety with minimum leaf blade length per leaf was observed in Punjab Bharpur (6.87 ± 3.04 cm). The sequence of all varieties from minimum to maximum leaf blade length per leaf was Punjab Bharpur < MAHY-91 < Manjushree < NBH-1214 < Nishant < Navkiran < VNR- 51C < Ajay (Table 11.1; Plate 4).

b. Leaf blade width (Centimeters)

The significant difference was observed in leaf blade width per leaf. The average leaf blade width per plant varied from between 5.10 to 8.33 cm. Varieties with maximum leaf blade width per leaf are Ajay (8.33 ± 2.25 cm) followed by

VNR-51C (7.93 ± 3.79 cm) whereas, varieties with minimum leaf blade width per leaf was recorded in Manjushree (6.17 ± 3.06 cm) and Punjab Bharpur (5.10 ± 1.28 cm). The sequence of all varieties from minimum to maximum leaf blade width per leaf was Punjab Bharpur < Manjushree < MAHY-91 < Nishant < NBH-1214 < Navkiran < VNR- 51C < Ajay (Table 11.1; Plate 4).

c. Leaf blade thickness (Millimeters)

The significant difference was observed in leaf blade thickness per leaf and average leaf blade thickness varied from between 0.65 to 0.80 mm. Varieties included with maximum leaf blade thickness per leaf are Ajay (0.80 ± 0.16 mm) and NBH-1214 (0.80 ± 0.22 mm) while varieties having minimum leaf blade thickness per leaf are Punjab Bharpur (0.68 ± 0.26 mm) and Nishant (0.65 ± 0.19 mm). The sequence of all varieties from minimum to maximum leaf blade thickness per leaf was Nishant < Punjab Bharpur < MAHY-91 < VNR- 51C < Navkiran < Manjushree < NBH-1214 < Ajay (Table 11.1; Plate 4).

d. Leaf blade lobing

Leaf blade lobing per leaf data was recorded and varieties with strong leaf blade lobing consist of NBH-1214, Punjab Bharpur and Nishant. Next varieties with intermediate types are Ajay followed by MAHY-91, Navkiran and VNR-51C. The weak leaf blade lobing was observed in Manjushree (Table 11.1; Plate 4).

e. Leaf blade color

The eight varieties are divided into three types of color like light green, green and dark green. Tolerant variety was Manjushree with light green leaf blade color per leaf while green color leaf blade varieties found resistance NBH-1214, Ajay and MAHY-91. Dark green color varieties are those which were more susceptible in pest infestation Punjab Bharpur, Navkiran, Nishant and VNR-51C (Table 11.1; Plate 4).

f. Leaf blade tip angle

The leaf blade tip angle per leaf was noted in two types acute and obtuse whereas leaf blade tip angle in acute shape is Punjab Bharpur, Ajay, NBH-1214 and MAHY-91 found resistance, while varieties with obtuse leaf blade tip angle were Manjushree, Nishant, Navkiran and VNR-51C (Table 11.1; Plate 4).

g. Leaf prickle numbers (Millimeters)

In comparison of all the eight varieties only few leaf prickles per leaf was found in Ajay 4-5 prickles (size 3.5 mm ℓ) and NBH-1214 has 5-6 prickles (size 4 mm ℓ), while rest of the varieties had no leaf prickles per leaf (Table 11.1; Plate 4).

h. Leaf petiole length (Centimeters)

Petiole length of per leaf was found significantly different in all the varieties. The average leaf petiole length per plant varied from between 2.45 to 4.60 cm. The maximum petiole length per leaf was noted in Navkiran (4.60 ± 0.08 cm) followed by VNR-51C (4.40 ± 0.13 cm). A variety having minimum petiole length per leaf was Manjushree (2.60 ± 0.28 cm) and Nishant (2.45 ± 0.34 cm). The sequence of all varieties from minimum to maximum leaf petiole length per leaf was Nishant < Manjushree < Punjab Bharpur < MAHY-91 < NBH-1214 < Ajay < VNR- 51C < Navkiran (Table 11.1; Plate 4).

i. Leaf petiole width (Millimeters)

Petiole width per leaf was found significantly different in all the varieties. The average leaf petiole width per plant varied from between 2.41 to 3.06 mm. Maximum petiole width per leaf was noted in Navkiran (3.06 ± 0.57 mm) and MAHY-91 (2.98 ± 0.56 mm). Varieties having minimum petiole width per leaf was observed in Nishant (2.67 ± 0.73 mm) followed by Punjab Bharpur (2.41 ± 0.59 mm). The sequence of all varieties from minimum to maximum leaf petiole width per leaf was Punjab Bharpur < Nishant < NBH-1214 < Ajay < VNR- 51C < Manjushree < MAHY-91 < Navkiran (Table 11.1; Plate 4).

j. Leaf petiole color

Leaf petiole color per leaf in all the varieties was divided in three types such has dark green, greenish white and greenish violet. Manjushree, NBH-1214, Ajay and Nishant are having dark green color while Punjab Bharpur and MAHY-91 has greenish white leaf petiole color per leaf. Varieties with greenish violet color are Navkiran and VNR-51C (Table 11.1; Plate 4).

The eight varieties of brinjal were screened against jassid, whitefly, hadda beetle and shoot and fruit borer and morphological characters of all varieties such as plant, leaf morphology, flower and fruit with their subparts with their effects on

pest population were studied (Table 11; Plate 4). The initial phase of morphological characterization serves as the primary stage in the process of delineating and categorizing genetic resources. Significant diversity was observed across eight distinct brinjal varieties concerning various attributes. The findings derived from the study have been documented in detail within (Table 11 and Plate 4).

Parida *et al.*, (2020) found that among the 35 genotypes studied, they could be categorized into three groups based on their plant growth habits: upright, intermediate, and prostrate. Out of these genetic variations, 26 genotypes were identified with an erect growth pattern, while eight genotypes showed an intermediary growth tendency. Notably, only one genotype was characterized by a prostrate growth habit. Shekar *et al.*, (2013) classified eggplant plants into two main types: erect and intermediate. They highlighted that the growth pattern of the plant served as a distinguishing factor among various eggplant varieties. Islam *et al.*, (2018) observed that among the genotypes studied, 48% exhibited an intermediate growth habit, 45% displayed an upright growth habit, and 7% showed a prostrate growth habit during the vegetative stage.

Kumar *et al.*, (2008) identified notable differences in both the length and width of the leaf blades in eggplant. Islam *et al.*, (2018) documented that in eggplant, 60% of the observed specimens exhibited weak leaf blade lobing, while 37% displayed intermediate lobing, and only 3% showed strong lobing. Additionally, they noted that 62% of the observed eggplant leaves had acute tips, 33% had very acute tips, and 5% had intermediate tip angles. Dash *et al.*, (2019) observed that numerous eggplant genotypes displayed acute angles at the tips of their leaf blades. Islam *et al.*, (2018) found that among the genotypes examined, 25% exhibited no leaf prickles, while the remaining genotypes displayed varying degrees of prickliness: 40% had very few, 25% had few, and 5% had an intermediate or abundant number of prickles. Furthermore, Dash *et al.*, (2019) noted the presence of prickles on various parts of the eggplant, including the stem, petiole, calyx (including peduncle), and leaf (including veins). Additionally, Kumar *et al.*, (2008) reported significant diversity in petiole length among eggplant varieties.

4.1.4.2 Morphometric characterization of brinjal varieties based on flower characters

a. Corolla color

In all the eight varieties data recorded on field through visual observation of flower corolla color was divided in three types like pale violet, light violet and bluish violet color. Pale violet corolla color per flower includes in Punjab Bharpur. Next light violet corolla color per flower was recorded in Manjushree, NBH-1214, Ajay and MAHY-91 varieties. Bluish violet corolla per flower was noted in Navkiran, Nishant and VNR-51C (Table 11.2; Plate 4).

b. Flower petiole diameter (Millimeters)

Diameter of per flower petiole was observed with significant difference in all the varieties. The maximum diameter of petiole per flower was observed in Navkiran (1.97 ± 0.23 mm) and Manjushree (1.93 ± 0.17 mm). Narrow diameter petiole per flower is recorded in Punjab Bharpur (1.10 ± 0.18 mm) and MAHY-91 (1.05 ± 0.20 mm). The sequence of all varieties from maximum to minimum flower petiole diameter was Navkiran > Manjushree > VNR-51C > Ajay > Nishant > NBH-1214 > Punjab Bharpur > MAHY-91 (Table 11.2; Plate 4).

c. Flowers inflorescence in numbers

The inflorescences of flower were noted and varieties with maximum per flower inflorescence were observed in NBH-1214 and Ajay. Varieties with less per flower inflorescence were observed in Navkiran and VNR-51C. The sequence of all varieties from maximum to minimum flower inflorescence in numbers are NBH-1214 > Ajay > MAHY-91 > Punjab Bharpur > Nishant > Manjushree > Navkiran > VNR-51C (Table 11.2; Plate 4).

Dash *et al.*, (2019) categorized eggplant flowering into three distinct patterns: solitary, cyme, and mixed. In addition, Islam *et al.*, (2018) discovered that among all eggplant genotypes, 53% exhibited light violet flowers, 37% had bluish violet flowers, and 10% displayed pale violet flowers. In contrast, Dash *et al.*, (2019) found purple- colored flowers in 61 out of 110 eggplant varieties studied, purple-white flowers in 30 genotypes, and white flowers in 19 genotypes. Thamburaj and Singh, (2001) noted that brinjal flowers can be classified into four

types according to the length of the style. These categories include long-styled, medium-styled, short-styled, and pseudo-short-styled. Parida *et al.*, (2020) noted various flowering patterns among twenty-one brinjal genotypes: one genotype exhibited (single germplasm per inflorescence have flowers in numbers like 1 germplasm = 1 to 2 flowers; 7 germplasm = 2 to 3 and 3 germplasm = 3 to 4; 2 germplasm = 4 to 5 and another 1 germplasm = 5 to 6 flowers).

4.1.4.3 Morphometric characterization of brinjal varieties based on fruit characters

a. Fruit calyx length (Centimeters)

The calyx length of three selected fruits was recorded with measuring scale. The average fruit calyx length per fruit was between 2.00 to 4.00 cm. The significantly minimum mean of fruit calyx length was recorded in variety Punjab Bharpur (2.00 ± 0.17 cm) whereas significantly maximum fruit calyx length in MAHY-91 and Ajay with (4.00 ± 0.30 cm) and (4.00 ± 0.36 cm). The sequence of all varieties from minimum to maximum fruit calyx in length are Punjab Bharpur < Nishant < NBH-1214 < Manjushree < Navkiran < VNR-51C < Ajay < MAHY-91 (Table 11.3; Plate 4).

b. Fruit calyx prickles in number

The observation on number of fruit prickles per calyx was recorded on field by visual observation. Maximum number of fruit prickles per calyx was recorded in Ajay (10 prickles having 1.5-2 mm size), while intermediate types was found in NBH-1214 (7- 8 prickles having 1-1.5 mm size). Variety Manjushree, Punjab Bharpur, MAHY-91, Navkiran, Nishant and VNR-51C had none of the fruit prickles on per calyx (Table 11.3; Plate 4).

c. Fruit pedicel length (Centimeters)

The fruit pedicel length of three selected fruits was recorded with digital vernier caliper. The average fruit pedicel length per fruit was between 2.20 to 5.00 cm. The significantly minimum mean of per fruit pedicel length was recorded in variety Nishant (2.90 ± 0.26 cm) and Punjab Bharpur (2.20 ± 0.26 cm). Varieties with maximum per fruit pedicel length were recorded in Manjushree (5.00 ± 1.17

cm), Navkiran (4.30 ± 0.21 cm). The sequence of all varieties from minimum to maximum fruit pedicle length are Punjab Bharpur < Nishant < NBH-1214 < MAHY-91 < VNR-51C < Ajay < Navkiran < Manjushree (Table 11.3; Plate 4).

d. Fruit pedicel width (Millimeters)

The fruit pedicel width of three selected fruits was recorded with digital vernier caliper. The average fruit pedicel width per fruit was between 5.84 to 10.23 mm. The significantly minimum mean of per fruit pedicel width was recorded in variety Punjab Bharpur (5.84 ± 2.01 mm) while varieties with maximum per fruit pedicel width was recorded in Manjushree (10.23 ± 5.05 mm) followed by Navkiran (9.55 ± 4.08 mm). The sequence of all varieties from minimum to maximum fruit pedicle width was Punjab Bharpur < MAHY-91 < VNR-51C < NBH-1214 < Ajay < Nishant < Navkiran < Manjushree (Table 11.3; Plate 4).

e. Fruit pedicel prickles in number

The observation on number of fruit prickles per pedicel was recorded on field by visual observation. Maximum number of fruit prickles per pedicel was recorded in Ajay and NBH-1214 having 1-5 in numbers with size of 1-2 mm. Variety Manjushree, Punjab Bharpur, MAHY-91, Navkiran, Nishant and VNR-51C has none of the fruit prickles on per pedicel (Table 11.3; Plate 4).

f. Fruit diameter (Millimeters)

The diameter of selected three fruits was recorded with digital vernier caliper. The average fruit diameter was between 36.87 to 64.01 mm. The significantly minimum mean diameter per fruit was recorded in variety Punjab Bharpur (39.75 ± 12.62 mm) followed by NBH-1214 (36.87 ± 11.80 mm) while, per fruit diameter recorded significantly maximum in Navkiran (64.01 ± 6.56 mm) followed by VNR-51C (54.75 ± 13.36 mm). The sequence of all varieties from minimum to maximum fruit pedicle width was NBH- 1214 < Punjab Bharpur < MAHY-91 < Ajay < Manjushree < Nishant < VNR-51C < Navkiran (Table 11.3; Plate 4).

g. Fruit color at commercial ripeness

In all the eight varieties data recorded on field through visual observation

of fruit color at ripeness and divided in five types like white, green with white strips, green- purple-white strips, light purple and dark violet. White color fruit variety was MAHY-91. Next green with white strips color fruit variety was NBH-1214 followed by green-purple- white strips variety Ajay. Light purple fruit color noted in Manjushree and continued with dark violet color fruited varieties are Punjab Bharpur, Navkiran, Nishant and VNR-51C at commercial ripeness (Table 11.3; Plate 4).

h. Fruit curvature

The observation was made for fruit curvature parameter were NBH-1214 and Nishant have slightly curved shape and remaining varieties Manjushree, Ajay, Punjab Bharpur, Navkiran, MAHY-91 and VNR-51C doesn't have curvature on fruit (Table 11.3; Plate 4).

i. Fruit shape

All the eight varieties are divided in two types of shape as rounded and long fruited varieties and these data was recorded on field through visual observation of fruit shape were rounded fruit shape varieties are Manjushree, Punjab Bharpur, MAHY-91, Navkiran and VNR-51C which are more susceptible on field due to its less seed compactness, thin fruit skin and purple color have more preference of the pest during feeding and oviposition except MAHY-91 has it has white color and hard fruit rind while NBH-1214 and Ajay are found long fruited type and resistance due to its hard fruit rind, skin and compactness in seeds but though Nishant was long fruited it has dark purple color and thin fruit skin, so it was also susceptible and having more infestation (Table 11.3; Plate 4).

j. Fruit cluster in numbers

In all the varieties, fruit clusters were different which showed variation in yield. The varieties having fewer fruiting clusters had less yield compare to other varieties VNR- 51C. Varieties having maximum fruiting cluster showed varied difference by providing high yield are NBH-1214, Ajay and MAHY-91 in comparison with all varieties (Table 11.3; Plate 4).

Kumar *et al.*, (2008) and Parida *et al.*, (2020) categorized brinjal genotypes into two groups based on fruit calyx length: one group with very short calyx length,

consisting of 18 genotypes, and another group with short calyx length, comprising 17 genotypes. Fruit color difference was noted by Shinde *et al.*, (2012), Solaiman *et al.*, (2014) and Parida *et al.*, (2020) they reported that (colour = 22 varieties - purple; 8 - green; 5 - greenish with white). Dash *et al.*, (2019) classified brinjal fruits into groups of six color: green, purple, milky white, purple-black, light purple or lilac grey, and scarlet red.

Studies have shown that brinjal fruits come in a variety of forms, including sickle, snake, curved, U, and fruits with no curvature (Solaiman *et al.*, 2014; Islam *et al.*, 2018). On fruit bearing or cluster forming was observed in all cultivars like (28 bearing- 1 fruits; 4 - 1 or 2 fruits; 1 - 2 to 3 fruits; 1 - 4 to 5 fruits, 1 - 5 to 6 fruits) in a cluster, (Parida *et al.*, 2020). According to Solaiman *et al.*, (2014), a large number of brinjal genotypes had a solitary fruit-bearing behaviour, whereas a small number of genotypes demonstrated a cluster-bearing habit. According to Islam *et al.*, (2018), among the genotypes of brinjals, 38% exhibited depressed, 34% rounded, and 28% protruded fruit apex forms.

In the present experiment eight varieties of brinjal were classified in various characters. The study revealed significant variability among the examined cultivars. Accurate characterization is crucial for preserving the genetic integrity of a cultivars. Cultivar exhibiting favorable morphological traits can be incorporated into crop breeding programs to cultivate superior genotypes. The findings of this study would prove invaluable to researchers focusing on brinjal cultivation in the North Indian region.

Table 11. Morphometric characterization of different varieties of brinjal

Table 11.1 Characterization of brinjal genotypes based on vegetative characters					
Sr. No.	Parts	Characteristics	State of expression	Size	Example genotypes
1.	Plant	a. Plant growth habit length in centimeter	Upright (50-70 cm)	60.33 ± 10.21 cm ℓ	NBH-1214
				60.00 ± 9.64 cm ℓ	VNR- 51C
				58.00 ± 15.87 cm ℓ	Navkiran
				51.67 ± 11.93 cm ℓ	Nishant
			Intermediate (40-50 cm)	48.67 ± 14.57 cm ℓ	Ajay
				45.67 ± 12.06 cm ℓ	MAHY-91
			Prostrate (30-40 cm)	40.00 ± 7.00 cm ℓ	Punjab Bharpur
				39.67 ± 6.43 cm ℓ	Manjushree
		b. Plant growth habit width in centimeter	Wide (70-90 cm)	81.67 ± 13.87 cm w	NBH-1214
				81.00 ± 24.39 cm w	MAHY-91
				71.00 ± 30.35 cm w	Nishant
				70.67 ± 25.32 cm w	Ajay
			Intermediate (60-70 cm)	68.33 ± 29.19 cm w	Navkiran
				67.67 ± 2.52 cm w	Manjushree
				67.33 ± 3.21 cm w	VNR- 51C
			Narrow (30-50 cm)	53.50 ± 8.05 cm w	Punjab Bharpur
2.	Leaf	a. Leaf blade length in centimeter	Wide (10-13 cm)	12.60 ± 1.85 cm	Ajay
				10.67 ± 5.03 cm	VNR- 51C
				10.50 ± 5.50 cm	Navkiran
				10.33 ± 4.51 cm	Nishant
			Intermediate (8-10 cm)	9.83 ± 3.75 cm	NBH-1214
				9.60 ± 3.77 cm	Manjushree
				9.00 ± 3.77 cm	MAHY-91
			Narrow (6-8 cm)	6.87 ± 3.04 cm	Punjab Bharpur
		b. Leaf blade width in centimeter	Wide (8-9 cm)	8.33 ± 2.25 cm	Ajay
			Intermediate (7-8 cm)	7.93 ± 3.79 cm	VNR- 51C
				7.90 ± 4.28 cm	Navkiran
				7.17 ± 3.01 cm	NBH-1214
			Narrow	6.67 ± 3.25 cm	Nishant

			(5-7 cm)	6.30 ± 2.56 cm	MAHY-91
				6.17 ± 3.06 cm	Manjushree
				5.10 ± 1.28 cm	Punjab Bharpur
		c. Leaf blade thickness in millimeter	Very thick (0.80-0.10 mm)	0.80 ± 0.16 mm	Ajay
				0.80 ± 0.22 mm	NBH-1214
			Intermediate (0.70-0.80 mm)	0.78 ± 0.15 mm	Manjushree
				0.77 ± 0.12 mm	Navkiran
				0.74 ± 0.12 mm	VNR- 51C
				0.71 ± 0.11 mm	MAHY-91
			Thick (0.60-0.70 mm)	0.68 ± 0.26 mm	Punjab Bharpur
				0.65 ± 0.19 mm	Nishant
		d. Leaf blade lobing	Strong	-----	NBH-1214
					Punjab Bharpur
					Nishant
			Intermediate	-----	Ajay
					MAHY-91
					Navkiran
					VNR- 51C
			Weak	-----	Manjushree
		e. Leaf blade color	Light green	-----	Manjushree
					NBH-1214
			Green	-----	Ajay
					MAHY-91
			Dark green	-----	Punjab Bharpur
					Navkiran
					Nishant
					VNR- 51C
		f. Leaf blade tip angle	Acute	-----	Punjab Bharpur
					Ajay
					NBH-1214
					MAHY-91
			Obtuse	-----	Nishant
					Manjushree
					Navkiran
					VNR- 51C
		g. Leaf prickle in numbers with	None	-----	Manjushree
					Punjab Bharpur

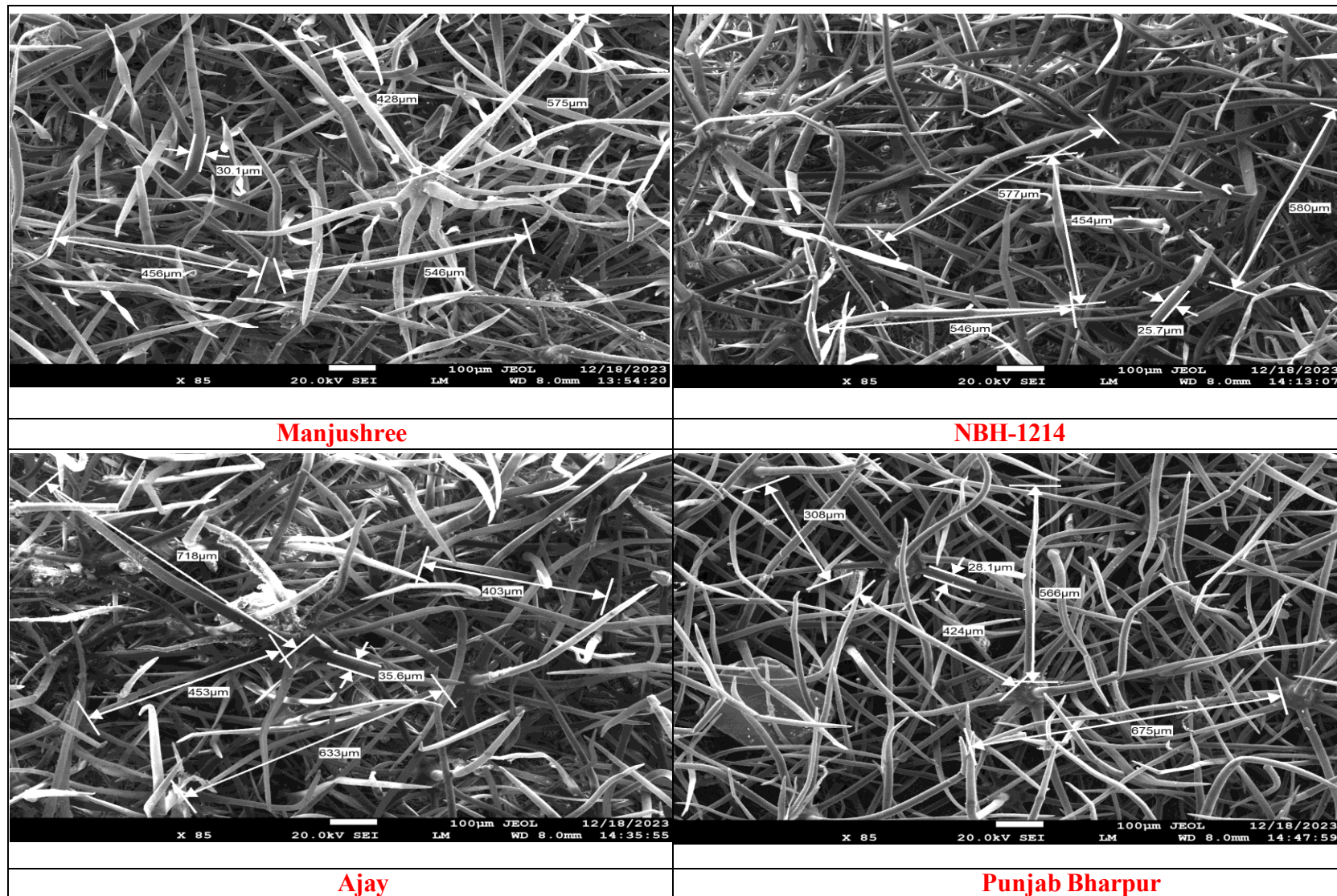
		millimeter			MAHY-91
					Navkiran
					Nishant
					VNR- 51C
			Few	4-5 prickles (3.5 mm ℓ)	Ajay
			Intermediate	5-6 prickles (4 mm ℓ)	NBH-1214
		h. Petiole length in centimeter	Long (4-5 cm)	4.60 ± 0.08 cm	Navkiran
				4.40 ± 0.13 cm	VNR- 51C
				4.20 ± 0.23 cm	Ajay
			Intermediate (3-4 cm)	4.00 ± 0.20 cm	NBH-1214
				3.60 ± 0.35 cm	MAHY-91
			Short (2-3 cm)	2.80 ± 0.24 cm	Punjab Bharpur
				2.60 ± 0.28 cm	Manjushree
				2.45 ± 0.34 cm	Nishant
		i. Petiole width in millimeter	Long (2.90-4.00 mm)	3.06 ± 0.57 mm	Navkiran
				2.98 ± 0.56 mm	MAHY-91
			Intermediate (2.70-2.90 mm)	2.77 ± 0.28 mm	Manjushree
				2.76 ± 0.78 mm	VNR- 51C
				2.73 ± 0.54 mm	Ajay
			Short (2.40-2.70 mm)	2.69 ± 0.51 mm	NBH-1214
				2.67 ± 0.73 mm	Nishant
				2.41 ± 0.59 mm	Punjab Bharpur
		j. Petiole color	Dark Green	-----	Manjushree
					NBH-1214
					Ajay
					Nishant
			Greenish White	-----	Punjab Bharpur, MAHY-91
					Navkiran
			Greenish Violet	-----	VNR- 51C
					Table 11.2 Characterization of brinjal genotypes based on flower characters
Sr. No.	Parts	Characteristics	State of expression		Example genotypes
1.	Flower	a. Corolla color	Pale violet	-----	Punjab Bharpur
			Light violet	-----	Manjushree

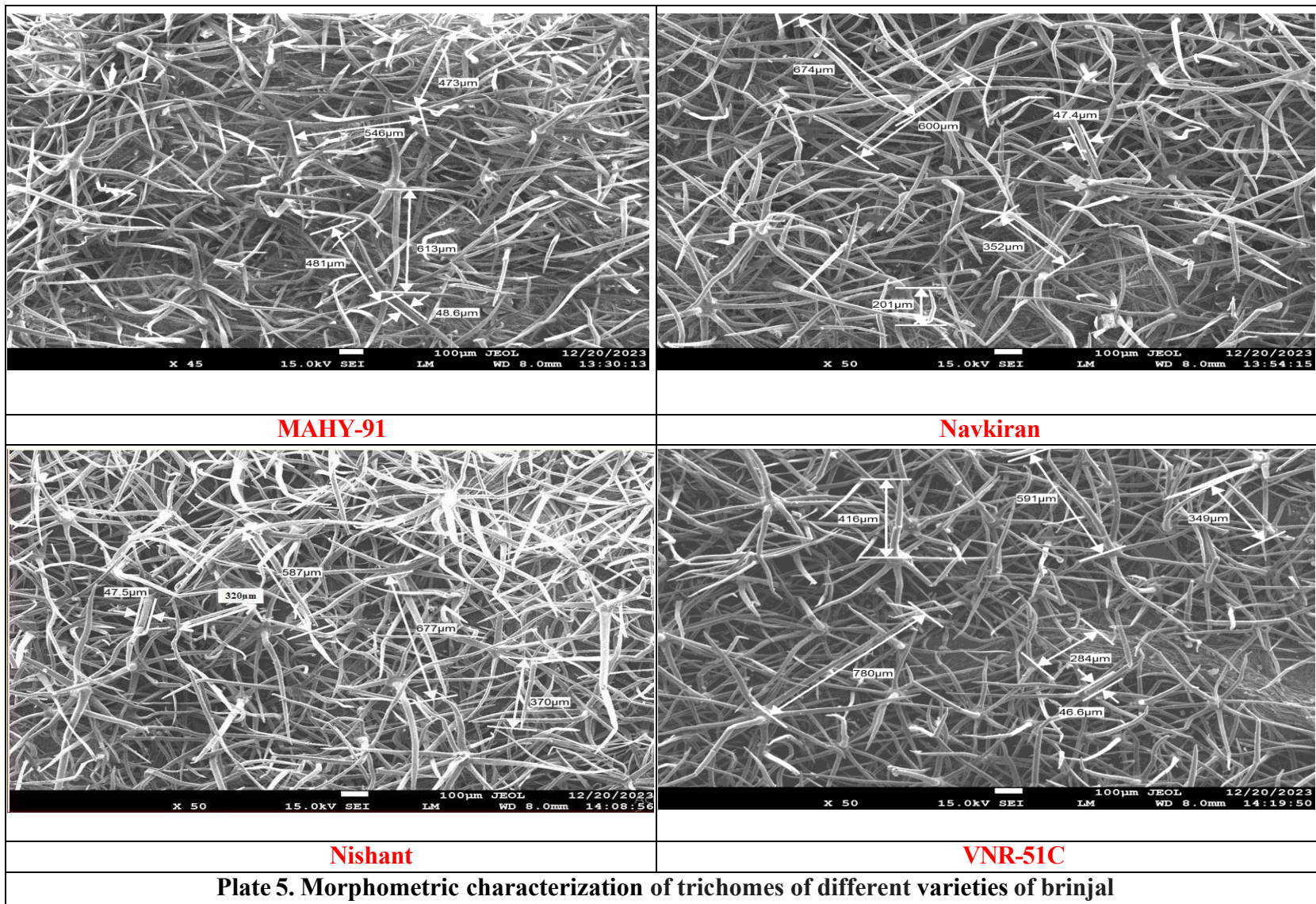
			Bluish violet	-----	NBH-1214
					Ajay
					MAHY-91
					Navkiran,
					Nishant
					VNR- 51C
		b. Flower petiole in diameter	Wide (1.70-2.00 mm)	1.97 ± 0.23 mm	Navkiran
				1.93 ± 0.17 mm	Manjushree
				1.88 ± 0.24 mm	VNR- 51C
				1.87 ± 0.21 mm	Ajay
			Intermediate (1.30-1.50 mm)	1.44 ± 0.22 mm	Nishant
				1.39 ± 0.24 mm	NBH-1214
			Narrow (1.00-1.30 mm)	1.10 ± 0.18 mm	Punjab Bharpur
				1.05 ± 0.20 mm	MAHY-91
		c. Flowers inflorescence in numbers	4-5	-----	NBH-1214
					Ajay
					MAHY-91
			3-4	-----	Punjab Bharpur
					Nishant
			2-3	-----	Manjushree
					Navkiran
					VNR- 51C
Table 11.3 Characterization of brinjal genotypes based on fruit characters					
1.	Fruit	a. Fruit calyx length in centimeter	Long (3-4 cm)	4.00 ± 0.30 cm	MAHY-91
				4.00 ± 0.36 cm	Ajay
				3.80 ± 0.33 cm	VNR- 51C
				3.20 ± 0.24 cm	Navkiran
			Medium (2-3 cm)	3.00 ± 0.29 cm	Manjushree
				2.90 ± 0.19 cm	NBH-1214
				2.80 ± 0.21 cm	Nishant
			Short (1-2 cm)	2.00 ± 0.17 cm	Punjab Bharpur
		b. Fruit calyx prickles in numbers	None	-----	Manjushree,
					Punjab Bharpur
					MAHY-91
					Navkiran
					Nishant

					VNR- 51C
			Intermediate	7-8 thorns	NBH-1214
			Many	10 thorns	Ajay
		c. Fruit pedicel length in centimeter	Long (4-5 cm)	5.00 ± 1.17 cm	Manjushree
				4.30 ± 0.21 cm	Navkiran
				4.00 ± 0.33 cm	Ajay
			Intermediate (3-4 cm)	3.80 ± 0.43 cm	VNR- 51C
				3.50 ± 0.34 cm	MAHY-91
				3.10 ± 0.33 cm	NBH-1214
			Short (2-3 cm)	2.90 ± 0.26 cm	Nishant
				2.20 ± 0.26 cm	Punjab Bharpur
		d. Fruit pedicel width in millimeter	Long (8-11 mm)	10.23 ± 5.05 mm	Manjushree
				9.55 ± 4.08 mm	Navkiran
				8.87 ± 2.70 mm	Nishant
				8.08 ± 3.44 mm	Ajay
			Intermediate (7-8 mm)	7.51 ± 3.68 mm	NBH-1214
				7.23 ± 2.76 mm	VNR- 51C
				7.08 ± 2.81 mm	MAHY-91
			Short (5-6 mm)	5.84 ± 2.01 mm	Punjab Bharpur
		e. Fruit pedicel prickles in numbers	None	-----	Manjushree
					Punjab Bharpur
					MAHY-91
					Navkiran
					Nishant,
					VNR- 51C
			Few	1-5 prickles	NBH-1214
					Ajay
		f. Fruit diamter in millimeter	Wide (50-60 mm)	64.01 ± 6.56 mm	Navkiran
				54.75 ± 13.36 mm	VNR- 51C
				54.19 ± 13.13 mm	Nishant
			Intermediate (40-50 mm)	49.50 ± 13.78 mm	Manjushree
				47.52 ± 12.69 mm	Ajay
				41.78 ± 14.55 mm	MAHY-91
			Narrow (30-40 mm)	39.75 ± 12.62 mm	Punjab Bharpur
				36.87 ± 11.80 mm	NBH-1214
		g. Fruit color @	White	-----	MAHY-91
			Green with	-----	NBH-1214

		commercial ripeness	white strips		
			Green-purple-white strips	-----	Ajay
			Light purple	-----	Manjushree
			Dark violet	-----	Punjab Bharpur
					Navkiran
					Nishant
					VNR- 51C
		h. Fruit curvature	None	-----	Manjushree
					Ajay
					Punjab Bharpur
					MAHY-91
					Navkiran
					VNR- 51C
			Slightly curved	-----	NBH-1214
		i. Fruit shape	Rounded	-----	Nishant
					Navkiran
					VNR- 51C
					Punjab Bharpur
			Long	-----	MAHY-91
					Manjushree
					Ajay
		j. Fruit cluster in numbers	3-4	-----	Nishant
					NBH-1214
					MAHY-91
			2-3	-----	Punjab Bharpur
					Nishant
					Manjushree
			1-2	-----	Navkiran
					VNR- 51C

4.1.5 Morphometric characterization of trichomes of different varieties of brinjal





The trichome diameter amongst the tested varies between 25.70 to 48.60 μm while length of trichome ranged between 349.67 to 525.67 μm . Varieties with longest trichome length denoted resistance characters while shortest trichome length as susceptible varieties in the present study (Table 12; Plate 5). In *Kharif* season 2023, interaction studies between the whitefly incidence and morphological characteristics on brinjal showed that leaf trichomes length had negative correlation with whitefly population in varieties like Manjushree ($r = -0.885^{\text{NS}}$), NBH- 1214 ($r = -0.941^{\text{NS}}$), Ajay ($r = -0.388^{\text{NS}}$) and MAHY-91 ($r = -0.451^{\text{NS}}$) while in other varieties leaf trichomes density had positive correlation in Punjab Bharpur ($r = 0.058^{\text{NS}}$), Navkiran ($r = 0.874^{\text{NS}}$) followed by Nishant ($r = 0.964^{\text{NS}}$) and VNR-51C variety ($r = 0.998^*$) with whitefly population incidence (Table 12; Plate 5).

The present result in a line with Laichattiwat *et al.*, (2018), who reported that the hair density and length are negatively correlated with jassid occurrence, while although non- significant relation with aphids and whiteflies. Indrayani and Sulistyowati, (2005) similarly found that leaves with a high density of trichomes exhibited a positive correlation with increased populations of *B. tabaci*, in contrast to leaves with fewer trichomes. The density of hairs on the lamina, vein, and midrib regions has a notable and positive influence on the population of whiteflies (Ashfaq *et al.*, 2010; Khan *et al.*, 2018). Naqvi *et al.*, (2008) demonstrated that area on leaf exhibited a significant impact on whitefly population, while density of trichome did not show a significant impact. They suggested that shorter leaf trichomes might facilitate the transportation of eggs and nymphs by wind, making them more susceptible to natural enemies' attacks. Studies on brinjal have shown that resistance to *B. tabaci* negatively correlated with the quantity of trichomes on the leaves (Soundarajan and Baskaran, 2001; Dharmendar *et al.*, 2002; Ayyasamy and Baskaran, 2005). Trichome density represents a significant morphological trait associated with plant resistance to sucking pests, exhibiting a positive correlation with the colonization of such pests (Aslam and Saeed, 2004). Hair length demonstrates a negative correlation with the population of whiteflies (Khan *et al.*, 2010).

Contradictory findings have been reported by various researchers like Valle *et al.*, (2012) indicated that higher trichome density and longer leaf trichomes create a more suitable habitat for the development of *B. tabaci* eggs and nymphs. Vieira *et al.*, (2011), suggesting that long trichomes may hinder the eggs from being carried away by the wind, potentially contributing to the retention and development of *B. tabaci* eggs. As per Taggar *et al.*, (2012), there is a strong positive link between the length of the trichome and the quantity of adults, nymphs, and eggs that are present. This implies that more eggs, nymphs, and adults are correlated with longer trichomes.

Table 12. Morphometric characterization of trichomes of different varieties of brinjal

Varieties	Trichome types (major shape)	Diameter (µm)	Length (µm)	Correlation of trichomes
Manjushree	Porrect-stellate multiradiate non-glandular hair with subulate rays (2–7 in number) and long central ray	30.10	476.67	-0.885 ^{NS}
NBH-214	Porrect stellate multiradiate non-glandular hair with subulate rays (3–10 in number) with long central ray and pedestal	25.70	525.67	-0.941 ^{NS}
Ajay	Porrect stellate multiradiate non-glandular hair with subulate rays (3–10 in number) with long central ray and pedestal	35.60	496.33	-0.388 ^{NS}
Punjab Bharpur	Porrect-stellate multiradiate non-glandular hair with subulate rays (2–7 in number) and long central ray	28.10	432.67	0.058 ^{NS}
MAHY-91	Porrect-stellate multiradiate non-glandular hair with subulate rays (2–7 in number) and short central ray	48.60	500.00	-0.451 ^{NS}
Navkiran	Porrect stellate multiradiate non-glandular hair with subulate rays (3–10 in number) with long central ray and pedestal	47.40	384.33	0.874 ^{NS}
Nishant	Porrect-stellate multiradiate non-glandular hair with subulate rays (3–10 in number) with long central ray and pedestal	47.50	425.67	0.964 ^{NS}
VNR-51C	Porrect-geminate stellate multiradiate nonglandular hair with subulate rays (2–16 in number) and short central ray	46.60	349.67	0.998*

4.1.6 Biochemical analysis of different varieties of brinjal

4.1.6.1 Phenol activity

The phenol activity of eight brinjal cultivars was differed significantly ($df_{(8,3)}$; $F = 794.209$; $P = 0.000$) during *Kharif* 2023 season. The phenol activity ranged between 82.75 and 128.17 (mg/100g) (Table 13, Fig. 10). The data revealed that minimum phenol activity was observed in varieties VNR-51C (82.75 ± 0.83 mg/100g) followed by Navkiran (88.58 ± 1.26 mg/100g). The maximum phenol activity was recorded in varieties NBH-1214 (128.17 ± 0.79 mg/100g) which differed significantly with Ajay (119.32 ± 0.54 mg/100g). The phenol was higher in resistant brinjal cultivars instead of susceptible varieties. The sequence of all varieties from minimum to maximum were VNR-51C < Navkiran < Nishant < Manjushree < Punjab Bharpur < MAHY-91 < Ajay < NBH-1214 (Table 13, Fig. 10).

4.1.6.2 Protein activity

The protein activity of eight brinjal cultivars was differed significantly ($df_{(8,3)}$; $F = 1297.097$; $P = 0.000$) during *Kharif* 2023 season. The protein activity ranged between 88.86 and 138.29 (mg/100g) (Table 13, Fig. 10). The data revealed that minimum protein activity was observed in varieties NBH-1214 (88.86 ± 0.91 mg/100g) which differed significantly with Ajay (95.64 ± 0.52 mg/100g). The maximum protein activity was recorded in varieties VNR-51C (138.29 ± 0.52 mg/100g) followed by Navkiran (133.46 ± 1.21 mg/100g). The protein was more in susceptible varieties as compared to resistance varieties. The sequence of all varieties from minimum to maximum were NBH-1214 < Ajay < MAHY-91 < Punjab Bharpur < Manjushree < Nishant < Navkiran < VNR-51C (Table 13, Fig. 10).

4.1.6.3 Proline activity

The proline activity of eight brinjal cultivars was differed significantly ($df_{(8,3)}$; $F = 305.995$; $P = 0.000$) during *Kharif* 2023 season. The proline activity ranged between 2.36 and 4.93 μ moles/g (Table 13, Fig. 10). The data revealed that the minimum proline activity was observed in varieties Navkiran (2.36 ± 0.15

μmoles/g) followed by VNR- 51C (2.46 ± 0.12 μmoles/g). The maximum proline activity was recorded in varieties Ajay (4.93 ± 0.03 μmoles/g) followed by NBH-1214 (4.85 ± 0.09 μmoles/g). The higher content of proline was noted in resistant varieties as related to susceptible varieties. The sequence of all varieties from minimum to maximum were Navkiran < VNR-51C < Nishant < Manjushree < Punjab Bharpur < MAHY-91 < NBH-1214 < Ajay (Table 13, Fig. 10).

4.1.6.4 Peroxidase activity

The peroxidase activity of eight brinjal cultivars during was differed significantly ($df_{(8,3)}$; $F = 57.997$; $P = 0.000$) during *Kharif* 2023 season. The peroxidase activity ranged between 0.87 and 1.37 μM/min/g proteins (Table 13, Fig. 10). The data revealed that minimum peroxidase activity was observed in varieties VNR-51C (0.87 ± 0.05 μM/min/g protein) followed by Navkiran (0.95 ± 0.04 μM/min/g protein). The maximum peroxidase content was recorded in varieties NBH-1214 (1.37 ± 0.04 μM/min/g protein) which differed significantly with Ajay (1.25 ± 0.04 μM/min/g protein). The higher peroxidase was found in resistant varieties instead of susceptible varieties. The sequence of all varieties from minimum to maximum were VNR-51C < Navkiran < Nishant < Manjushree < Punjab Bharpur < MAHY-91 < Ajay < NBH-1214 (Table 13, Fig. 10).

4.1.6.5 Phenylalanine ammonia lyase activity

The PAL activity of eight brinjal cultivars was differed significantly ($df_{(8,3)}$; $F = 5654.802$; $P = 0.000$) during *Kharif* 2023 season. The phenylalanine ammonia lyase activity ranged between 30.16 and 47.31 μM cinnamic acid/min/g (Table 13, Fig. 10). The data revealed that minimum phenylalanine ammonia lyase activity was observed in varieties VNR-51C (30.16 ± 0.09 μM cinnamic acid/min/g) followed by Navkiran (32.56 ± 0.07 μM cinnamic acid/min/g). The maximum phenylalanine ammonia lyase activity was recorded in varieties Ajay (47.31 ± 0.12 μM cinnamic acid/min/g) which differed significantly with NBH-1214 (45.88 ± 0.04 μM cinnamic acid/min/g). The phenylalanine ammonia lyase activity was higher in resistant varieties as comparison to susceptible varieties. The sequence of all varieties from minimum to maximum were VNR-51C < Navkiran < Nishant <

Manjushree < Punjab Bharpur < MAHY-91 < NBH-1214 < Ajay (Table 13, Fig. 10).

Numerous reports have highlighted the diverse biochemical components of host plants that insects preferred based on their nutritional requirements. For instance, brinjal leaves with higher levels of moisture, nitrogen, chlorophyll, proline, and sugar tend to experience higher infestations of jassids and other sucking insect pests of brinjal (Le Gall and Behmer, 2014; Khan *et al.*, 2015; Laichattiwat *et al.*, 2018; Shipa *et al.*, 2021).

The presence of phenols directly inhibits lepidopteran pests, in addition to influencing fruit color (Amin *et al.*, 2014). In comparison with fruit colors, violet (pink) was observed to be highly susceptible, followed by light green. However, white-colored fruits of brinjal exhibited higher flavonoid content, which contributed to resistance against shoot and fruit borers (Kumari *et al.*, 2014). The amount of phenol in the crop varied among genotypes and increased with crop age. The infestation of *L. orbonalis* was thus found to be negatively and significantly correlated with phenols (Prasad *et al.*, 2014; Dar *et al.*, 2017a; Nagappan *et al.*, 2017; Rameshkumar *et al.*, 2019).

This finding is in line with the conclusions drawn by numerous other researchers, who have found that varieties with higher levels of glycoalkaloids (such as solasodine), total phenols, and polyphenol oxidase activity exhibit better resistance to shoot and fruit borer (*L. orbonalis*) infestation (Prasad *et al.*, 2014; Docimo *et al.*, 2016; Dar *et al.*, 2017a).

The wild varieties of brinjal exhibited higher phenylalanine ammonia lyase (PAL) activity, resulting in increased resistance against fruit and shoot borer in India. Additionally, higher lignin content was associated with the lowest shoot and fruit borer (*L. orbonalis*) infestation across different varieties, as indicated by their research (Khorsheduzzaman *et al.*, 2010). Polyphenol oxidase activity is responsible for the browning of brinjal fruit. The study findings suggested that genotypes with high polyphenol oxidase activity responded defensively to borer attacks, indicating a strong positive correlation between polyphenol oxidase activity and resistance to pest attacks (Khorsheduzzaman *et al.*, 2010;

Rameshkumar *et al.*, 2019). Elanchezhyan *et al.*, (2009) noted that brinjal hybrid Swetha shown strong resistance to the fruit borer and shoot borer. Swetha had greater total phenol and ash content levels, whereas Bejo Sheetal had lower levels and was more vulnerable to fruit borer and shoot borer infestations. Moreover, a strong inverse correlation was found between shoot damage and total phenols and ash concentrations. Prabhu *et al.*, (2009) observed increased polyphenol oxidase activity in the interspecific cross F6 EP65 x *S. viarum*. As a result, it was shown that the biochemical elements of superior genotypes were connected with resistance from the fruit and shoot borer.

Table 13. Biochemical analysis of different cultivars of brinjal

Varieties	Phenol (mg/100g)	Protein (mg/100g)	Proline (μmoles/g)	Peroxidase (μM/min/g protein)	Phenylalanine ammonia lyase (μM cinnamic acid/min/g)
Manjushree	98.06 ± 1.25 ^e	117.71 ± 1.05 ^d	3.57 ± 0.10 ^d	1.12 ± 0.03 ^c	38.32 ± 0.34 ^e
NBH-214	128.17 ± 0.79 ^a	88.86 ± 0.91 ^h	4.85 ± 0.09 ^a	1.37 ± 0.04 ^a	45.88 ± 0.04 ^b
Ajay	119.32 ± 0.54 ^b	95.64 ± 0.52 ^g	4.93 ± 0.03 ^a	1.25 ± 0.04 ^b	47.31 ± 0.12 ^a
Punjab Bharpur	101.71 ± 0.78 ^d	103.34 ± 0.69 ^e	4.01 ± 0.08 ^c	1.20 ± 0.03 ^b	39.15 ± 0.06 ^d
MAHY-91	113.17 ± 1.09 ^c	99.32 ± 0.53 ^f	4.41 ± 0.05 ^b	1.24 ± 0.04 ^b	42.15 ± 0.06 ^c
Navkiran	88.58 ± 1.26 ^g	133.46 ± 1.21 ^b	2.36 ± 0.15 ^f	0.95 ± 0.04 ^d	32.56 ± 0.07 ^g
Nishant	94.31 ± 0.94 ^f	124.04 ± 1.24 ^c	3.12 ± 0.13 ^e	1.10 ± 0.03 ^c	36.70 ± 0.04 ^f
VNR-51C	82.75 ± 0.83 ^h	138.29 ± 0.52 ^a	2.46 ± 0.12 ^f	0.87 ± 0.05 ^e	30.16 ± 0.09 ^h
P value	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}
F value	794.209	1297.097	305.995	57.997	5654.802

- Mean of three replicates of each treatment were taken and expressed as per their units
- P Value- Probability, F Value - Ratio of two variances, ± Standard Deviation Values,
- *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant

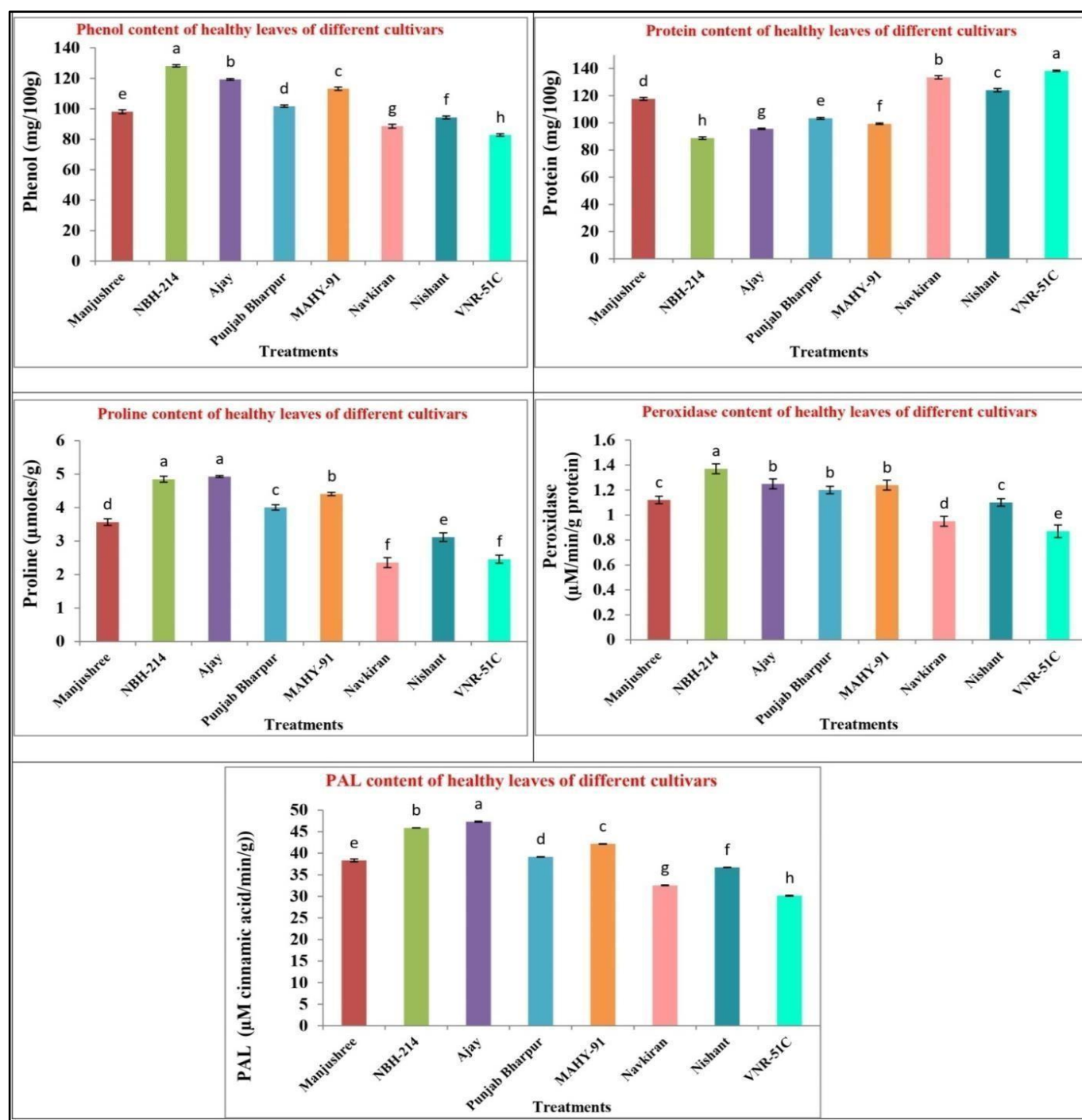


Fig. 10 Biochemical analysis of brinjal varieties

4.2. To screen biorational pesticides for management of major pests of brinjal.

4.2.1. Effectiveness of eco-friendly insecticides against Jassid (nymph and adult) (*Amrasca biguttula biguttula*) during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The population of jassid (nymph and adult) ranged from 15.20 to 22.80 per plant and 14.45 to 17.20 per plant recorded during 2021 and 2022 *Rabi* season before spraying (Table 14, Fig. 11). All the treatments performed significant impact on jassid at 1 DAT (df_(6,4); P = 0.004; df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.000; df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.001; df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000; df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.041; df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000; df_(6,4); P = 0.000) during 2021 and 2022 *Rabi* season (Table 14, Fig. 11). The minimum mean of treatment (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l for jassid population (4.92 and 3.93 per plant) was recorded in *Rabi* 2021 and 2022 respectively (Table 14, Fig. 11). The maximum reduction percent over control was obtained in treatment (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l (43.44 and 71.82 %) followed by (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l offering (35.63 and 67.74 %), (T₂) - NSKE 1% @ 2ml/l offering (35.17 and 59.56 %), followed by (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (32.06 and 56.05 %) and last was (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (27.47 and 48.88 %) (Table 14, Fig. 11). In interaction of years and treatments, the application of biorational pesticides were performed significantly impact on jassid population in 1 DAT (df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during *Rabi* season 2021 and 2022 (Table 14, Fig. 11).

In *Kharif* season of 2022 and 2023, the population of jassid (nymph and adult) ranged from 15.55 to 17.05 per plant and 10.60 to 14.30 per plant recorded during 2022 and 2023 *Kharif* season before spraying (Table 15, Fig. 12). All the treatments were performed significant impact on jassid at 1 DAT (df_(6,4); P = 0.011; df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.001; df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.003; df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000; df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000; df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.002; df_(6,4); P = 0.000) during 2022 and 2023 *Kharif* season (Table 15, Fig. 12). The minimum jassid population (4.13 and 3.44 per plant) was recorded in *Kharif* 2022 and 2023 respectively. The maximum reduction percent over control was obtained in application of (T₂) - NSKE 1% @ 2ml/l offering (61.80 and 74.03 %), followed by (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (59.57 and 67.16 %), (T₃) -

B. bassiana 1×10^8 conidia/ml @ 10 ml/l (42.00 and 63.62 %) followed by (T₄) - *M. anisopliae* 1×10^8 conidia/ml @ 10 ml/l (37.18 and 58.49 %) and last was (T₅) - *V. lecanii* 1×10^8 conidia/ml @ 10 ml/l offering (22.94 and 55.84 %) (Table 15, Fig. 12). In interaction of years and treatments, the application of biorational pesticides were performed significantly impact on jassid population in 1 DAT (df_(6,4); P= 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during *Kharif* season 2022 and 2023 (Table 15, Fig. 12).

In second spray of *Kharif* season 2023, all the treatments significantly reduced the jassid population. The initial population was ranged from 5.35 to 12.25 on precount day. All the treatments were highly significant against jassid at 1 DAT (df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during in *Kharif* season 2023 (Table 16, Fig. 13). The minimum jassid population (1.46 per plant) was recorded in *Kharif* 2023 (Table 16, Fig. 13). The maximum reduction percent over control was noted in (T₂) - NSKE 1% @ 2ml/l with (87.31 %), continued with (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (79.84 %) followed by those treated with (T₃) - *B. bassiana* 1×10^8 conidia/ml @ 10 ml/l giving (75.06 %), (T₄) - *M. anisopliae* 1×10^8 conidia/ml @ 10 ml/l (68.28 %) and less effective treatment was (T₅) - *V. lecanii* 1×10^8 conidia/ml @ 10 ml/l (67.94 %) (Table 16, Fig. 13).

The population of jassid was directly correlated with various factors like temperature, moisture in the environment, geographic location, leaves structure and biochemical parameters (Ramzan *et al.*, 2019; Naeem-Ullah *et al.*, 2020). The population of jassid was reported peak incidence at 46th SMW in 2nd week of November (Tupe *et al.*, 2022), 45th SMW in 1st week of November (Berani *et al.*, 2020) and 1st SMW in January (Lal *et al.*, 2019). Doses with partial quantity of entomopathogenic fungi like *M. anisopliae*, *V. lecanii* and *B. bassiana*, with botanicals like neem seed oil have been found effective against the sucking pest like jassid, whitefly, aphids and thrips (Abdel-Raheem and Al-Keridis, 2017; Halder *et al.*, 2017; Javed *et al.*, 2018; Jugno *et al.*, 2018; Manivannan *et al.*, 2018, Halder, *et al.*, 2023).

The sole application of *B. bassiana* and *Trichoderma harzianum* showed lesser mortality against the jassid in the brinjal crop but in combination with *B. bassiana* and *T. harzianum*, the mortality rate increased by more than 10 % (Javed *et al.*, 2018). Spinosad application exhibited maximum reduction of jassid and whitefly population (Reshma and Behera, 2018; Khare and Sneha, 2021; Singh *et al.*, 2021).

In neem plant, apart from the azadirachtin compound, other active compounds are neem oil, neemark, bioneem, nimbicidin, etc that are effectively controlling sucking pest like aphid, whitefly and jassid (Mane and Kulkarni, 2010; Alzohairy, 2016). However, Products made from neem greatly decreased jassid populations. Additionally, it concurs with those who used neem, dhatura, neem seed water extract at different concentrations to significantly reduce the amount of whitefly and jassids, among other sucking insect pests (Khattak *et al.*, 2006; Dutt, 2007; Bardin *et al.*, 2008).

All the biorational insecticides helps us to provide a eco-friendly approaches for control of pest having sap sucking nature or feeding type in brinjal and it will help for prevention against resistance of pesticides as well as bio magnification and bio accumulation can be avoided from future concern.

Table 14. Efficacy of biorational insecticides against Jassid (nymph and adult) in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of <i>Amrasca biguttula biguttula</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> - 22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Spinosad 45% SC @ 0.4ml/l	19.25 ± 4.71 ^{ab}	15.80 ± 1.50 ^{ab}	9.25 ± 3.38 ^{ab}	12.85 ± 1.96 ^b	7.25 ± 0.19 ^{bc}	10.40 ± 2.28 ^b	7.05 ± 1.85 ^b	5.15 ± 3.13 ^{bc}	6.25 ± 0.34 ^{bc}	7.75 ± 0.34 ^b	4.40 ± 0.71 ^b	3.45 ± 0.71 ^b	3.70 ± 0.11 ^b	3.20 ± 0.28 ^b	6.31	7.13	27.47	48.88
NSKE 1% @ 2ml/l	18.40 ± 3.14 ^{ab}	15.45 ± 2.00 ^{ab}	7.30 ± 2.47 ^b	11.20 ± 1.78 ^{bc}	6.00 ± 0.33 ^{cd}	6.30 ± 1.37 ^c	5.90 ± 1.61 ^{bc}	7.45 ± 2.37 ^b	5.85 ± 0.44 ^{bc}	4.15 ± 1.42 ^{cd}	4.85 ± 0.55 ^{ab}	2.55 ± 0.99 ^{bc}	3.95 ± 0.19 ^{ab}	2.20 ± 0.43 ^{bc}	5.64	5.64	35.17	59.56
<i>Beauveria bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	15.20 ± 3.12 ^b	14.45 ± 0.94 ^b	3.65 ± 1.27 ^c	9.05 ± 1.73 ^c	5.60 ± 0.95 ^d	5.80 ± 1.23 ^c	4.70 ± 1.24 ^c	3.15 ± 1.76 ^c	6.95 ± 0.75 ^b	2.75 ± 0.10 ^d	4.45 ± 0.41 ^b	1.80 ± 0.43 ^c	4.20 ± 0.16 ^a	1.05 ± 0.30 ^d	4.92	3.93	43.44	71.82
<i>Metarhizium anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	22.80 ± 3.64 ^a	16.55 ± 1.30 ^{ab}	8.00 ± 2.12 ^b	12.25 ± 2.68 ^{bc}	7.45 ± 0.19 ^b	6.85 ± 1.15 ^c	6.45 ± 0.41 ^{bc}	8.65 ± 1.43 ^b	6.05 ± 0.34 ^{bc}	4.75 ± 0.75 ^c	4.30 ± 0.52 ^b	2.30 ± 0.70 ^{bc}	3.25 ± 0.37 ^c	2.00 ± 0.43 ^{cd}	5.91	6.13	32.06	56.05
<i>Verticillium lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	15.90 ± 3.97 ^b	17.20 ± 1.60 ^a	7.40 ± 2.79 ^b	9.10 ± 2.08 ^c	6.75 ± 0.71 ^{bcd}	5.75 ± 0.52 ^c	5.80 ± 1.21 ^{bc}	4.90 ± 3.13 ^{bc}	5.55 ± 0.19 ^c	3.85 ± 1.76 ^{cd}	4.80 ± 0.36 ^{ab}	2.10 ± 0.25 ^{bc}	3.30 ± 0.25 ^c	1.35 ± 0.25 ^{cd}	5.60	4.50	35.63	67.74
Control (water);	19.95 ± 4.42 ^{ab}	17.15 ± 1.57 ^a	11.80 ± 1.29 ^a	18.25 ± 2.83 ^a	10.75 ± 1.63 ^a	18.45 ± 1.34 ^a	9.80 ± 0.81 ^a	16.15 ± 2.80 ^a	10.50 ± 1.79 ^a	10.65 ± 0.59 ^a	5.65 ± 0.78 ^a	12.45 ± 1.85 ^a	3.70 ± 0.25 ^b	7.80 ± 1.47 ^a	8.70	13.95		
P value	0.119 ^{NS}	0.128 ^{NS}	0.004 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.001 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.041 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}				
F value	2.056	1.996	5.163	9.353	18.852	49.509	7.361	13.421	19.225	34.048	2.994	71.518	9.147	53.645				
Year*Treatment's																		
P value	0.042 [*]		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}					
F value	2.586		13.765		22.738		12.759		23.988		9.943		6.774					
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Amrasca biguttula biguttula</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Amrasca biguttula biguttula</i> of per plant), PTC - Pretreatment count; DAT - Days after Treatment; ± Standard Deviation Values • *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

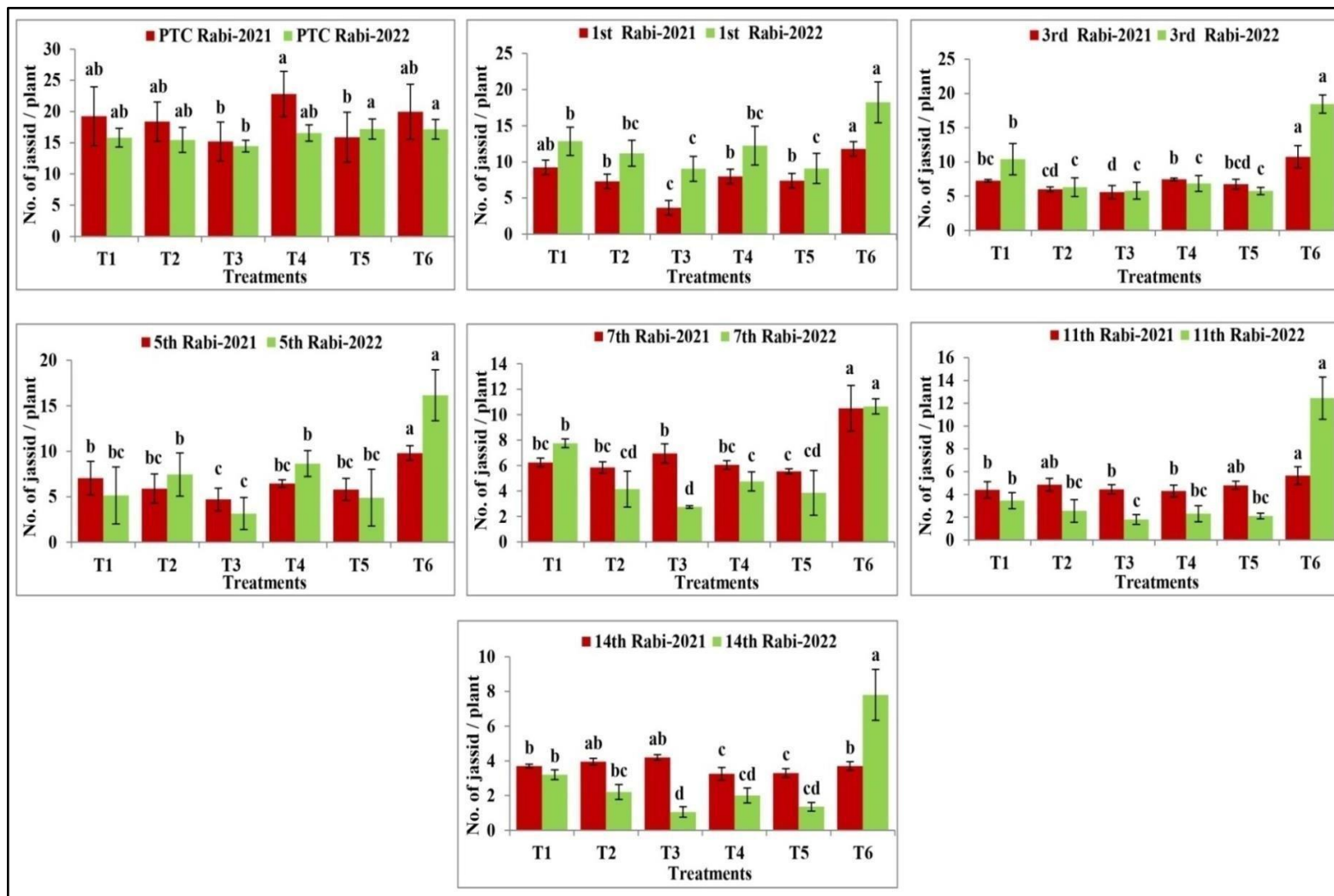


Fig. 11 Efficacy of biorational insecticides against jassid (*Amrasca biguttula biguttula*) in Rabi season 2021 and 2022

Table 15. Efficacy of biorational insecticides against Jassid (nymph and adult) in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of <i>Amrasca biguttula biguttula</i> / per plant*																	
	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Kharif</i> -22	<i>Kharif</i> -23	<i>Kharif</i> -22	<i>Kharif</i> - 23
Spinosad 45% SC @ 0.4ml/l	17.05 ± 0.50 ^a	10.60 ± 1.88 ^b	11.20 ± 2.32 ^{bc}	8.70 ± 2.12 ^{bc}	5.15 ± 1.23 ^c	6.40 ± 1.47 ^{bc}	3.95 ± 1.41 ^c	4.65 ± 0.92 ^{bc}	3.25 ± 1.20 ^{cd}	3.65 ± 0.80 ^{cd}	1.55 ± 0.77 ^{de}	1.80 ± 0.36 ^d	1.15 ± 0.59 ^c	0.90 ± 0.11 ^{cd}	4.37	4.35	59.57	67.16
NSKE 1% @ 2ml/l	16.60 ± 0.33 ^{ab}	11.95 ± 1.98 ^{ab}	11.85 ± 1.41 ^{bc}	7.25 ± 1.98 ^c	4.65 ± 1.73 ^c	5.55 ± 0.86 ^c	3.75 ± 1.45 ^c	3.25 ± 0.73 ^c	2.25 ± 0.52 ^d	2.85 ± 0.19 ^d	1.25 ± 0.25 ^e	1.10 ± 0.25 ^c	1.05 ± 0.80 ^c	0.65 ± 0.19 ^d	4.13	3.44	61.80	74.03
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	16.95 ± 0.53 ^{ab}	11.70 ± 0.74 ^{ab}	10.25 ± 0.99 ^c	9.30 ± 0.35 ^{bc}	8.95 ± 2.34 ^b	6.70 ± 1.36 ^{bc}	7.95 ± 2.77 ^{bc}	5.70 ± 1.27 ^b	4.95 ± 1.45 ^{bcd}	4.15 ± 0.91 ^{bc}	3.25 ± 0.98 ^{cd}	1.10 ± 0.25 ^c	2.30 ± 0.70 ^{bc}	2.00 ± 0.36 ^b	6.27	4.82	42.00	63.62
<i>Metarhiziu m anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	15.95 ± 0.87 ^{ab}	14.30 ± 1.08 ^a	11.55 ± 3.02 ^{bc}	10.40 ± 1.35 ^b	9.05 ± 4.09 ^b	7.15 ± 1.27 ^{bc}	8.45 ± 2.00 ^{ab}	6.20 ± 0.81 ^b	5.25 ± 1.22 ^{bc}	4.85 ± 0.44 ^{bc}	3.85 ± 2.11 ^{bc}	3.00 ± 0.36 ^c	2.55 ± 0.99 ^{bc}	1.45 ± 0.19 ^{bcd}	6.79	5.50	37.18	58.49
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	15.95 ± 0.50 ^{ab}	12.90 ± 2.78 ^{ab}	15.05 ± 1.50 ^{ab}	9.65 ± 2.29 ^{bc}	9.55 ± 1.70 ^b	8.30 ± 1.29 ^b	8.75 ± 2.79 ^{ab}	6.45 ± 0.95 ^b	7.65 ± 3.33 ^{ab}	5.15 ± 0.66 ^b	5.55 ± 1.48 ^{ab}	3.80 ± 0.28 ^b	3.45 ± 1.70 ^{ab}	1.80 ± 0.16 ^{bc}	8.33	5.85	22.94	55.84
Control (water);	15.55 ± 1.76 ^b	13.40 ± 3.35 ^{ab}	17.70 ± 5.16 ^a	16.25 ± 1.16 ^a	13.35 ± 1.56 ^a	17.65 ± 2.00 ^a	12.85 ± 5.22 ^a	15.30 ± 1.77 ^a	10.15 ± 1.36 ^a	12.85 ± 1.36 ^a	5.95 ± 1.02 ^a	9.20 ± 0.48 ^a	4.90 ± 1.85 ^a	8.30 ± 1.37 ^a	10.81	13.25		
P value	0.147 ^{NS}	0.242 ^{NS}	0.011 [*]	0.000 ^{**}	0.001 [*]	0.000 ^{**}	0.003 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.002 [*]	0.000 ^{**}				
F value	1.884	1.492	4.182	13.733	7.647	40.279	5.551	56.310	11.035	79.490	9.882	313.822	5.757	93.585				
Year*Treatment's																		
P value	0.831^{NS}		0.000^{**}		0.000^{**}		0.000^{**}		0.000^{**}		0.000^{**}		0.000^{**}					
F value	0.421		10.855		23.158		20.716		55.448		26.172		21.434					
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Amrasca biguttula biguttula</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Amrasca biguttula biguttula</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), • **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

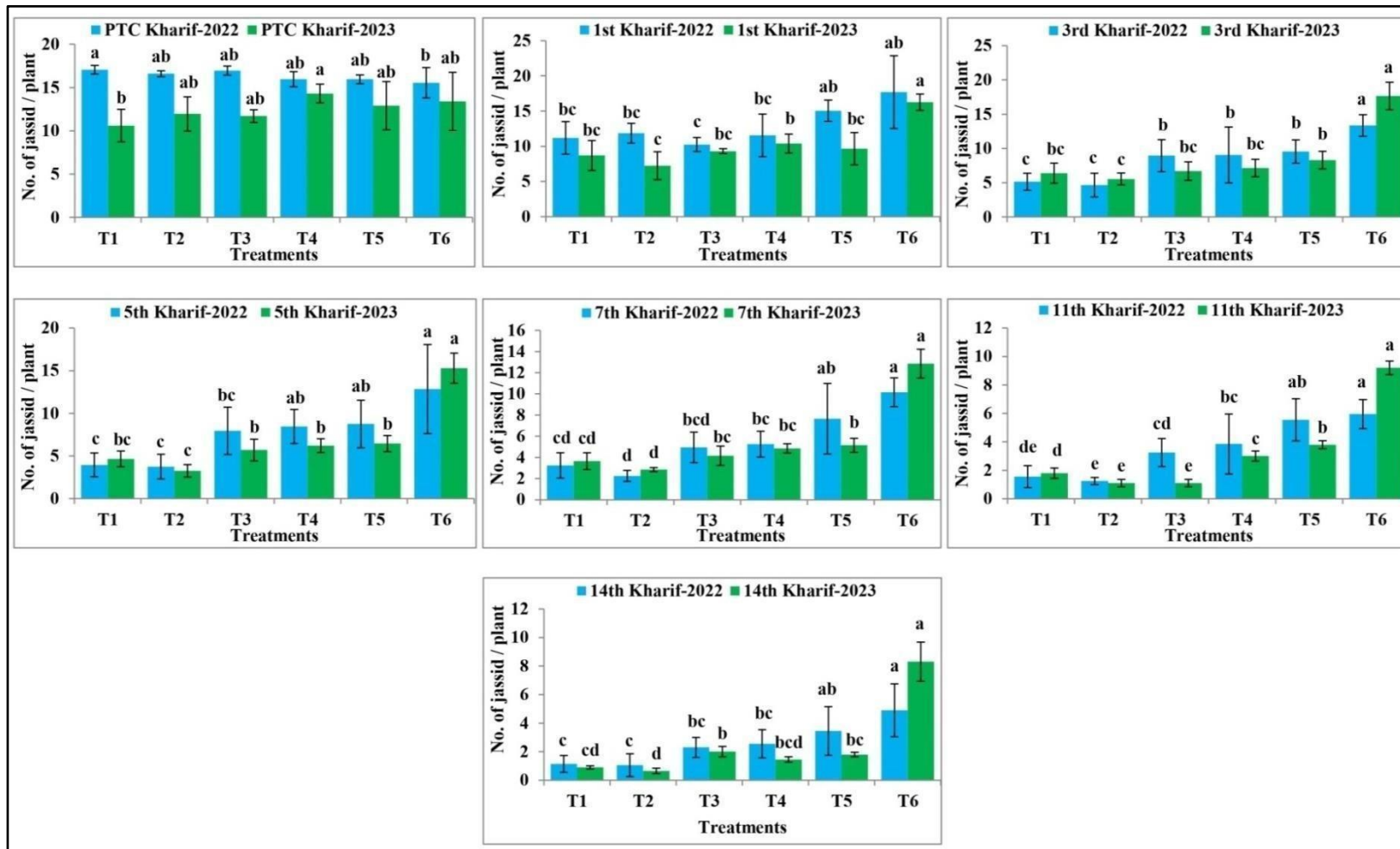


Fig. 12 Efficacy of biorational insecticides against jassid (*Amrasca biguttula biguttula*) in Kharif season 2022 and 2023

Table 16. Efficacy of biorational insecticides against jassid (nymph and adult) in brinjal of *Kharif* season 2023 (Second Spray)

Treatments	No. of <i>Amrasca biguttula biguttula</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Spinosad 45% SC @ 0.4ml/l	6.15 ± 2.75 ^b	4.50 ± 0.68 ^{bc}	3.60 ± 0.59 ^{cd}	2.80 ± 1.48 ^c	1.90 ± 0.34 ^{bc}	0.70 ± 0.62 ^{cd}	0.45 ± 0.19 ^{bc}	2.32	79.84
NSKE 1% @ 2ml/l	5.35 ± 3.03 ^b	3.35 ± 1.21 ^c	2.85 ± 0.68 ^d	1.25 ± 0.95 ^c	0.85 ± 0.19 ^c	0.35 ± 0.47 ^d	0.15 ± 0.19 ^c	1.46	87.31
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	7.25 ± 3.39 ^{ab}	4.55 ± 0.96 ^{bc}	5.60 ± 0.59 ^b	3.15 ± 1.43 ^{bc}	2.20 ± 1.21 ^{bc}	1.10 ± 0.84 ^{bcd}	0.65 ± 0.30 ^{bc}	2.87	75.06
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	7.55 ± 3.02 ^{ab}	6.50 ± 1.27 ^b	5.55 ± 0.87 ^b	3.15 ± 1.52 ^{bc}	4.05 ± 0.77 ^b	1.80 ± 0.37 ^b	0.90 ± 0.26 ^{bc}	3.65	68.28
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	8.05 ± 3.88 ^{ab}	6.40 ± 1.67 ^b	4.25 ± 0.44 ^c	5.75 ± 1.13 ^b	3.15 ± 1.32 ^{bc}	1.60 ± 0.59 ^{bc}	1.00 ± 0.16 ^b	3.69	67.94
Control (water);	12.25 ± 3.51 ^a	14.45 ± 2.22 ^a	14.30 ± 1.29 ^a	12.30 ± 3.19 ^a	11.45 ± 3.75 ^a	9.35 ± 0.85 ^a	7.25 ± 1.07 ^a	11.51	
P value	0.109 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	2.122	31.695	111.837	19.904	19.644	110.267	125.638		
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Amrasca biguttula biguttula</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Amrasca biguttula biguttula</i> of per plant), PTC – Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values • *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

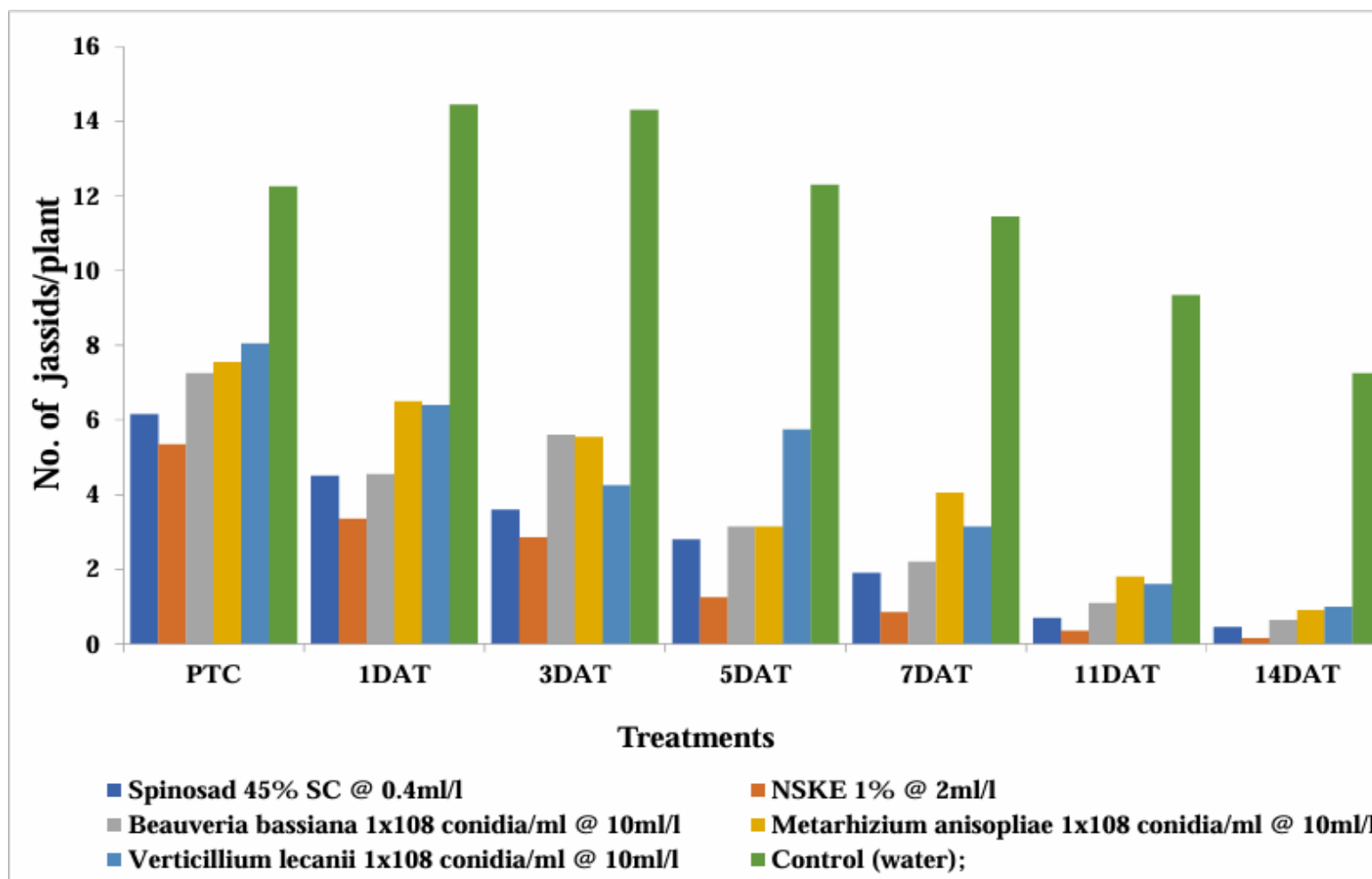


Fig. 13 Efficacy of biorational insecticides against jassid (*Amrasca biguttula biguttula*) in Kharif season 2023

4.2.2. Efficacy of biorational insecticides against whitefly (adult) in brinjal during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The population of whitefly (adult) before spraying ranged from 8.55 to 10.55 per plant and 9.85 to 13.05 per plant recorded during 2021 and 2022 *Rabi* season (Table 17, Fig. 14). All the treatments performed significant impact on whitefly population at where ($P < 0.0005$) from 1 DAT till 14 DAT during 2021 and 2022 *Rabi* season (Table 17, Fig. 14). The mean of minimum whitefly population, 2.96 and 3.05 per plant was recorded in *Rabi* 2021 and 2022, respectively. The maximum reduction percent over control was obtained in application of (T₅) - *V. lecanii* 1×10^8 conidia/ml @ 10 ml/l offering (75.53 and 78.39 %), followed by (T₃) - *B. bassiana* 1×10^8 conidia/ml @ 10 ml/l (72.97 and 74.64 %), (T₂) - NSKE 1% @ 2ml/l offering (70.90 and 69.05 %), followed by (T₄) - *M. anisopliae* 1×10^8 conidia/ml @ 10 ml/l (68.76 and 58.28 %) and last was (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (66.11 and 56.86 %) (Table 17, Fig. 14). In interaction of years and treatments, the application of biorational pesticides exerted significantly impact on whitefly population in 1 DAT (df_(6,4); $P = 0.000$), 3 DAT (df_(6,4); $P = 0.000$), 5 DAT (df_(6,4); $P = 0.000$), 7 DAT (df_(6,4); $P = 0.000$), 11 DAT (df_(6,4); $P = 0.000$) and 14 DAT (df_(6,4); $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 17, Fig. 14).

In *Kharif* season of 2022 and 2023, the population of whitefly (adult) ranged from 8.25 to 12.35 per plant and 10.75 to 12.55 per plant recorded during 2022 and 2023 *Kharif* season before spraying (Table 18, Fig. 15). All the treatments showed significant impact on whitefly ($P < 0.001$) from 1 DAT till 14th DAT during 2022 and 2023 *Kharif* season (Table 18, Fig. 15). The mean of minimum whitefly population, 2.89 and 3.28 per plant was recorded in *Kharif* 2022 and 2023, respectively (Table 18, Fig. 15). The maximum reduction percent over control was obtained in application of (T₂) - NSKE 1% @ 2ml/l offering (80.11 and 74.33 %), followed by (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (75.08 and 71.83 %), (T₅) - *V. lecanii* 1×10^8 conidia/ml @ 10 ml/l offering (72.47 and 69.40 %), followed by (T₃) - *B. bassiana* 1×10^8 conidia/ml @ 10 ml/l (69.02 and 65.41 %) and last was (T₄) - *M. anisopliae* 1×10^8 conidia/ml @ 10 ml/l (67.24 and 61.81 %) (Table 18, Fig. 15).

In interaction of years and treatments, the application of biorational pesticides were performed significantly impact on whitefly population in 1 DAT (df_(6,4); $P = 0.000$), 3 DAT

(df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during *Kharif* season 2022 and 2023 (Table 18, Fig. 15).

In second spray of *Kharif* season 2023, all the treatments significantly reduced the whitefly population. The initial population was ranged from 4.65 to 6.95 on precount day. All the treatments performed significant impact on whitefly at 1 DAT (df_(6,4); P = 0.020), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during in *Kharif* season 2023 (Table 19, Fig. 16). The minimum whitefly population (1.96 per plant) was recorded in *Kharif* 2023 (Table 19, Fig. 16). The maximum reduction percent over control was noted in (T₂) - NSKE 1% @ 2ml/l with (78.41 %), continued with (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l (73.56 %), (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (70.26 %) followed by those treated with (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l giving (68.28 %) and less effective treatment was (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (66.96 %) (Table 19, Fig. 16).

Our research is aligning with similar findings were Spinosad and Azadirachtin, research trail conducted on eggs, nymphs, and adult whiteflies in laboratory and greenhouse settings and indicated that both pesticides had significant effects in reducing fertility and hatching of eggs, as well as the emergence of adults. Additionally, there was substantial mortality observed in nymphs and adults. Interestingly, Azadirachtin outperformed Spinosad in terms of effectiveness (Ghosh, 2014; Neupane *et al.*, 2016; Abdel-Razek *et al.*, 2017; Shannag *et al.*, 2018). The potential of strains of *Verticillium lecanii* (*Lecanicillium* spp.) as microbial control agents for whiteflies on tomato aligns with our investigated findings. Additionally, nymphal stages of *B. tabaci* are highly susceptible to infection by *B. bassiana* (Vicentini *et al.*, 2001; Koike *et al.*, 2004). Karkar *et al.*, (2014 a,b) reported the efficacy and potential of *Lecanicillium lecanii* in reducing the whitefly population in brinjal fields at lower doses. Additionally, they demonstrated the antifeedant, repellency, and toxicity of fungal metabolite toxins of *L. lecanii* against sweet potato whitefly under laboratory conditions. Lower numbers of adult whiteflies were observed compared to the control when using neem leaf extract on okra plants. Additionally, in combination with neem liquid formation helps to minimizes the *B. tabaci*, accompanied by the highest yield (Ali *et al.*, 2017b; Mandal *et al.*, 2018; Patel *et al.*, 2019; Mandavgane and Kulkarni, 2020).

Table 17. Efficacy of biorational insecticides against whitefly (adult) in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of <i>Bemisia tabaci</i> / per plant*																Mean		% Reduction over control	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022						
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> - 21	<i>Rabi</i> - 22	<i>Rabi</i> - 21	<i>Rabi</i> - 22		
Spinosad 45% SC @ 0.4ml/l	9.00 ± 0.16 ^{ab}	12.30 ± 2.25 ^{ab}	7.25 ± 2.18 ^b	10.40 ± 1.40 ^b	6.15 ± 0.77 ^b	9.30 ± 0.68 ^b	4.55 ± 0.25 ^b	6.30 ± 0.47 ^b	3.25 ± 0.44 ^b	4.35 ± 1.78 ^{bc}	2.20 ± 0.32 ^b	3.55 ± 2.04 ^b	1.25 ± 0.34 ^{bc}	2.65 ± 0.99 ^{bc}	4.10	6.09	66.11	56.86		
NSKE 1% @ 2ml/l	9.15 ± 0.75 ^{ab}	11.95 ± 1.94 ^{ab}	6.95 ± 2.27 ^b	8.25 ± 1.59 ^{bc}	4.80 ± 0.43 ^c	6.30 ± 0.34 ^d	3.85 ± 0.19 ^{bc}	4.80 ± 0.16 ^c	2.90 ± 0.26 ^{ab}	3.75 ± 1.23 ^{bc}	0.85 ± 0.34 ^d	1.35 ± 0.61 ^{bc}	1.80 ± 0.71 ^{bc}	1.80 ± 0.43 ^{bcd}	3.52	4.37	70.90	69.05		
<i>Beauveria bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	10.20 ± 0.77 ^{ab}	13.05 ± 2.03 ^a	6.35 ± 1.83 ^b	6.05 ± 1.45 ^c	4.55 ± 0.41 ^c	5.80 ± 0.16 ^d	3.55 ± 0.86 ^{bc}	3.95 ± 0.34 ^d	2.75 ± 0.50 ^{ab}	2.85 ± 2.37 ^{bc}	1.60 ± 0.43 ^{bc}	1.95 ± 0.98 ^{bc}	0.85 ± 0.25 ^{bc}	0.90 ± 0.47 ^d	3.27	3.58	72.97	74.64		
<i>Metarhizium anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	10.55 ± 1.80 ^a	9.85 ± 1.30 ^b	7.05 ± 1.85 ^b	8.65 ± 1.60 ^{bc}	5.15 ± 0.50 ^c	7.90 ± 0.57 ^c	4.05 ± 0.66 ^{bc}	6.65 ± 0.52 ^b	3.10 ± 0.12 ^{ab}	5.40 ± 1.60 ^b	1.35 ± 0.38 ^{cd}	3.75 ± 1.79 ^b	2.00 ± 0.43 ^b	3.00 ± 0.63 ^b	3.78	5.89	68.76	58.28		
<i>Verticillium lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	8.55 ± 0.66 ^b	10.15 ± 1.26 ^{ab}	6.25 ± 1.75 ^b	6.05 ± 1.90 ^c	4.10 ± 0.62 ^c	4.80 ± 0.16 ^c	3.30 ± 0.34 ^c	3.60 ± 0.36 ^d	2.30 ± 0.68 ^c	1.60 ± 1.60 ^c	1.20 ± 0.37 ^{cd}	0.75 ± 0.44 ^c	0.65 ± 0.19 ^c	1.50 ± 0.52 ^{cd}	2.96	3.05	75.53	78.39		
Control (water);	9.95 ± 1.79 ^{ab}	10.05 ± 2.41 ^{ab}	13.45 ± 2.31 ^a	16.30 ± 3.70 ^a	14.55 ± 1.02 ^a	18.10 ± 1.16 ^a	14.00 ± 0.99 ^a	16.40 ± 0.36 ^a	12.60 ± 0.94 ^a	15.10 ± 1.65 ^a	10.10 ± 0.77 ^a	10.05 ± 2.59 ^a	7.90 ± 1.54 ^a	8.80 ± 1.50 ^a	12.10	14.12				
P value	0.164 ^{NS}	0.120 ^{NS}	0.001 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}						
F value	1.799	2.046	7.246	13.207	143.973	245.669	173.210	602.593	203.940	31.186	236.941	17.603	54.684	46.045						
Year*Treatment's																				
P value	0.176 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}							
F value	1.629		22.685		213.002		314.022		79.259		62.782		94.039							
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Bemisia tabaci</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Bemisia tabaci</i> of per plant), PTC – Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																				

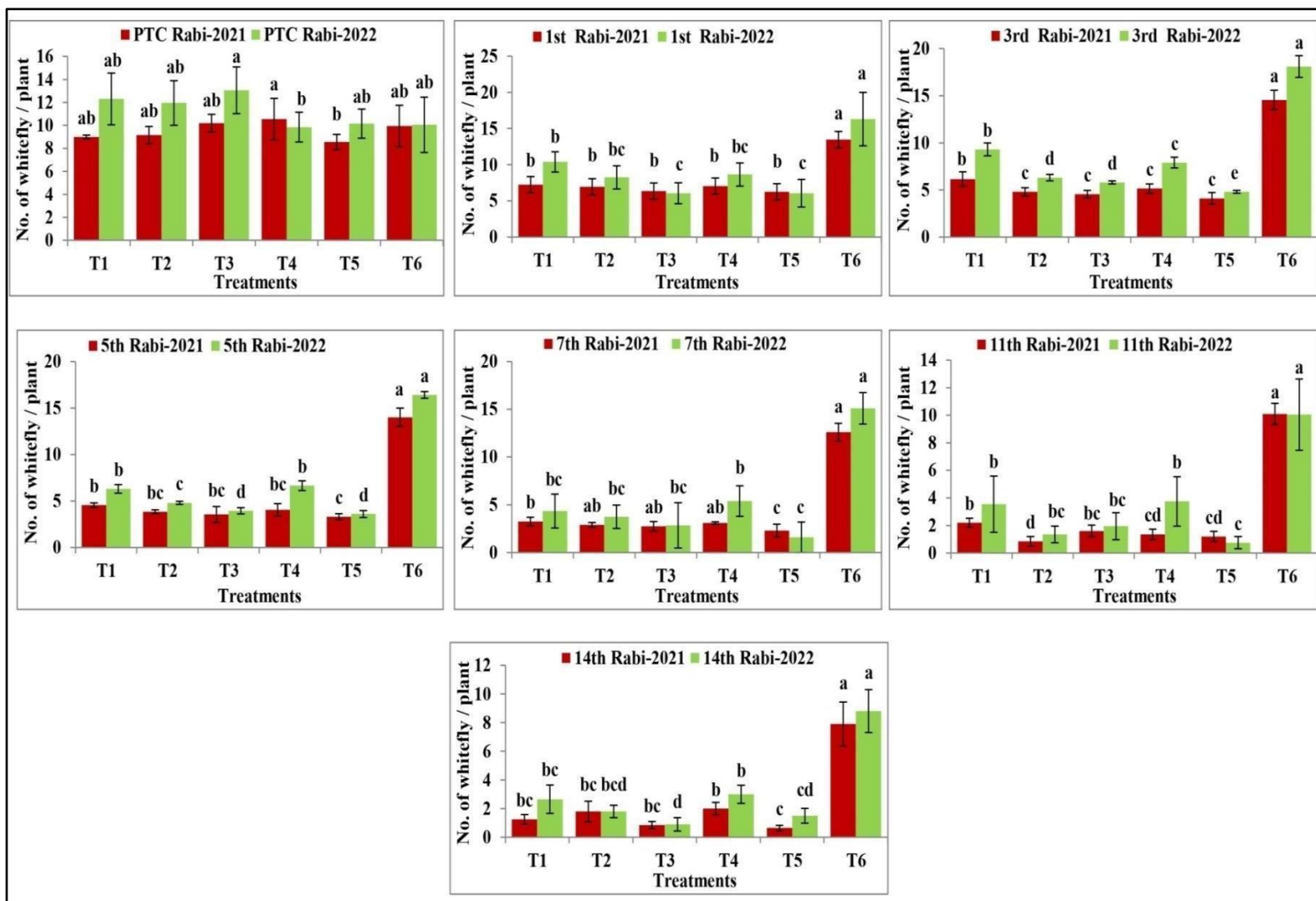


Fig. 14 Efficacy of biorational insecticides against whitefly (*Bemisia tabaci*) in Rabi season 2021 and 2022

Table 18. Efficacy of biorational insecticides against whitefly (adult) in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of <i>Bemisia tabaci</i> / per plant*																	
	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Kharif</i> - 22	<i>Kharif</i> - 23	<i>Kharif</i> - 22	<i>Kharif</i> - 23
Spinosad 45% SC @ 0.4ml/l	12.35 ± 2.34 ^a	10.75 ± 0.81 ^b	7.05 ± 0.60 ^{bc}	6.75 ± 0.34 ^{cd}	5.35 ± 0.90 ^c	5.75 ± 1.18 ^{bc}	3.85 ± 0.64 ^{bc}	3.90 ± 0.25 ^c	2.75 ± 0.34 ^{cd}	2.70 ± 0.25 ^c	1.85 ± 0.44 ^{bc}	1.65 ± 0.19 ^{de}	0.90 ± 0.26 ^{bc}	0.85 ± 0.37 ^c	3.62	3.60	75.08	71.83
NSKE 1% @ 2ml/l	10.80 ± 1.89 ^{ab}	11.35 ± 0.66 ^{ab}	6.25 ± 0.57 ^c	6.40 ± 0.57 ^d	4.45 ± 0.47 ^d	5.10 ± 0.88 ^c	2.60 ± 0.34 ^c	3.75 ± 0.19 ^c	1.95 ± 0.19 ^d	2.40 ± 0.43 ^c	1.40 ± 0.36 ^c	1.35 ± 0.19 ^c	0.70 ± 0.26 ^c	0.70 ± 0.25 ^c	2.89	3.28	80.11	74.33
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	9.25 ± 2.64 ^{ab}	11.70 ± 0.96 ^{ab}	7.75 ± 0.76 ^{bc}	7.50 ± 0.26 ^{bc}	6.25 ± 0.71 ^{bc}	6.80 ± 0.99 ^{bc}	4.75 ± 1.08 ^b	4.95 ± 0.34 ^b	3.95 ± 0.85 ^b	4.20 ± 0.36 ^b	2.85 ± 0.25 ^b	2.10 ± 0.25 ^c	1.45 ± 0.30 ^b	1.00 ± 0.16 ^c	4.50	4.42	69.02	65.41
<i>Metarhiziu m anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	8.25 ± 1.85 ^b	11.85 ± 0.94 ^{ab}	7.95 ± 0.84 ^b	8.00 ± 0.63 ^b	6.45 ± 0.68 ^b	6.90 ± 0.87 ^b	5.15 ± 0.93 ^b	5.20 ± 0.36 ^b	4.40 ± 0.69 ^b	4.75 ± 0.41 ^b	3.05 ± 0.57 ^b	2.60 ± 0.16 ^b	1.60 ± 0.63 ^b	1.85 ± 0.19 ^b	4.76	4.88	67.24	61.81
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	9.20 ± 3.05 ^{ab}	10.90 ± 0.58 ^{ab}	7.55 ± 0.57 ^{bc}	7.30 ± 0.93 ^{bcd}	5.55 ± 0.41 ^{bc}	5.85 ± 0.99 ^{bc}	4.15 ± 0.90 ^{bc}	4.65 ± 0.44 ^b	3.05 ± 0.19 ^c	3.00 ± 0.16 ^c	2.50 ± 0.42 ^{bc}	1.80 ± 0.16 ^{cd}	1.20 ± 0.54 ^{bc}	0.90 ± 0.25 ^c	4.00	3.91	72.47	69.40
Control (water);	12.25 ± 2.26 ^a	12.55 ± 1.77 ^a	18.30 ± 1.80 ^a	17.25 ± 0.93 ^a	17.70 ± 0.41 ^a	16.30 ± 1.50 ^a	15.25 ± 1.96 ^a	14.65 ± 0.90 ^a	14.20 ± 0.82 ^a	13.95 ± 1.63 ^a	13.85 ± 1.81 ^a	8.00 ± 0.36 ^a	9.65 ± 0.50 ^a	6.55 ± 0.25 ^a	14.53	12.78		
P value	0.115 ^{NS}	0.194 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}				
F value	2.084	1.667	88.971	156.611	254.560	59.514	70.293	309.38	242.141	142.363	128.987	468.931	248.846	308.752				
Year*Treatment's																		
P value	0.141^{NS}		0.000^{**}		0.000^{**}		0.000^{**}		0.000^{**}		0.000^{**}		0.000^{**}					
F value	1.779		232.123		207.454		218.596		402.838		65.493		124.805					
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Bemisia tabaci</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Bemisia tabaci</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

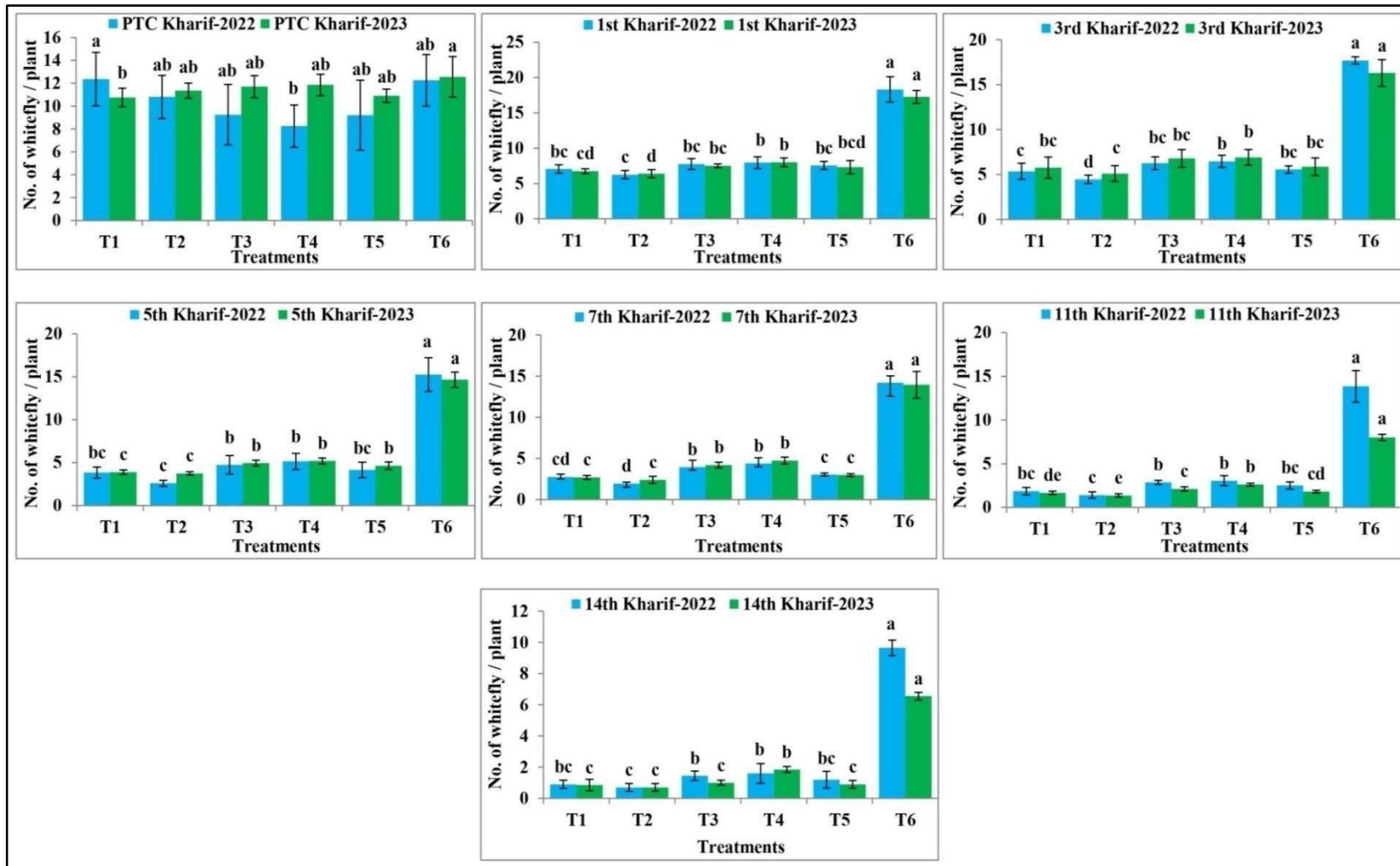


Fig. 15 Efficacy of biorational insecticides against whitefly (*Bemisia tabaci*) in Kharif season 2022 and 2023

Table 19. Efficacy of biorational insecticides against whitefly (adult) in brinjal of *Kharif* season 2023 (Second Spray)

Treatments	No. of <i>Bemisia tabaci</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Spinosad 45% SC @ 0.4ml/l	6.95 ± 1.51 ^a	5.60 ± 1.36 ^{ab}	4.30 ± 0.62 ^b	2.85 ± 0.77 ^c	1.25 ± 0.34 ^c	1.60 ± 0.86 ^b	0.60 ± 0.16 ^c	2.70	70.26
NSKE 1% @ 2ml/l	5.75 ± 0.62 ^{ab}	4.05 ± 1.17 ^b	2.20 ± 0.73 ^c	3.25 ± 0.44 ^{bc}	1.20 ± 0.36 ^c	0.45 ± 0.57 ^c	0.65 ± 0.50 ^c	1.96	78.41
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	5.60 ± 1.43 ^{ab}	3.85 ± 0.82 ^b	3.30 ± 0.53 ^{bc}	4.55 ± 1.02 ^b	2.20 ± 1.21 ^{bc}	1.20 ± 0.37 ^{bc}	2.20 ± 0.71 ^b	2.88	68.28
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	4.65 ± 1.69 ^b	4.10 ± 1.39 ^b	4.55 ± 0.68 ^b	2.75 ± 0.50 ^c	3.40 ± 0.43 ^b	1.90 ± 0.26 ^b	1.35 ± 0.94 ^{bc}	3.00	66.96
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	4.70 ± 0.60 ^b	3.30 ± 1.08 ^b	3.55 ± 0.82 ^{bc}	3.05 ± 0.59 ^{bc}	2.00 ± 0.43 ^{bc}	1.60 ± 0.71 ^b	0.95 ± 0.97 ^c	2.40	73.56
Control (water);	6.35 ± 1.55 ^{ab}	7.25 ± 2.73 ^a	10.50 ± 1.78 ^a	12.60 ± 1.89 ^a	10.50 ± 2.34 ^a	8.00 ± 0.67 ^a	5.65 ± 1.00 ^a	9.08	
P value	0.145 ^{NS}	0.020 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	1.894	3.565	37.831	58.998	39.977	81.790	24.722		
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Bemisia tabaci</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Bemisia tabaci</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

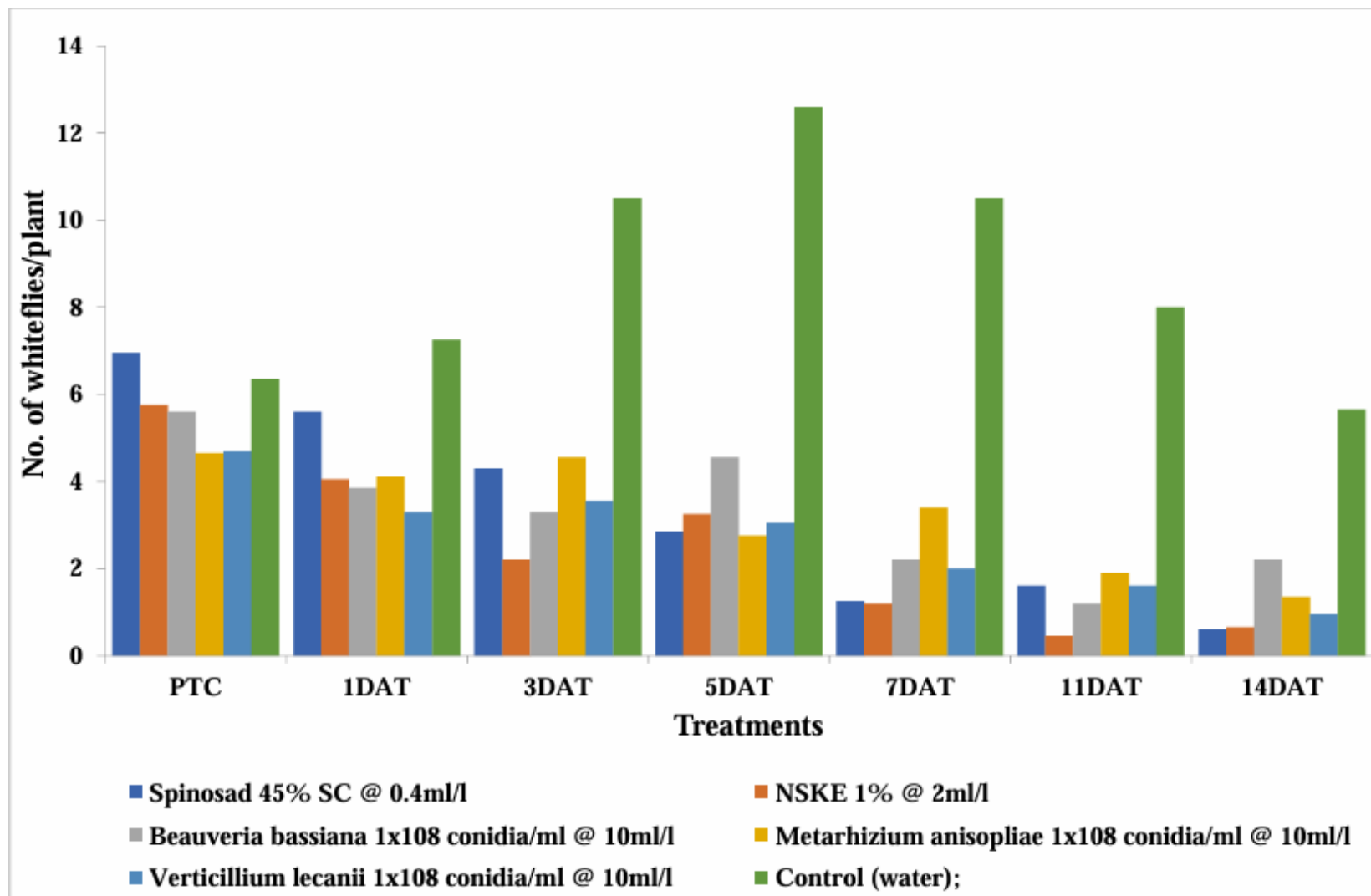


Fig. 16 Efficacy of biorational insecticides against whitefly (*Bemisia tabaci*) in Kharif season 2023

4.2.3. Efficacy of biorational insecticides against hadda beetle (grub and adult) in brinjal during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The population of hadda beetle (grub and adult) ranged from 1.15 to 1.45 per plant and 1.65 to 2.50 per plant recorded during 2021 and 2022 *Rabi* season before spraying (Table 20, Fig. 17). All the treatments were performed significant impact on hadda beetle ($P < 0.005$) from 1 DAT till 14th DAT during 2021 and 2022 *Rabi* season (Table 21, Fig. 17). The minimum hadda beetle population (0.53 and 0.84 per plant) was recorded in *Rabi* 2021 and 2022 respectively (Table 20, Fig. 17). The maximum reduction percent over control was obtained in application of (T₂) - NSKE 1% @ 2ml/l offering (81.13 and 80.77 %) followed by (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (77.93 and 76.43 %), (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (74.73 and 72.08 %), (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l (71.53 and 70.48 %) and least effective was (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l offering (67.97 and 66.81 %) (Table 20, Fig. 17). In interaction of years and treatments, the application of biorational pesticides were performed significantly impact on hadda beetle population in 1 DAT (df_(6,4); $P = 0.000$), 3 DAT (df_(6,4); $P = 0.000$), 5 DAT (df_(6,4); $P = 0.000$), 7 DAT (df_(6,4); $P = 0.000$), 11 DAT (df_(6,4); $P = 0.000$) and 14 DAT (df_(6,4); $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 20, Fig. 17).

In *Kharif* season of 2022 and 2023, the population of hadda beetle (grub and adult) was ranged from 0.90 to 1.95 per plant and 2.25 to 2.75 per plant recorded during 2022 and 2023 *Kharif* season before spraying (Table 21, Fig. 18). All the treatments were performed significant impact on hadda beetle ($P < 0.005$) from 1 DAT till 14th DAT during 2022 and 2023 *Kharif* season (Table 21, Fig. 18). The minimum hadda beetle (grub and adult) population (0.29 and 0.73 per plant) was recorded in *Kharif* 2022 and 2023 respectively (Table 21, Fig. 18). The maximum reduction percent over control was obtained in application of (T₂) - NSKE 1% @ 2ml/l offering (82.09 and 84.56 %), followed by (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (77.16 and 82.24 %), (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (70.98 and 78.01 %), followed by (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l (63.58 and 73.57 %) and least effective was (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l offering (53.70 and 75.47 %).

%) (Table 22, Fig. 18). In interaction of years and treatments, the application of biorational pesticides were performed significantly impact on hadda beetle (grub and adult) population in 1 DAT (df_(6,4); P= 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during *Kharif* season 2022 and 2023 (Table 21, Fig. 18).

In second spray of *Kharif* season 2023, all the treatments significantly reduced hadda beetle (grub and adult) population. The initial population was ranged from 1.45 to 2.10 on precount day. All the treatments performed significant impact on hadda beetle (P < 0.001) from 1 DAT till 14th DAT during *Kharif* season 2023 (Table 22, Fig. 19). The minimum hadda beetle population (0.70 per plant) was recorded in *Kharif* 2023 (Table 22, Fig. 19). The maximum reduction percent over control was noted in (T₂) - NSKE 1% @ 2ml/l with (80.76 %), continued with (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (79.39 %), (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (76.64 %), (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l (75.27 %) and (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l giving (70.05 %) (Table 22, Fig. 19).

Similar findings related to our study have been reported by many researchers. For instance, hadda beetle incidence was observed during December to January 2021, with minimum population levels observed up to the fruiting stages of the crop (Yadav and Chang, 2014). The damage symptoms as leaf eating, cutting and scrapping on leaves were noted in hadda beetle was notified in August (34th SMW) and reached its peak in September (37th and 38th SMW), as reported by (Bharadiya and Patel, 2005; Latif *et al.*, 2009; Manikandan *et al.*, 2019; Kumar *et al.*, 2021).

Swaminathan *et al.*, (2010) recorded higher adult mortality under laboratory conditions due to application of neem oil. Among the biopesticides tested, including *Metarhizium anisopliae* and neem oil, they provided the highest protection over the control. Furthermore, they exhibited compatibility and synergistic activity when used in combination (Vishwakarma *et al.*, 2011; Kodandaram *et al.*, 2014). *Azadirachta indica*, neem cake extracts, neem oil, and nimbecidine, contain various active compounds. These components lower the chance of resistance development and makes them effective in

managing hadda beetle populations (Anam *et al.*, 2006; Murugesan and Muruges, 2008; Podder *et al.*, 2013).

Spinosad has been found to be effective against both the grub and adult stages of the hadda beetle in spine gourd (Reddy *et al.*, 2016; Birjhu *et al.*, 2020; Shrestha *et al.*, 2020; Birjhu *et al.*, 2023). For efficient integrated control of epilachna beetle and other foliage-feeding beetles, local vegetable producers are advised to apply a combination of Spinosad and neem in foliar spray (Hanif *et al.*, 2021).

Table 20. Efficacy of biorational insecticides against hadda beetle (grub and adult) in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of <i>Henosepilachna vigintioctopunctata</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> - 22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Spinosad 45% SC @ 0.4ml/l	1.35 ± 0.19 ^{ab}	2.50 ± 0.35 ^a	1.05 ± 0.19 ^{bc}	1.45 ± 0.25 ^{bc}	0.85 ± 0.19 ^{bc}	1.35 ± 0.19 ^{bc}	0.70 ± 0.34 ^{bc}	0.95 ± 0.19 ^c	0.55 ± 0.19 ^{bc}	1.05 ± 0.19 ^{bc}	0.35 ± 0.19 ^{bc}	0.60 ± 0.16 ^c	0.25 ± 0.19 ^c	0.80 ± 0.28 ^b	0.62	1.03	77.93	76.43
NSKE 1% @ 2ml/l	1.25 ± 0.10 ^{ab}	2.20 ± 0.16 ^{ab}	0.95 ± 0.10 ^c	1.35 ± 0.10 ^c	0.75 ± 0.10 ^c	1.15 ± 0.10 ^c	0.55 ± 0.30 ^c	1.05 ± 0.19 ^c	0.40 ± 0.16 ^c	0.55 ± 0.34 ^c	0.20 ± 0.00 ^c	0.70 ± 0.11 ^c	0.34 ± 0.16 ^b	0.25 ± 0.19 ^c	0.53	0.84	81.13	80.77
<i>Beauveria</i> <i>bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.45 ± 0.19 ^a	1.85 ± 0.53 ^{ab}	1.20 ± 0.16 ^{bc}	1.65 ± 0.19 ^b	1.05 ± 0.19 ^{bc}	1.50 ± 0.12 ^b	0.90 ± 0.34 ^{bc}	1.25 ± 0.19 ^c	0.75 ± 0.19 ^b	1.40 ± 0.16 ^b	0.40 ± 0.16 ^{bc}	1.10 ± 0.25 ^{bc}	0.50 ± 0.11 ^{bc}	0.85 ± 0.19 ^b	0.80	1.29	71.53	70.48
<i>Metarhizium</i> <i>anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.20 ± 0.16 ^{ab}	2.15 ± 0.41 ^{ab}	1.10 ± 0.12 ^{bc}	1.55 ± 0.19 ^{bc}	0.80 ± 0.16 ^{bc}	1.40 ± 0.16 ^{bc}	0.95 ± 0.25 ^{bc}	1.35 ± 0.19 ^{bc}	0.70 ± 0.11 ^b	1.15 ± 0.19 ^{bc}	0.45 ± 0.10 ^{bc}	1.00 ± 0.28 ^{bc}	0.30 ± 0.11 ^c	0.90 ± 0.47 ^b	0.71	1.22	74.73	72.08
<i>Verticillium</i> <i>lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.45 ± 0.19 ^a	2.05 ± 0.68 ^{ab}	1.30 ± 0.26 ^b	1.65 ± 0.10 ^b	1.15 ± 0.10 ^b	1.45 ± 0.19 ^b	1.05 ± 0.30 ^b	1.70 ± 0.25 ^b	0.85 ± 0.19 ^b	1.60 ± 0.36 ^b	0.60 ± 0.16 ^b	1.25 ± 0.57 ^b	0.45 ± 0.10 ^{bc}	1.05 ± 0.50 ^b	0.90	1.45	67.97	66.81
Control (water);	1.15 ± 0.19 ^b	1.65 ± 0.66 ^b	4.20 ± 0.23 ^a	4.85 ± 0.19 ^a	3.60 ± 0.43 ^a	5.20 ± 0.28 ^a	3.00 ± 0.23 ^a	4.75 ± 0.52 ^a	2.70 ± 0.25 ^a	5.80 ± 0.90 ^a	1.95 ± 0.34 ^a	3.90 ± 0.38 ^a	1.45 ± 0.25 ^a	1.70 ± 0.25 ^a	2.81	4.37		
P value	0.106 ^{NS}	0.274 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.001 [*]				
F value	2.149	1.393	185.303	229.738	95.530	290.292	36.555	102.780	80.354	76.095	46.237	55.348	28.420	7.536				
Year*Treatment's																		
P value	0.184 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}					
F value	1.597		445.744		145.466		71.341		37.928		43.763		15.149					
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Henosepilachna vigintioctopunctata</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Henosepilachna vigintioctopunctata</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																		

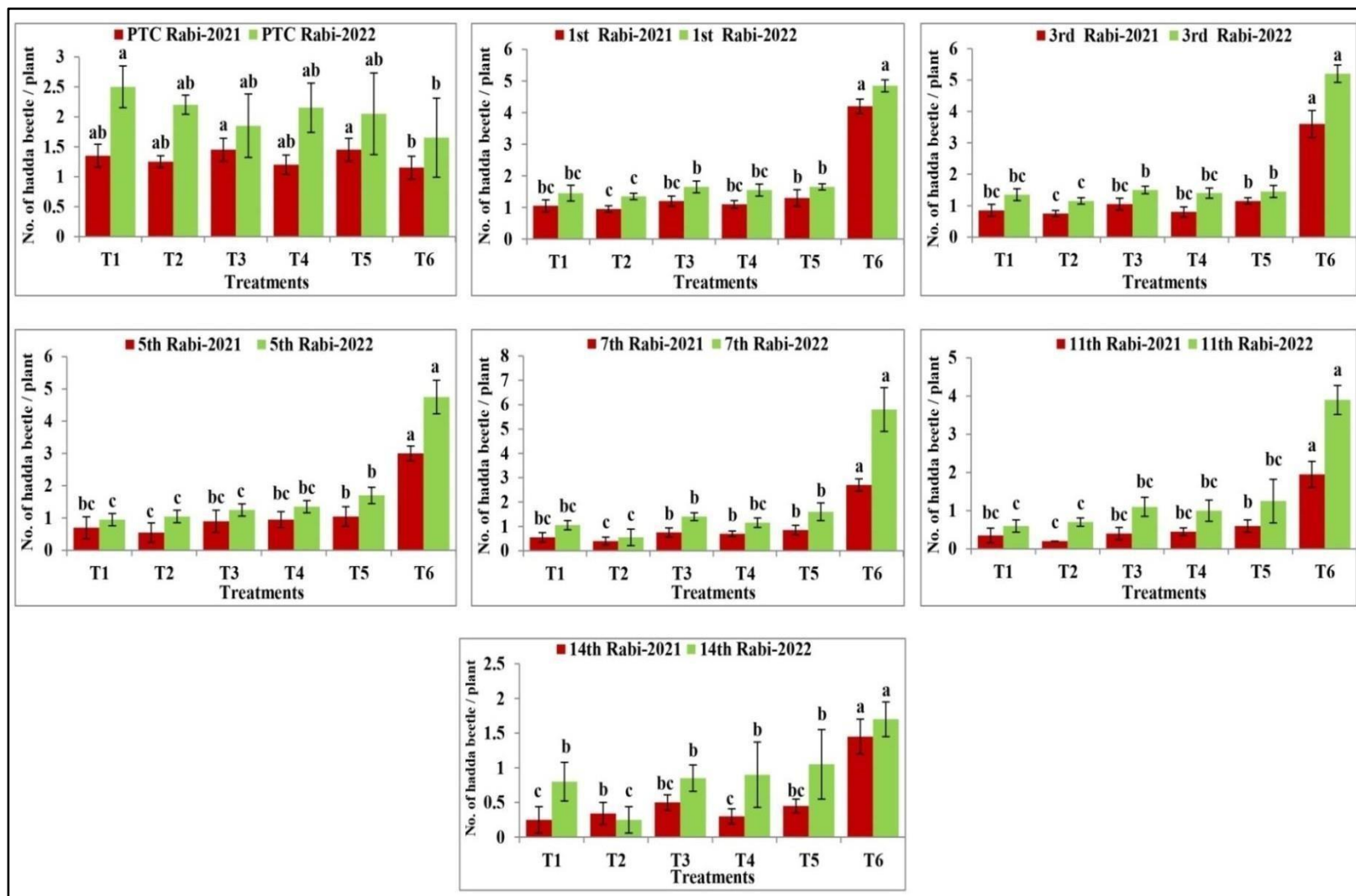


Fig. 17 Efficacy of biorational insecticides against hadda beetle (*Henosepilachna vigintioctopunctata*) in Rabi season 2021 and 2022

Table 21. Efficacy of biorational insecticides against hadda beetle (grub and adult) in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of <i>Henosepilachna vigintioctopunctata</i> / per plant*																	
	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Kharif -22	Kharif -23	Kharif -22	Kharif -23
Spinosad 45% SC @ 0.4ml/l	1.40 ± 0.91 ^{ab}	2.35 ± 0.19 ^{ab}	0.85 ± 0.41 ^{bc}	1.85 ± 1.36 ^b	0.65 ± 0.19 ^{bc}	1.25 ± 0.52 ^c	0.35 ± 0.25 ^{bc}	0.85 ± 0.10 ^d	0.20 ± 0.16 ^c	0.60 ± 0.16 ^c	0.15 ± 0.19 ^{bc}	0.30 ± 0.25 ^{bc}	0.05 ± 0.10 ^c	0.20 ± 0.16 ^c	0.37	0.84	77.16	82.24
NSKE 1% @ 2ml/l	1.30 ± 0.73 ^{ab}	2.25 ± 0.10 ^b	0.65 ± 0.53 ^c	1.65 ± 1.33 ^b	0.55 ± 0.34 ^c	1.15 ± 0.47 ^c	0.25 ± 0.25 ^c	0.70 ± 0.25 ^d	0.15 ± 0.10 ^c	0.55 ± 0.19 ^c	0.05 ± 0.10 ^c	0.20 ± 0.16 ^c	0.10 ± 0.11 ^{bc}	0.15 ± 0.19 ^c	0.29	0.73	82.09	84.56
<i>Beauveria bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.45 ± 0.34 ^{ab}	2.60 ± 0.37 ^{ab}	1.00 ± 0.43 ^{bc}	1.85 ± 1.34 ^b	0.80 ± 0.43 ^{bc}	2.15 ± 0.34 ^b	0.75 ± 0.19 ^{bc}	1.30 ± 0.11 ^{bc}	0.45 ± 0.25 ^{bc}	1.00 ± 0.16 ^b	0.30 ± 0.11 ^{bc}	0.45 ± 0.34 ^{bc}	0.25 ± 0.10 ^{bc}	0.75 ± 0.25 ^b	0.59	1.25	63.58	73.57
<i>Metarhiziu m anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	0.90 ± 0.62 ^b	2.75 ± 0.25 ^a	0.95 ± 0.34 ^{bc}	1.90 ± 1.29 ^b	0.65 ± 0.38 ^{bc}	1.55 ± 0.19 ^{bc}	0.40 ± 0.16 ^{bc}	1.05 ± 0.30 ^{cd}	0.35 ± 0.10 ^{bc}	0.80 ± 0.36 ^{bc}	0.30 ± 0.11 ^{bc}	0.40 ± 0.28 ^{bc}	0.20 ± 0.16 ^{bc}	0.55 ± 0.19 ^b	0.47	1.04	70.98	78.01
<i>Verticillium lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.95 ± 0.25 ^a	2.55 ± 0.19 ^{ab}	1.35 ± 0.19 ^b	2.00 ± 1.39 ^b	1.15 ± 0.19 ^b	1.20 ± 0.43 ^c	0.85 ± 0.19 ^b	1.60 ± 0.28 ^b	0.55 ± 0.19 ^b	0.85 ± 0.19 ^{bc}	0.35 ± 0.19 ^b	0.75 ± 0.19 ^b	0.30 ± 0.12 ^b	0.60 ± 0.16 ^b	0.75	1.16	53.70	75.47
Control (water);	1.90 ± 0.35 ^a	2.60 ± 0.37 ^{ab}	2.15 ± 0.44 ^a	6.40 ± 2.12 ^a	2.85 ± 0.28 ^a	5.60 ± 0.85 ^a	1.45 ± 0.74 ^a	4.75 ± 0.34 ^a	1.25 ± 0.25 ^a	5.00 ± 0.16 ^a	1.05 ± 0.19 ^a	3.70 ± 0.52 ^a	1.00 ± 0.16 ^a	2.95 ± 0.19 ^a	1.62	4.73		
P value	0.168 ^{NS}	0.135 ^{NS}	0.001*	0.002*	0.000**	0.000**	0.002*	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**				
F value	1.779	1.955	7.039	6.128	29.520	46.077	6.226	148.041	18.333	253.144	20.400	72.303	28.960	116.118				
Year*Treatment's																		
P value	0.235 ^{NS}		0.000**		0.000**		0.000**		0.000**		0.000**		0.000**					
F value	1.431		7.019		32.444		18.549		17.195		17.718		25.446					
* P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Henosepilachna vigintioctopunctata</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Henosepilachna vigintioctopunctata</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed). NS - Non Significant																		

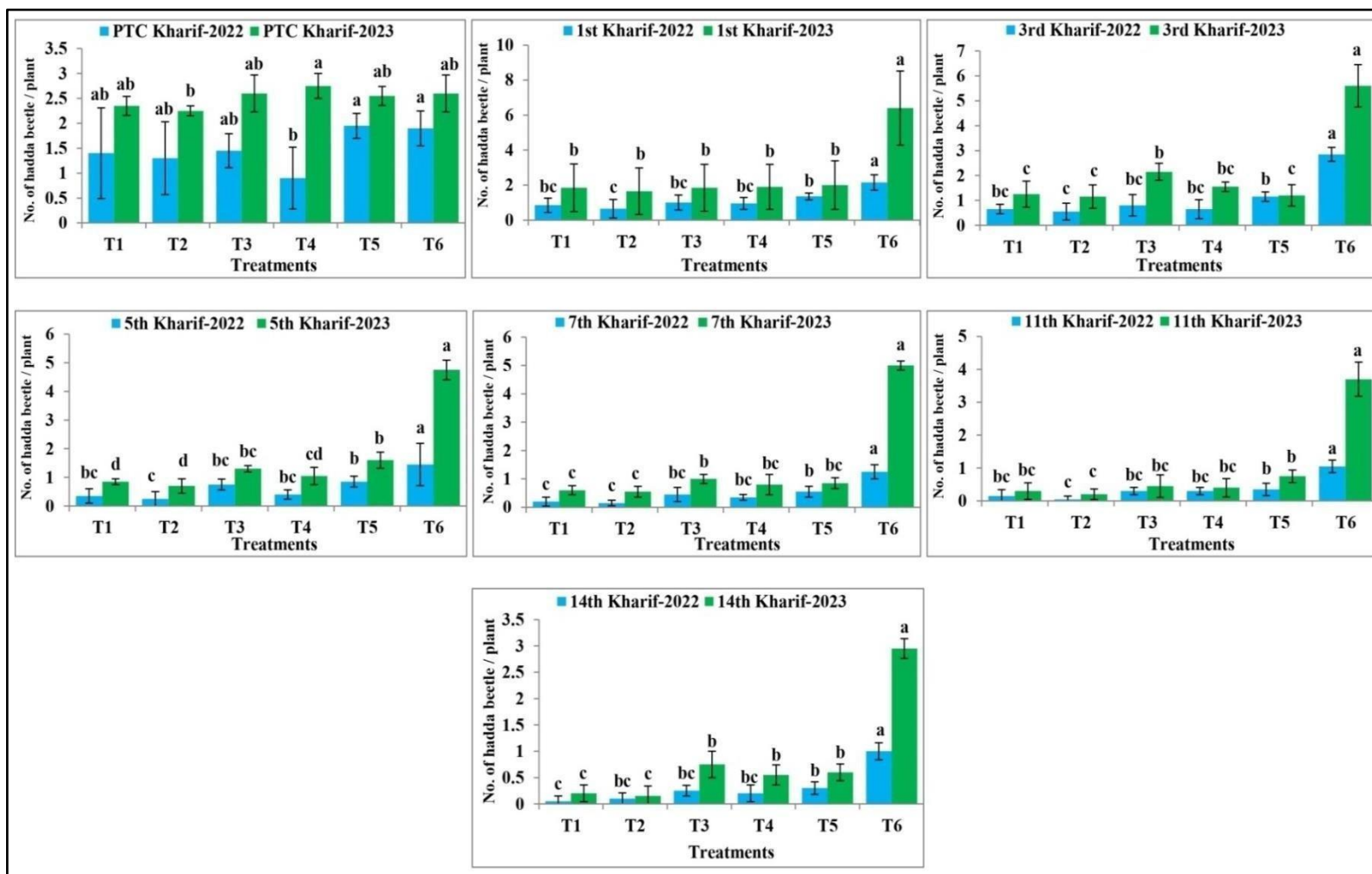


Fig. 18 Efficacy of biorational insecticides against hadda beetle (*Henosepilachna vigintioctopunctata*) in Kharif season 2022 and 2023

Table 22. Efficacy of biorational insecticides against hadda beetle (grub and adult) in brinjal of *Kharif* season 2023 (Second Spray)

Treatments	No. of <i>Henosepilachna vigintioctopunctata</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Spinosad 45% SC @ 0.4ml/l	1.95 ± 0.34 ^{ab}	1.25 ± 0.30 ^c	0.90 ± 0.26 ^c	1.10 ± 0.26 ^{bc}	0.75 ± 0.10 ^c	0.15 ± 0.19 ^d	0.35 ± 0.19 ^{bc}	0.75	79.39
NSKE 1% @ 2ml/l	1.85 ± 0.34 ^{ab}	1.35 ± 0.19 ^{bc}	1.05 ± 0.30 ^{bc}	0.65 ± 0.19 ^c	0.80 ± 0.16 ^c	0.25 ± 0.19 ^{cd}	0.10 ± 0.12 ^c	0.70	80.76
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	1.45 ± 0.44 ^b	1.65 ± 0.19 ^b	1.45 ± 0.25 ^b	1.25 ± 0.19 ^b	1.10 ± 0.12 ^b	0.70 ± 0.26 ^b	0.40 ± 0.16 ^{bc}	1.09	70.05
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	2.10 ± 0.26 ^a	1.20 ± 0.28 ^c	1.15 ± 0.34 ^{bc}	0.95 ± 0.19 ^{bc}	0.75 ± 0.19 ^c	0.35 ± 0.19 ^{cd}	0.70 ± 0.26 ^b	0.85	76.64
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	1.75 ± 0.25 ^{ab}	1.45 ± 0.30 ^{bc}	1.35 ± 0.19 ^{bc}	0.85 ± 0.34 ^{bc}	1.10 ± 0.12 ^b	0.50 ± 0.12 ^{bc}	0.20 ± 0.23 ^c	0.90	75.27
Control (water);	1.50 ± 0.41 ^b	4.65 ± 0.19 ^a	5.15 ± 0.34 ^a	4.55 ± 0.68 ^a	3.40 ± 0.23 ^a	2.25 ± 0.30 ^a	1.85 ± 0.34 ^a	3.64	
P value	0.110 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	2.116	117.259	130.600	69.476	167.270	52.629	31.940		
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Henosepilachna vigintioctopunctata</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Henosepilachna vigintioctopunctata</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

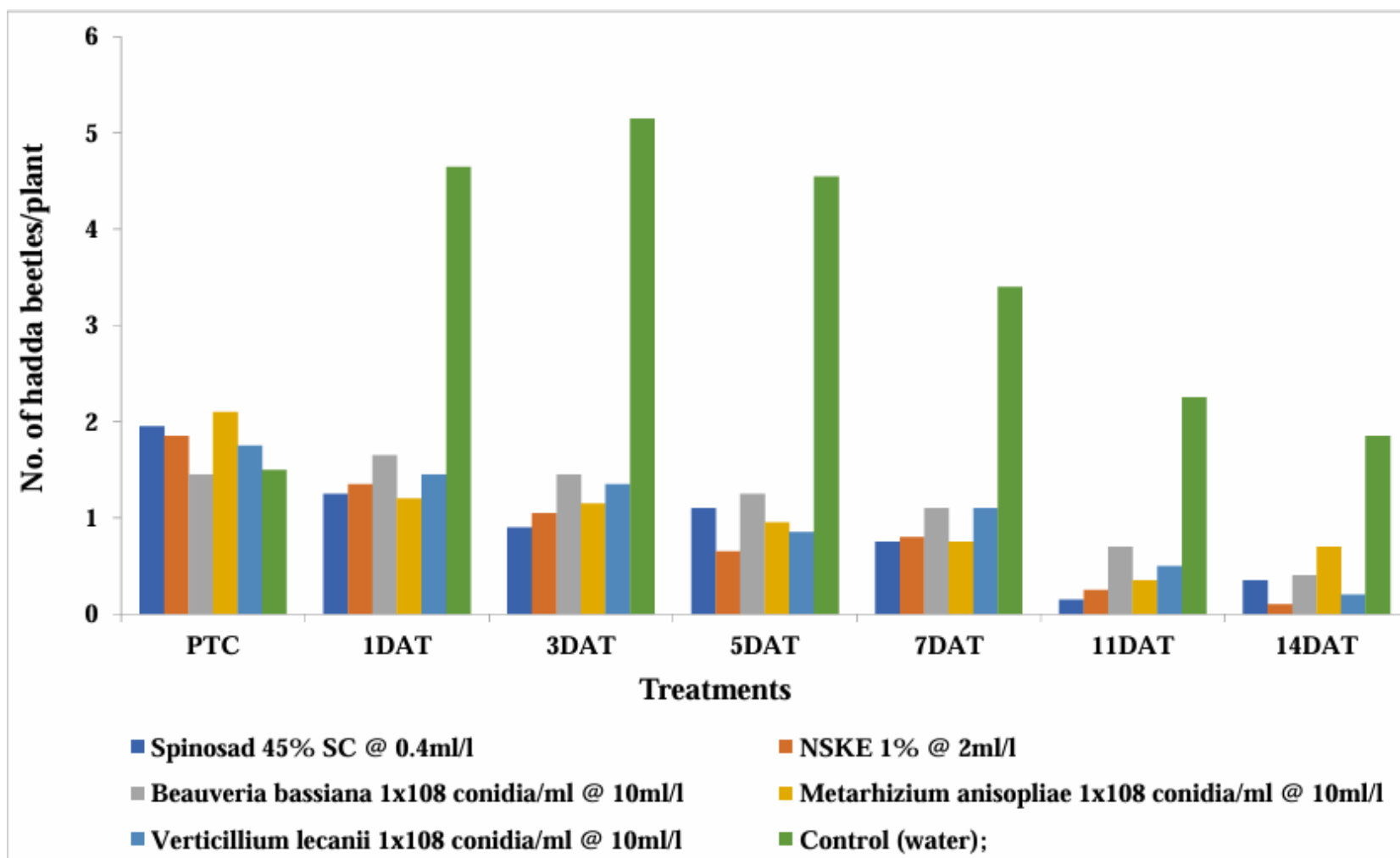


Fig. 19 Efficacy of biorational insecticides against hadda beetle (*Henosepilachna vigintioctopunctata*) in Kharif season 2023

4.2.4. Efficacy of biorational insecticides against shoot and fruit borer (larva) in brinjal during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The population of shoot borer damage was ranged from 1.40 to 2.05 per plant and 2.25 to 3.05 per plant recorded during 2021 and 2022 *Rabi* season before spraying (Table 23, Fig. 20). All the treatments were performed significant impact on shoot borer at ($P < 0.001$) from 1 DAT till 14th DAT during 2021 and 2022 *Rabi* season (Table 23, Fig. 20). The minimum shoot borer damage population (0.62 and 0.88 per plant) was recorded in *Rabi* 2021 and 2022 respectively (Table 23, Fig. 20). The maximum reduction percent over control was obtained in application of (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (84.61 and 82.64 %) followed by (T₄) - *M. anisopliae* 1×10^8 conidia/ml @ 10 ml/l (81.63 and 80.27 %), (T₂) - NSKE 1% @ 2ml/l offering (78.90 and 78.10 %), (T₅) - *V. lecanii* 1×10^8 conidia/ml @ 10 ml/l offering (75.93 and 72.38 %) and (T₃) - *B. bassiana* 1×10^8 conidia/ml @ 10 ml/l offering (71.46 and 68.44 %) (Table 23, Fig. 20). In interaction of years and treatments, the application of biorational pesticides were performed significantly impact on shoot borer population in 1 DAT ($df_{(6,4)}$; $P = 0.000$), 3 DAT ($df_{(6,4)}$; $P = 0.000$), 5 DAT ($df_{(6,4)}$; $P = 0.000$), 7 DAT ($P = 0.000$), 11 DAT ($df_{(6,4)}$; $P = 0.000$) and 14 DAT ($df_{(6,4)}$; $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 23, Fig. 20).

In *Kharif* season of 2022 and 2023, the population of shoot borer damaged was ranged from 1.85 to 2.35 per plant and 2.85 to 3.90 per plant recorded during 2022 and 2023 *Kharif* season before spraying (Table 24, Fig. 21). All the treatments were performed significantly against shoot borer damage at 1 DAT, 3 DAT, 5 DAT, 7 DAT, 11 DAT and 14 DAT during 2022 and 2023 *Kharif* season (Table 24, Fig. 21). The minimum shoot borer damage population (1.09 and 0.95 per plant) was recorded in *Kharif* 2022 and 2023 respectively (Table 24, Fig. 21). The maximum reduction percent over control was obtained in application of (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (74.53 and 81.11 %) followed by (T₄) - *M. anisopliae* 1×10^8 conidia/ml @ 10 ml/l (71.72 and 74.75 %), (T₂) - NSKE 1% @ 2ml/l offering (69.85 and 79.72 %), next was (T₅) - *V. lecanii* 1×10^8 conidia/ml @ 10 ml/l offering (66.82 and 67.79 %) and least effective was (T₃) - *B. bassiana* 1×10^8 conidia/ml @ 10 ml/l (64.48 and 68.38 %) (Table 24, Fig. 21). In interaction of years and treatments, the application of biorational pesticides were

performed significantly impact on shoot borer population ($P < 0.001$) from 1 DAT till 14th DAT during *Kharif* season 2022 and 2023 (Table 24, Fig. 21).

In second spray of *Kharif* season 2023, all the treatments significantly reduced shoot borer damage population. Initial population was between 1.10 to 1.45 on precount day. All the treatments performed significant impact on shoot and fruit borer ($P < 0.005$) from 1 DAT till 14th DAT during *Kharif* season 2023 (Table 25, Fig. 22). The minimum shoot borer damage population (0.47 per plant) was found in *Kharif* 2023 (Table 25, Fig. 22). The maximum reduction percent over control was noted in (T₁) - Spinosad 45 % SC @ 0.4 ml/l offering (82.46 %) followed by (T₂) - NSKE 1% @ 2ml/l with (78.73 %), (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (77.61 %), (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l giving (74.25 %), and least effective was (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l (71.26 %) (Table 25, Fig. 22).

Findings from multiple studies align with our research, indicating that the highest fruit infestation occurred around the 46th week of the cropping season, while the lowest infestation was noted around the 39th week, specifically during the *Kharif* season (Shukla and Khatri, 2010; Kaur and Singh, 2013; Kaur *et al.*, 2014; Kumar *et al.*, 2021).

According to prior findings, Spinosad emerged as the most effective pesticide for managing insect pests in brinjal cultivation. It outperformed other treatments in controlling infestations of shoot and fruit borers, notably *L. orbonalis*, demonstrating superior results in managing these pests (Devi *et al.*, 2014; Mamum, *et al.*, 2014; Mainali *et al.*, 2015). Studies conducted by researchers indicate that both spinosad and neem seed kernel extracts have been effective in controlling the brinjal shoot and fruit borer. These treatments have shown significant reductions in fruit infestation and have led to increased yields. This consensus is derived from the majority of studies focused on managing *Leucinodes orbanalis* infestations in brinjal crops (Shirale *et al.*, 2012; Islam, 2013; Saha *et al.*, 2014; Ali *et al.*, 2016; Khare and Sneha, 2021).

According to Thompson *et al.*, (2000), Legocki *et al.*, (2010), Tescari *et al.*, (2014), Spinosad has been approved for use against a broad variety of target pests, including Lepidoptera (such as cotton pests), Diptera (such as fruit flies and mosquitoes), Thysanoptera, Isoptera, and Coleoptera. Spinosad exhibited the highest effectiveness in limiting fruit damage within treated plots compared to untreated control plots. These

current findings regarding the efficacy of Spinosad against *L. orbonalis* are consistent with earlier research conducted by various scientists (Deshmukh and Bhamare, Adiroubane and Raghuraman, 2008; Sharma and Kaushik, 2010).

Based on various spray schedules, it was discovered that 5% NSKE and neem oil were the most successful treatments in decreasing the infestation of whiteflies, shoots, and fruit borer on brinjal while also producing the highest possible yield of brinjal (Nayak *et al.*, 2012; Karkar *et al.*, 2014a,b; Karmakar *et al.*, 2018).

In their study, Tripura *et al.*, (2017), *B. bassiana* and *Bt.* were the most successful biopesticides for lowering shoot infestation. According to Chandravanshi *et al.*, (2019), the efficient method to control okra shoot borer involved Fipronil soil application after germination, followed by spraying with *Metarhizium anisopliae*. This treatment resulted in overall lower fruit infestation rates and higher fruit yields compared to other methods. Nevertheless, treatments involving Azadirachtin, *Bt. Kurstaki*, and NSKE (Neem Seed Kernel Extract) were deemed significantly effective in managing shoot and fruit borer infestations after all three spray applications in continuation with entomopathogenic fungi application (Soulakhe, *et al.*, 2021)

The findings from the current investigation demonstrate the viability of utilizing all the mentioned biorational insecticides at their recommended doses alongside Spinosad. This approach not only has the potential to decrease environmental pollution and the development of pesticide resistance but also to reduce the overall cost of plant protection measures.

Table 23. Efficacy of biorational insecticides against shoot and fruit borer (larva) in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of <i>Leucinodes orbonalis</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> - 22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Spinosad 45% SC @ 0.4ml/l	1.40 ± 0.43 ^b	3.05 ± 0.34 ^a	1.15 ± 0.19 ^c	1.95 ± 0.19 ^{bc}	0.95 ± 0.10 ^c	1.25 ± 0.38 ^d	0.55 ± 0.19 ^d	0.95 ± 0.34 ^c	0.60 ± 0.23 ^c	0.65 ± 0.19 ^c	0.30 ± 0.12 ^c	0.30 ± 0.11 ^c	0.20 ± 0.16 ^c	0.20 ± 0.16 ^c	0.62	0.88	84.61	82.64
NSKE 1% @ 2ml/l	1.45 ± 0.37 ^{ab}	2.25 ± 0.19 ^b	1.25 ± 0.10 ^{bc}	1.80 ± 0.16 ^{bc}	1.10 ± 0.20 ^{bc}	1.55 ± 0.30 ^{bcd}	0.85 ± 0.19 ^{bcd}	1.10 ± 0.25 ^c	0.75 ± 0.34 ^{bc}	0.75 ± 0.19 ^c	0.55 ± 0.10 ^{bc}	0.95 ± 0.19 ^b	0.65 ± 0.25 ^{bc}	0.55 ± 0.19 ^{bc}	0.85	1.11	78.90	78.10
<i>Beauveria</i> <i>bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	2.05 ± 0.30 ^a	2.85 ± 0.34 ^{ab}	1.60 ± 0.28 ^b	2.60 ± 0.49 ^b	1.35 ± 0.19 ^b	2.05 ± 0.38 ^b	1.05 ± 0.30 ^b	1.65 ± 0.44 ^b	1.15 ± 0.30 ^b	1.40 ± 0.28 ^b	0.85 ± 0.30 ^b	1.05 ± 0.10 ^b	0.95 ± 0.25 ^b	0.85 ± 0.34 ^b	1.15	1.60	71.46	68.44
<i>Metarhizium</i> <i>anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.55 ± 0.41 ^{ab}	2.55 ± 0.19 ^{ab}	1.20 ± 0.16 ^c	1.55 ± 0.44 ^c	1.05 ± 0.25 ^{bc}	1.30 ± 0.26 ^{cd}	0.65 ± 0.25 ^{cd}	1.05 ± 0.19 ^c	0.70 ± 0.25 ^{bc}	0.70 ± 0.25 ^c	0.50 ± 0.12 ^{bc}	0.80 ± 0.16 ^b	0.35 ± 0.19 ^c	0.65 ± 0.25 ^b	0.74	1.00	81.63	80.27
<i>Verticillium</i> <i>lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.95 ± 0.34 ^{ab}	2.65 ± 0.34 ^{ab}	1.45 ± 0.19 ^{bc}	2.25 ± 0.66 ^{bc}	1.20 ± 0.16 ^{bc}	1.90 ± 0.38 ^{bc}	1.00 ± 0.16 ^{bc}	1.45 ± 0.34 ^{bc}	0.85 ± 0.30 ^{bc}	1.30 ± 0.20 ^b	0.65 ± 0.25 ^{bc}	0.70 ± 0.25 ^b	0.70 ± 0.34 ^{bc}	0.80 ± 0.28 ^b	0.97	1.40	75.93	72.38
Control (water);	1.85 ± 0.34 ^{ab}	2.80 ± 0.71 ^{ab}	4.55 ± 0.41 ^a	4.60 ± 0.82 ^a	5.85 ± 0.25 ^a	6.40 ± 0.59 ^a	4.90 ± 0.26 ^a	6.65 ± 0.41 ^a	3.95 ± 0.41 ^a	5.50 ± 0.57 ^a	2.80 ± 0.49 ^a	3.10 ± 0.47 ^a	2.15 ± 0.59 ^a	4.20 ± 0.33 ^a	4.03	5.07		
P value	0.096 ^{NS}	0.132 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}				
F value	2.228	1.972	117.111	18.463	373.167	100.580	210.900	168.856	68.673	143.137	48.079	61.895	17.520	122.870				
Year*Treatment's																		
P value	0.068 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}					
F value	2.263		63.233		367.222		195.033		108.478		109.536		36.880					
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Leucinodes orbonalis</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Leucinodes orbonalis</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values. *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

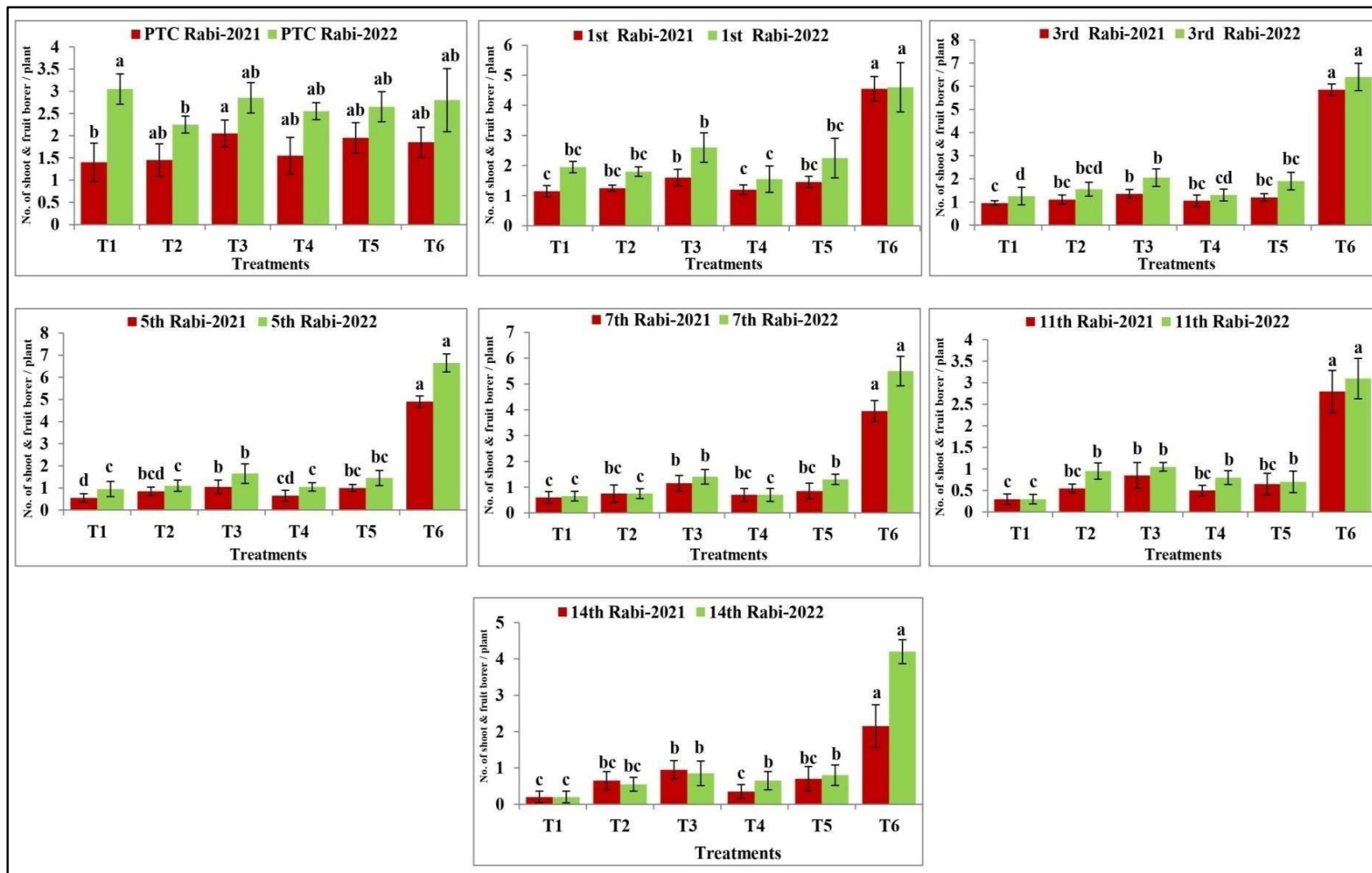


Fig. 20 Efficacy of biorational insecticides against shoot and fruit borer (*Leucinodes orbonalis*) in Rabi season 2021 and 2022

Table 24. Efficacy of biorational insecticides against shoot and fruit borer (larva) in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of <i>Leucinodes orbonalis</i> / per plant*																	
	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Kharif</i> -22	<i>Kharif</i> -23	<i>Kharif</i> -22	<i>Kharif</i> -23
Spinosad 45% SC @ 0.4ml/l	2.05 ± 0.19 ^{ab}	2.90 ± 0.26 ^{ab}	1.75 ± 0.10 ^c	2.30 ± 0.35 ^c	1.45 ± 0.25 ^c	1.35 ± 1.36 ^c	1.25 ± 0.19 ^c	1.00 ± 0.16 ^c	1.05 ± 0.10 ^{bc}	0.60 ± 0.16 ^c	0.65 ± 0.25 ^c	0.30 ± 0.12 ^c	0.40 ± 0.23 ^d	0.15 ± 0.10 ^c	1.09	0.95	74.53	81.11
NSKE 1% @ 2ml/l	2.10 ± 0.26 ^{ab}	2.85 ± 0.79 ^b	1.95 ± 0.19 ^{bc}	2.25 ± 0.25 ^c	1.75 ± 0.19 ^{bc}	1.45 ± 1.31 ^c	1.45 ± 0.19 ^{bc}	1.15 ± 0.19 ^c	1.20 ± 0.16 ^{bc}	0.70 ± 0.12 ^c	0.80 ± 0.16 ^{bc}	0.40 ± 0.00 ^{bc}	0.60 ± 0.16 ^{cd}	0.20 ± 0.28 ^c	1.29	1.02	69.85	79.72
<i>Beauveria bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	2.35 ± 0.34 ^a	3.45 ± 0.91 ^{ab}	2.15 ± 0.19 ^b	3.10 ± 0.26 ^b	1.95 ± 0.25 ^b	2.45 ± 1.36 ^b	1.65 ± 0.25 ^b	1.80 ± 0.16 ^b	1.35 ± 0.19 ^b	1.15 ± 0.34 ^b	1.15 ± 0.19 ^b	0.60 ± 0.16 ^b	0.90 ± 0.11 ^b	0.45 ± 0.25 ^{bc}	1.52	1.59	64.48	68.38
<i>Metarhizium anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.95 ± 0.19 ^{ab}	3.25 ± 0.25 ^{ab}	1.85 ± 0.19 ^{bc}	2.65 ± 0.19 ^{bc}	1.50 ± 0.26 ^c	1.95 ± 1.40 ^{bc}	1.25 ± 0.19 ^c	1.20 ± 0.28 ^c	0.90 ± 0.20 ^c	0.80 ± 0.16 ^{bc}	1.10 ± 0.11 ^{bc}	0.40 ± 0.16 ^{bc}	0.70 ± 0.11 ^{bc}	0.65 ± 0.30 ^b	1.21	1.27	71.72	74.75
<i>Verticillium lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.85 ± 0.30 ^b	3.90 ± 0.26 ^a	2.00 ± 0.28 ^{bc}	3.05 ± 0.34 ^b	1.80 ± 0.16 ^{bc}	2.55 ± 1.14 ^b	1.55 ± 0.19 ^{bc}	1.90 ± 0.12 ^b	1.25 ± 0.19 ^b	1.10 ± 0.26 ^b	1.10 ± 0.11 ^{bc}	0.55 ± 0.19 ^{bc}	0.85 ± 0.19 ^b	0.60 ± 0.16 ^b	1.42	1.62	66.82	67.79
Control (water);	2.30 ± 0.38 ^{ab}	3.20 ± 0.82 ^{ab}	4.80 ± 0.16 ^a	6.60 ± 0.63 ^a	4.65 ± 0.38 ^a	7.05 ± 2.53 ^a	4.55 ± 0.30 ^a	5.45 ± 0.55 ^a	4.20 ± 0.32 ^a	4.70 ± 0.37 ^a	3.85 ± 0.30 ^a	3.45 ± 0.25 ^a	3.65 ± 0.10 ^a	2.95 ± 0.34 ^a	4.28	5.03		
P value	0.154 ^{NS}	0.226 ^{NS}	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**				
F value	1.849	1.543	146.294	80.746	89.740	64.142	131.840	140.778	147.312	161.670	141.181	217.728	233.635	69.310				
Year*Treatment's																		
P value	0.381^{NS}		0.000**		0.000**		0.000**		0.000**		0.000**		0.000**					
F value	1.092		108.390		56.638		159.576		213.788		346.242		187.093					
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Leucinodes orbonalis</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Leucinodes orbonalis</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																		

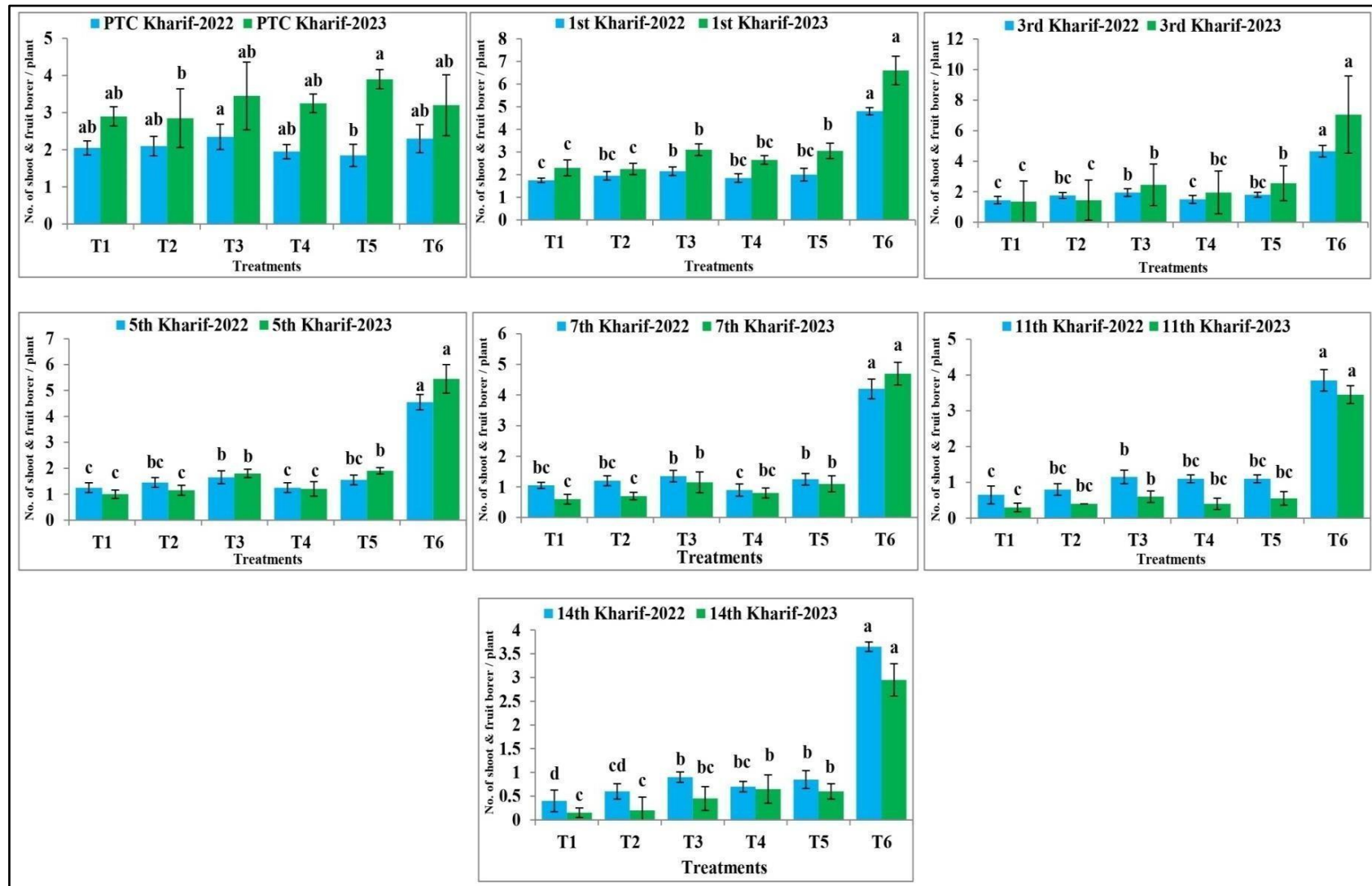


Fig. 21 Efficacy of biorational insecticides against shoot and fruit borer (*Leucinodes orbonalis*) in Kharif season 2022 and 2023

Table 25. Efficacy of biorational insecticides against shoot and fruit borer (larva) in brinjal of *Kharif* season 2023 (Second Spray)

Treatments	No. of <i>Leucinodes orbonalis</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Spinosad 45% SC @ 0.4ml/l	1.20 ± 0.16 ^{ab}	1.00 ± 0.43 ^b	0.75 ± 1.03 ^b	0.35 ± 0.34 ^c	0.50 ± 0.12 ^c	0.20 ± 0.16 ^c	0.05 ± 0.10 ^d	0.47	82.46
NSKE 1% @ 2ml/l	1.10 ± 0.12 ^b	0.85 ± 0.59 ^b	1.10 ± 0.91 ^b	0.60 ± 0.33 ^{bc}	0.45 ± 0.10 ^c	0.30 ± 0.12 ^{bc}	0.15 ± 0.19 ^{cd}	0.57	78.73
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	1.35 ± 0.19 ^{ab}	1.20 ± 0.81 ^b	0.90 ± 1.05 ^b	0.75 ± 0.19 ^{bc}	0.60 ± 0.16 ^{bc}	0.25 ± 0.25 ^{bc}	0.45 ± 0.25 ^b	0.69	74.25
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	1.25 ± 0.19 ^{ab}	1.10 ± 0.41 ^b	0.80 ± 0.67 ^b	0.50 ± 0.35 ^{bc}	0.70 ± 0.12 ^b	0.20 ± 0.16 ^c	0.35 ± 0.19 ^{bc}	0.60	77.61
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	1.45 ± 0.19 ^a	1.25 ± 0.62 ^b	0.80 ± 0.78 ^b	1.00 ± 0.37 ^b	0.70 ± 0.12 ^b	0.55 ± 0.19 ^b	0.35 ± 0.10 ^{bc}	0.77	71.26
Control (water);	1.30 ± 0.12 ^{ab}	2.25 ± 0.52 ^a	4.20 ± 1.85 ^a	3.25 ± 0.44 ^a	2.50 ± 0.12 ^a	1.85 ± 0.25 ^a	2.05 ± 0.19 ^a	2.68	
P value	0.104 ^{NS}	0.002 [*]	0.002 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	2.167	5.928	5.965	40.048	164.911	43.557	68.234		
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Leucinodes orbonalis</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Leucinodes orbonalis</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

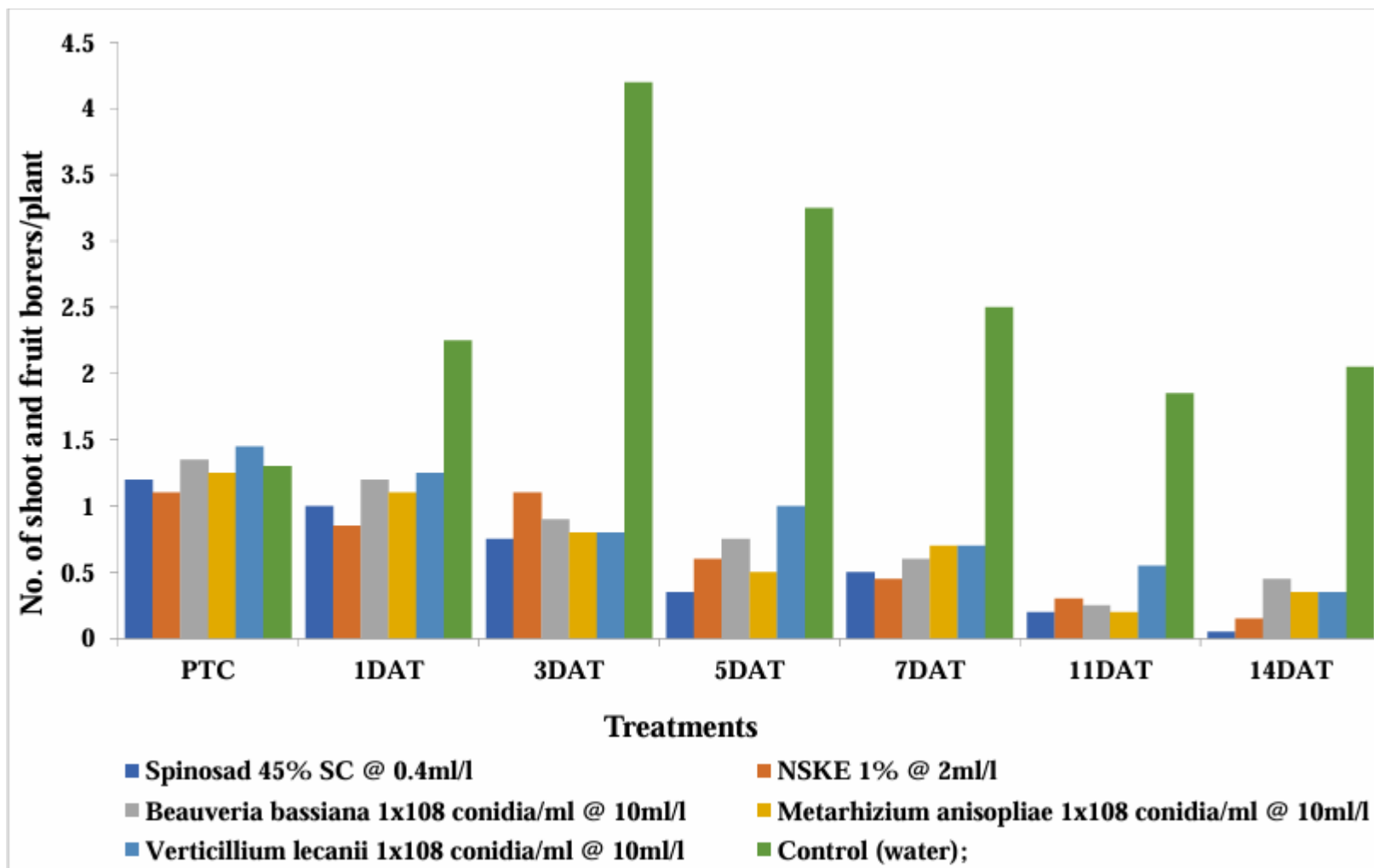


Fig. 22 Efficacy of biorational insecticides against shoot and fruit borer (*Leucinodes orbonalis*) in Kharif season 2023

4.2.5. Effect of biorational insecticides on predatory coccinellids during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The initial population of predatory coccinellid beetles on precount day ranged from 0.70 to 2.20 coccinellid beetles per plant and 0.60 to 1.55 coccinellid beetles per plant during *Rabi* 2021 and 2022 and *Kharif* season 2022 and 2023 respectively (Table 26 and 28, Fig. 23 and 24). However, at the end of 14 DAT the population ranged between mean 0.35 to 1.85 coccinellid per plant (Table 26, Fig. 23) and 0.25 to 0.85 coccinellid beetles per plant (Table 27, Fig. 24) during both seasons. The populations of predatory coccinellid beetles were observed with no significant difference on pretreatment count day during *Rabi* season of 2021 and 2022 with ($df_{(6,4)}$; $P > 0.201$) (Table 26, Fig. 23) and while found significant in *Kharif* season of 2022 and 2023 with ($df_{(6,4)}$; $P < 0.035$) (Table 27, Fig. 24). Predatory coccinellid populations fluctuated as they increased and decreased until 14 DAT during *Rabi* season of 2021 and 2022 and *Kharif* season 2022 and 2023 (Table 26 and 27, Fig. 23 and 24).

During second spray of *Kharif* season 2023, the initial population of predatory coccinellid beetles on precount day ranged from 0.35 to 0.90 coccinellid beetles per plant (Table 28, Fig. 25). However, at the end of 14 DAT the population ranged between mean 0.00 to 0.25 coccinellid per plant *Kharif* seasons 2023 (Table 28, Fig. 25). The populations of predatory coccinellid beetles were observed with no significant difference on precount day ($df_{(6,4)}$; $P > 0.155$) as well as at 1 DAT ($df_{(6,4)}$; $P > 0.206$), 3 DAT ($df_{(6,4)}$; $P > 0.187$), 5 DAT ($df_{(6,4)}$; $P > 0.067$), 7 DAT ($df_{(6,4)}$; $P > 0.137$), 11 DAT ($df_{(6,4)}$; $P > 0.544$) and 14 DAT ($df_{(6,4)}$; $P > 0.190$) during *Kharif* season of 2023 (Table 28, Fig. 25). Predatory coccinellid populations fluctuated as they increased and decreased until 14 DAT during *Kharif* season 2023 (Table 28, Fig. 25).

The entomopathogenic fungus, *Beauveria bassiana* showed least or negligible harmful effects on *Coccinella septempunctata* while another report mentioned that neem products and *B. bassiana* doesn't have harmful effect on predatory coccinellids (Akmal *et al.*, 2013; Vanlaldiki *et al.*, 2013). The occurrence of predatory coccinellids shows that they could be safely integrated into integrated pest management programs.

Numerous studies evidenced that Spinosad, *V. lecanii* and *B. bassiana* is relatively safe to natural enemies; where the list includes foliage-dwelling predators as well as sucking insect pests viz., *Coccinella septempunctata*, *Chrysoperla carnea*, *Episyrphus balteatus*, ground dwelling predator, *Poecilus cupreus* and parasitoids *Trichramma atopovirilia*, *Trathala flavoorbitalis* an larval pupal parasitoid of brinjal fruit and shoot borer (BFSB) (Prithiva *et al.*, 2018; Rajeshwari *et al.*, 2019).

Similar findings were observed in studies by Miles, (2003) which indicated that applying Spinosad to blooming crops at times when bee activity is low was safe for *Apis mellifera*, implying that there would be no negative impact on honeybee numbers. Bailey *et al.*, (2005), Spinosad exhibited little to no damage to honey bee populations based on a study of oral toxicities and contact of residue in straight formed. Initially, Spinosad was deemed harmless to various beneficial insect or predators, leading to its approval and subsequent expansion for crop protection purposes (Miles, 2003; Sarfraz *et al.*, 2005), the perceived selectivity of Spinosad, particularly in organic production, has faced challenges over time (Biondi *et al.*, 2012). Scott-Dupree *et al.*, (2009) discovered that Spinosad showed only moderate toxicity towards *B. impatiens*, *M. rotundata* and *O. lignaria* bee species in their investigation into the effects of different insecticides on these bee species. *M. quadrifasciata* adult stingless bee workers showed a high oral pesticide sensitivity to spinosad as well as imidacloprid particularly (Tome *et al.*, 2015).

The impact of botanical pesticides particularly on natural enemies were found to be less toxic against the coccinellid predators i.e., *C. septempunctata*, *Brumoides suturalis* and *Menochilus sexmaculatus* recorded in the study (Baker *et al.*, 2016; Dutta *et al.*, 2017; Kunbhar *et al.*, 2018).

Table 26. Effect of biorational insecticides on predatory coccinellids in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of Coccinellids / per plant*															
	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Mean	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Rabi -21	Rabi -22
Spinosad 45% SC @ 0.4ml/l	1.90 ± 0.26 ^{ab}	1.05 ± 0.34 ^{ab}	1.65 ± 0.50 ^{ab}	1.00 ± 0.16 ^{ab}	1.05 ± 0.52 ^{ab}	1.10 ± 0.12 ^{ab}	1.25 ± 1.03 ^{ab}	0.90 ± 0.26 ^{ab}	0.85 ± 0.66 ^{ab}	0.70 ± 0.26 ^{abc}	0.60 ± 0.51 ^b	0.75 ± 0.10 ^a	0.45 ± 0.57 ^b	0.55 ± 0.19 ^{ab}	0.97	0.83
NSKE 1% @ 2ml/l	2.10 ± 0.26 ^{ab}	0.95 ± 0.19 ^{ab}	1.85 ± 0.41 ^{ab}	1.20 ± 0.16 ^a	1.30 ± 0.68 ^{ab}	1.15 ± 0.19 ^a	1.55 ± 0.99 ^{ab}	0.95 ± 0.19 ^{ab}	1.20 ± 0.23 ^{ab}	1.05 ± 0.34 ^a	1.05 ± 0.52 ^{ab}	0.80 ± 0.00 ^a	0.90 ± 0.84 ^{ab}	0.85 ± 0.25 ^a	1.30	1.00
<i>Beauveria bassiana</i> 1x10 ⁸ conidia/ml @ 10ml/l	2.00 ± 0.16 ^{ab}	1.15 ± 0.19 ^a	1.55 ± 0.70 ^{ab}	0.85 ± 0.19 ^b	1.10 ± 0.52 ^{ab}	0.90 ± 0.12 ^{ab}	0.75 ± 0.34 ^b	0.65 ± 0.19 ^b	0.95 ± 0.93 ^{ab}	0.45 ± 0.34 ^c	0.60 ± 0.51 ^b	0.55 ± 0.19 ^{ab}	0.40 ± 0.56 ^b	0.35 ± 0.30 ^b	0.89	0.62
<i>Metarhizium anisopliae</i> 1x10 ⁸ conidia/ml @ 10ml/l	1.80 ± 0.16 ^b	0.70 ± 0.12 ^b	1.25 ± 0.64 ^{ab}	1.05 ± 0.10 ^{ab}	0.85 ± 0.34 ^b	0.95 ± 0.19 ^{ab}	1.05 ± 0.77 ^{ab}	0.75 ± 0.19 ^{ab}	0.50 ± 0.41 ^b	0.65 ± 0.19 ^{abc}	0.65 ± 0.59 ^b	0.75 ± 0.19 ^a	0.40 ± 0.48 ^b	0.40 ± 0.28 ^b	0.78	0.75
<i>Verticillium lecanii</i> 1x10 ⁸ conidia/ml @ 10ml/l	2.20 ± 0.23 ^a	0.80 ± 0.37 ^{ab}	1.05 ± 0.52 ^b	0.95 ± 0.19 ^{ab}	0.90 ± 0.34 ^{ab}	0.75 ± 0.10 ^b	0.75 ± 0.82 ^b	0.85 ± 0.30 ^{ab}	0.60 ± 0.82 ^b	0.50 ± 0.26 ^{bc}	0.35 ± 0.34 ^b	0.45 ± 0.33 ^b	0.45 ± 0.52 ^b	0.35 ± 0.41 ^b	0.68	0.64
Control (water)	2.20 ± 0.29 ^a	0.85 ± 0.25 ^{ab}	2.05 ± 0.68 ^a	1.10 ± 0.26 ^{ab}	1.80 ± 0.78 ^a	0.90 ± 0.48 ^{ab}	2.20 ± 0.71 ^a	1.05 ± 0.19 ^a	2.00 ± 1.45 ^a	0.95 ± 0.34 ^{ab}	2.00 ± 1.65 ^a	0.75 ± 0.25 ^a	1.85 ± 1.33 ^a	0.80 ± 0.16 ^{ab}	1.98	0.92
P value	0.127 ^{NS}	0.195 ^{NS}	0.210 ^{NS}	0.176 ^{NS}	0.215 ^{NS}	0.231 ^{NS}	0.153 ^{NS}	0.207 ^{NS}	0.199 ^{NS}	0.057 ^{NS}	0.111 ^{NS}	0.084 ^{NS}	0.102 ^{NS}	0.060 ^{NS}		
F value	2.000	1.660	1.604	1.741	1.584	1.527	1.852	1.615	1.645	2.662	2.113	2.337	2.183	2.623		
Year*Treatment's																
P value	0.201 ^{NS}		0.098 ^{NS}		0.130 ^{NS}		0.040*		0.035*		0.034*		0.010*			
F value	1.537		2.020		1.830		2.615		2.695		2.725		3.519			
* P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (Coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. Coccinellids of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values. *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																

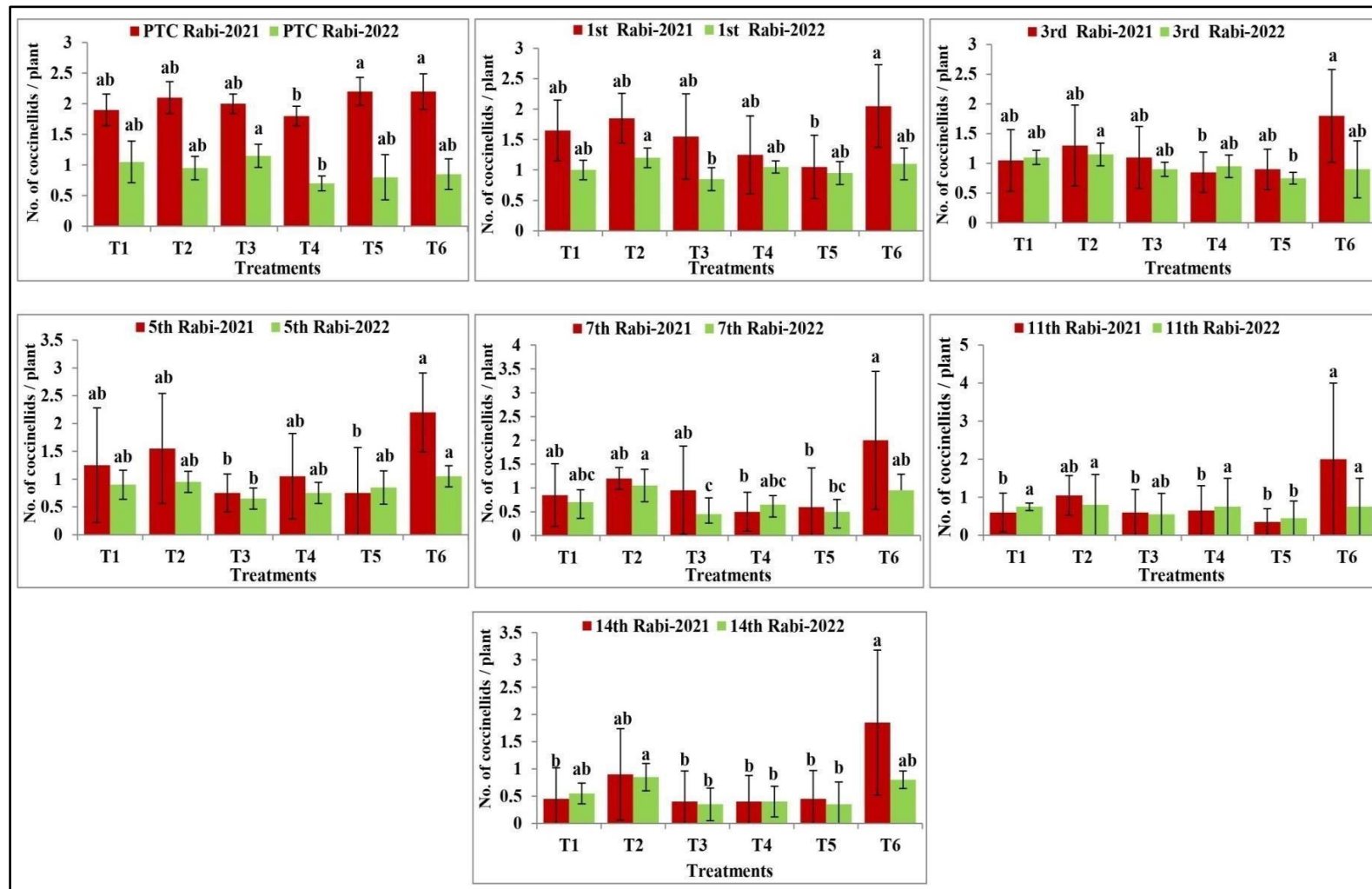


Fig. 23 Efficacy of biorational insecticides on predatory coccinellids in *Rabi* season 2021 and 2022

Table 27. Effect of biorational insecticides on predatory coccinellids in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of Coccinellids / per plant*															
	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Mean	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Kharif-22	Kharif-23
Spinosad 45% SC @ 0.4ml/l	1.05 ± 0.41 ^{ab}	1.30 ± 0.26 ^{ab}	0.75 ± 0.34 ^{ab}	0.90 ± 0.12 ^b	0.85 ± 0.50 ^{ab}	1.20 ± 0.16 ^a	0.65 ± 0.30 ^{ab}	0.85 ± 0.25 ^{ab}	0.50 ± 0.12 ^b	0.65 ± 0.30 ^b	0.55 ± 0.25 ^{ab}	0.50 ± 0.26 ^{ab}	0.25 ± 0.10 ^b	0.45 ± 0.19 ^b	0.59	0.75
NSKE 1% @ 2ml/l	1.40 ± 0.59 ^a	1.55 ± 0.19 ^a	0.70 ± 0.12 ^b	1.00 ± 0.28 ^{ab}	1.20 ± 0.51 ^a	0.75 ± 0.25 ^b	1.30 ± 0.60 ^a	1.20 ± 0.43 ^a	0.65 ± 0.19 ^{ab}	0.65 ± 0.19 ^b	0.85 ± 0.30 ^a	0.70 ± 0.26 ^{ab}	0.40 ± 0.10 ^{ab}	0.60 ± 0.16 ^{ab}	0.85	0.81
Beauveria bassiana 1x10 ⁸ conidia/ml @ 10ml/l	0.90 ± 0.26 ^{ab}	1.20 ± 0.37 ^{ab}	1.25 ± 0.34 ^a	1.10 ± 0.12 ^{ab}	0.85 ± 0.34 ^{ab}	1.10 ± 0.12 ^{ab}	0.60 ± 0.43 ^{ab}	0.80 ± 0.16 ^{ab}	0.90 ± 0.35 ^{ab}	0.90 ± 0.26 ^{ab}	0.40 ± 0.36 ^{ab}	0.50 ± 0.20 ^{ab}	0.50 ± 0.26 ^{ab}	0.45 ± 0.19 ^b	0.75	0.80
Metarhizium anisopliae 1x10 ⁸ conidia/ml @ 10ml/l	0.80 ± 0.43 ^{ab}	0.85 ± 0.30 ^b	1.15 ± 0.34 ^{ab}	1.15 ± 0.19 ^{ab}	0.55 ± 0.19 ^b	1.15 ± 0.19 ^{ab}	0.70 ± 0.41 ^{ab}	1.05 ± 0.38 ^{ab}	0.70 ± 0.26 ^{ab}	1.15 ± 0.34 ^a	0.35 ± 0.19 ^b	0.45 ± 0.10 ^b	0.60 ± 0.16 ^a	0.85 ± 0.19 ^a	0.75	0.96
Verticillium lecanii 1x10 ⁸ conidia/ml @ 10ml/l	0.60 ± 0.28 ^b	1.25 ± 0.44 ^{ab}	0.85 ± 0.25 ^{ab}	1.05 ± 0.19 ^{ab}	0.75 ± 0.25 ^{ab}	0.85 ± 0.25 ^{ab}	0.40 ± 0.43 ^b	0.65 ± 0.19 ^b	0.55 ± 0.34 ^{ab}	0.75 ± 0.19 ^{ab}	0.35 ± 0.25 ^b	0.55 ± 0.19 ^{ab}	0.40 ± 0.16 ^{ab}	0.60 ± 0.28 ^{ab}	0.55	0.74
Control (water);	1.30 ± 0.50 ^{ab}	1.10 ± 0.35 ^{ab}	0.95 ± 0.44 ^{ab}	1.25 ± 0.19 ^a	1.20 ± 0.28 ^a	0.90 ± 0.48 ^{ab}	1.00 ± 0.48 ^{ab}	1.15 ± 0.34 ^{ab}	0.95 ± 0.19 ^a	1.00 ± 0.43 ^{ab}	0.80 ± 0.37 ^{ab}	0.80 ± 0.16 ^a	0.55 ± 0.19 ^a	0.60 ± 0.33 ^{ab}	0.90	0.95
P value	0.126 ^{NS}	0.129 ^{NS}	0.151 ^{NS}	0.202 ^{NS}	0.136 ^{NS}	0.151 ^{NS}	0.125 ^{NS}	0.133 ^{NS}	0.119 ^{NS}	0.155 ^{NS}	0.082 ^{NS}	0.160 ^{NS}	0.113 ^{NS}	0.213 ^{NS}		
F value	2.010	1.993	1.864	1.634	1.948	1.865	2.013	1.967	2.056	1.845	2.354	1.816	2.094	1.590		
Year*Treatment's																
P value	0.035*		0.027*		0.716 ^{NS}		0.006*		0.022*		0.002*		0.026*			
F value	2.695		2.878		0.579		3.888		3.010		4.771		2.904			
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (Coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. Coccinellids of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																

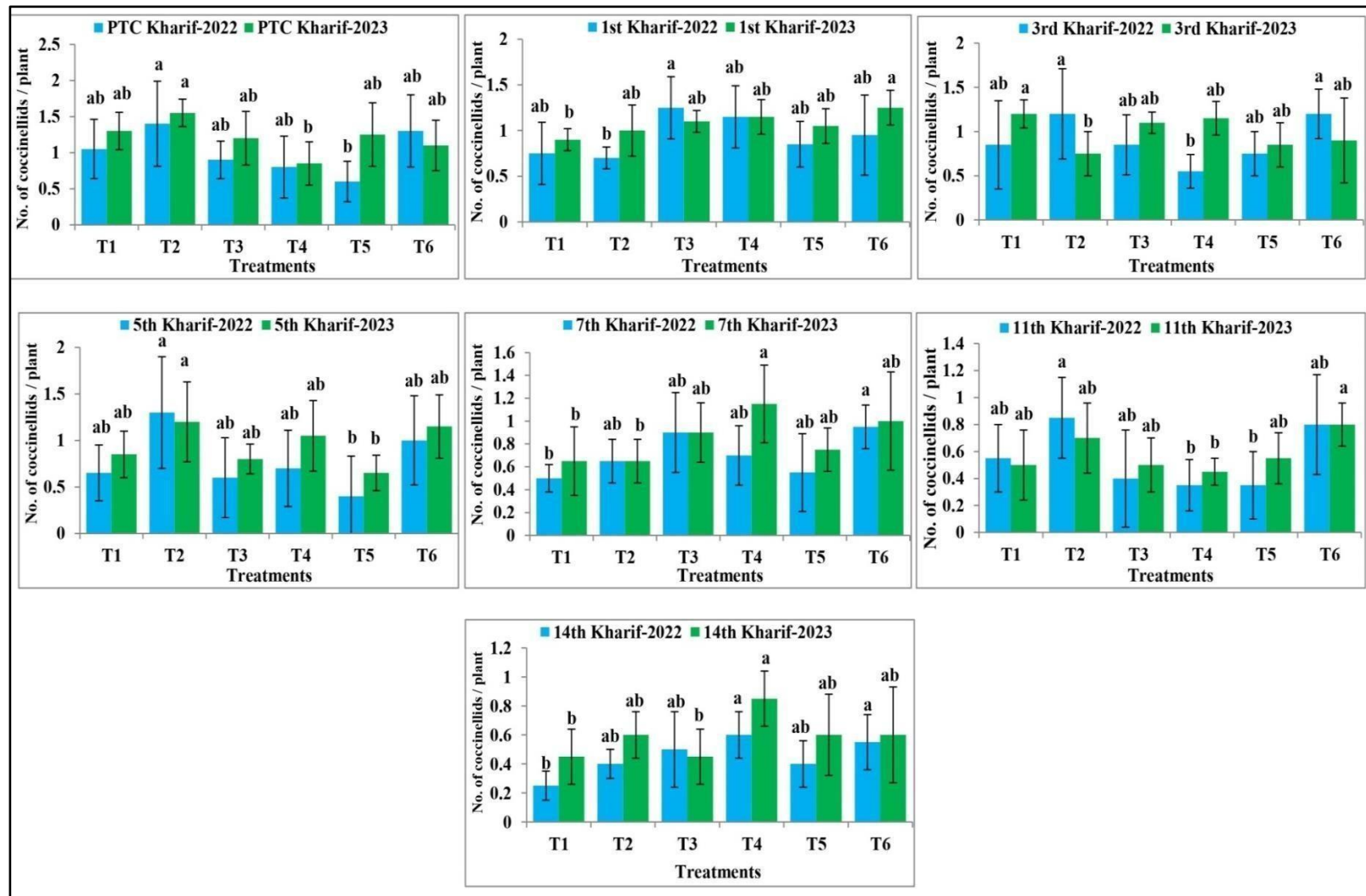


Fig. 24 Efficacy of biorational insecticides on predatory coccinellids in *Kharif* season 2022 and 2023

Table 28. Effect of biorational insecticides on predatory coccinellids in brinjal of *Kharif* season 2023 (Second Spray)

Treatments	No. of Coccinellids / per plant*							
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean
Spinosad 45% SC @ 0.4ml/l	0.75 ± 0.19 ^{ab}	0.75 ± 0.19 ^{ab}	0.60 ± 0.16 ^{ab}	0.45 ± 0.10 ^{ab}	0.25 ± 0.10 ^b	0.30 ± 0.38 ^a	0.00 ± 0.00 ^b	0.39
NSKE 1% @ 2ml/l	0.65 ± 0.19 ^{ab}	0.55 ± 0.38 ^{ab}	0.50 ± 0.12 ^{ab}	0.40 ± 0.00 ^{abc}	0.25 ± 0.19 ^b	0.30 ± 0.25 ^a	0.10 ± 0.12 ^{ab}	0.35
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	0.45 ± 0.19 ^{ab}	0.40 ± 0.16 ^b	0.55 ± 0.10 ^{ab}	0.25 ± 0.19 ^c	0.55 ± 0.19 ^a	0.05 ± 0.10 ^a	0.10 ± 0.12 ^{ab}	0.31
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	0.35 ± 0.34 ^b	0.75 ± 0.19 ^{ab}	0.65 ± 0.10 ^a	0.35 ± 0.10 ^{abc}	0.30 ± 0.12 ^{ab}	0.05 ± 0.10 ^a	0.15 ± 0.30 ^{ab}	0.37
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	0.80 ± 0.43 ^{ab}	0.80 ± 0.16 ^{ab}	0.40 ± 0.16 ^b	0.50 ± 0.12 ^a	0.25 ± 0.19 ^b	0.25 ± 0.38 ^a	0.15 ± 0.19 ^{ab}	0.39
Control (water)	0.90 ± 0.42 ^a	0.85 ± 0.41 ^a	0.60 ± 0.16 ^{ab}	0.30 ± 0.12 ^{bc}	0.35 ± 0.19 ^{ab}	0.20 ± 0.23 ^a	0.25 ± 0.26 ^a	0.42
P value	0.155 ^{NS}	0.206 ^{NS}	0.187 ^{NS}	0.067 ^{NS}	0.137 ^{NS}	0.544 ^{NS}	0.190 ^{NS}	
F value	1.841	1.618	1.694	2.520	1.941	0.831	1.683	
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (Coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. Coccinellids of per plant) , PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant								

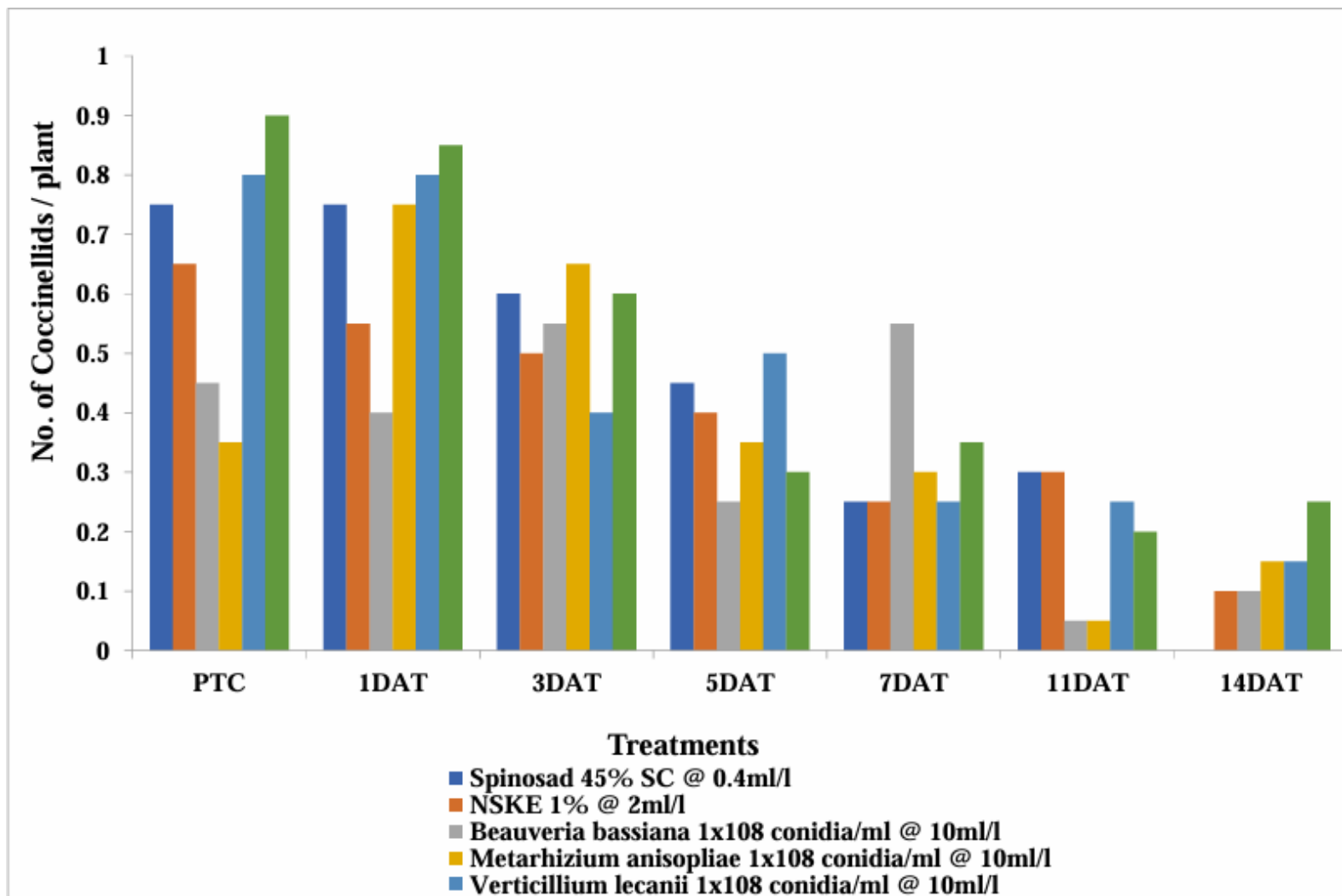


Fig. 25 Efficacy of biorational insecticides on predatory coccinellids in *Kharif* season 2023

4.2.6. Yield of different biorational insecticides against major arthropod pest of brinjal of *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023.

In *Rabi* season 2021 and 2022, all the treatments had significant difference in yield. All the treatments showed significant impact on yield at 1st picking ($df_{(8,3)}$; $P = 0.002$; $df_{(8,3)}$; $P = 0.001$), 2nd picking ($df_{(8,3)}$; $P = 0.011$; $df_{(8,3)}$; $P = 0.000$), 3rd picking ($df_{(8,3)}$; $P = 0.001$; $df_{(8,3)}$; $P = 0.000$), 4th picking ($df_{(8,3)}$; $P = 0.003$; $df_{(8,3)}$; $P = 0.008$), 5th picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.002$) and 6th picking ($df_{(8,3)}$; $P = 0.010$; $df_{(8,3)}$; $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 29 and 30, Fig. 26 and 27).

In *Rabi* season 2021 and 2022, all the treatments significantly increased in yield over the control. The maximum fruit yield of (14973.95 and 16022.85 kg ha⁻¹) was recorded from the fields treated with (T₁) - Spinosad 45 % SC @ 0.4 ml/l followed by those treated with (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (12550.63 and 13418.69 kg ha⁻¹), (T₂) - NSKE 1% @ 2ml/l offering (12369.79 and 13310.18kg ha⁻¹), (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l offering (10561.34 and 12261.28kg ha⁻¹), (T₃) - *B. bassiana* 1x10⁸ conidia/ml @ 10 ml/l (10271.99 and 11357.06 kg ha⁻¹) and last was (T₆) - untreated plots with yield of (5606.19 and 5931.71 kg ha⁻¹) (Table 29 and 30, Fig. 26 and 27).

In *Kharif* season 2022 and 2023, all the treatments had significant difference in yield. All the treatments showed significant impact on yield at 1st picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.033$), 2nd picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.006$), 3rd picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.000$), 4th picking ($df_{(8,3)}$; $P = 0.003$; $df_{(8,3)}$; $P = 0.000$), 5th picking ($df_{(8,3)}$; $P = 0.034$; $df_{(8,3)}$; $P = 0.002$) and 6th picking ($df_{(8,3)}$; $P = 0.036$; $df_{(8,3)}$; $P = 0.027$) during *Kharif* season 2022 and 2023 (Table 31 and 32, Fig. 26 and 27).

In *Kharif* season 2022 and 2023, all the treatments significantly increased in yield over the control. The maximum fruit yield of (15154.80 and 15914.35 kg ha⁻¹) was recorded from the fields treated with (T₁) - Spinosad 45 % SC @ 0.4 ml/l followed by those treated with (T₂) - NSKE 1% @ 2ml/l offering (14359.08 and 15118.63 kg ha⁻¹), (T₄) - *M. anisopliae* 1x10⁸ conidia/ml @ 10 ml/l (13237.84 and 13129.34 kg ha⁻¹), (T₅) - *V. lecanii* 1x10⁸ conidia/ml @ 10 ml/l (11284.72 and 11574.07 kg ha⁻¹), (T₃) - *B. bassiana*

1x10⁸ conidia/ml @ 10 ml/l (11031.53 and 10706.01 kg ha⁻¹), last was (T₆) - untreated plots with yield of (6293.40 and 6257.23 kg ha⁻¹) (Table 31 and 32, Fig. 26 and 27).

The current research findings align with earlier reports indicating higher yields associated with Spinosad usage. This consistency suggests support for the effectiveness of Spinosad in enhancing yields, as evidenced by both present and past research (Deshmukh and Bhamare, 2006; Naik *et al.*, 2008; Sharma and Kaushik, 2010; Mallick *et al.*, 2019). Various researchers stated that Carbosulfan resulted in the highest yield, followed by Spinosad, when compared to the untreated control against shoot and fruit borer infestation in brinjal. Among the newer insecticide molecules evaluated, rynaxypyr showed superiority and recorded a higher fruit yield, followed by Spinosad (Sinha *et al.*, 2009; Chowdary *et al.*, 2010; Wargantiwar *et al.*, 2010; Mane and Kulkarni, 2011). Another report stated that Emamectin benzoate and Spinosad were the best in controlling damage caused by BSFB, while also increasing the yield of marketable fruit (Anil and Sharma 2010; Kalawate and Dethe, 2012). According to Tripura *et al.*, (2017), Chlorantraniliprole having the little fruit damaged with high yield, followed by Spinosad and Chlorfenapyr.

Instead of untreated plots, application of seed and leaf powder of neem plant or its extracts greatly enhanced grain production in treated cowpea (Salako *et al.*, 2008). Lokanadhan *et al.*, (2012) further said that neem cake offers essential macronutrients necessary for overall plant growth. It aids in increasing plant yields over the long term, is biodegradable, eco-friendly, and found as best soil conditioner. Verma *et al.*, (2018) witnessed the treatment of neem seed extract resulted in considerably more numbers of pods per plant, grains per pod and stalk yields. According to Nayak *et al.*, (2012) biorational insecticides tested, spray of *Bacillus thuringiensis* shown least incidence on shoot and fruit of brinjal, with more valuable yield, followed by Neem Seed Kernel Extract (NSKE). Mandal *et al.*, (2010) mentioned neem seed kernel extract spray at concentration of five percent was best in managing whitefly population, as well as shoot and fruit borers on brinjal, across various spray schedules. Additionally, this treatment resulted in the maximum yield of eggplant.

Table 29. Yield of different biorational insecticides against major arthropod pest in brinjal of *Rabi* season 2021

Treatments	No. of Pickings Kg / Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Spinosad 45% SC @ 0.4ml/l	16.00 ± 0.58 ^a	17.50 ± 0.73 ^a	21.00 ± 0.63 ^a	20.50 ± 0.73 ^a	16.75 ± 0.19 ^a	11.75 ± 0.50 ^a	103.50	14973.95	14.97
NSKE 1% @ 2ml/l	11.50 ± 0.93 ^{ab}	16.00 ± 0.84 ^a	19.75 ± 1.01 ^a	16.75 ± 0.55 ^{ab}	12.50 ± 0.26 ^b	9.00 ± 0.58 ^{ab}	85.50	12369.79	12.36
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	9.25 ± 0.59 ^b	13.00 ± 0.67 ^{ab}	15.75 ± 0.44 ^{ab}	13.00 ± 0.71 ^{bc}	12.25 ± 0.60 ^b	7.75 ± 0.34 ^{bc}	71.00	10271.99	10.27
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	11.50 ± 0.62 ^{ab}	16.50 ± 0.88 ^a	19.50 ± 0.57 ^a	15.75 ± 0.92 ^{ab}	13.25 ± 0.38 ^b	10.25 ± 0.53 ^{ab}	86.75	12550.63	12.55
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	11.25 ± 0.44 ^{ab}	11.50 ± 0.62 ^{ab}	13.50 ± 0.68 ^{bc}	14.25 ± 0.55 ^b	12.50 ± 0.77 ^b	10.00 ± 0.49 ^{ab}	73.00	10561.34	10.56
Control (water)	4.50 ± 0.25 ^c	7.00 ± 0.84 ^b	9.00 ± 0.58 ^c	8.50 ± 0.47 ^c	5.00 ± 0.33 ^c	4.75 ± 0.34 ^c	38.75	5606.19	5.06
P value	0.002*	0.011*	0.001*	0.003*	0.000**	0.010*			
F value	6.072	4.129	7.327	5.615	10.798	4.236			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

Table 30. Yield of different biorational insecticides against major arthropod pest in brinjal of *Rabi* season 2022

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Spinosad 45% SC @ 0.4ml/l	17.00 ± 0.51 ^a	17.75 ± 0.30 ^a	20.00 ± 0.28 ^a	21.00 ± 0.84 ^a	18.75 ± 0.68 ^a	16.25 ± 0.59 ^a	110.75	16022.85	16.02
NSKE 1% @ 2ml/l	14.25 ± 0.50 ^{ab}	15.50 ± 0.20 ^{abc}	19.00 ± 0.28 ^{ab}	15.50 ± 0.95 ^b	14.25 ± 0.77 ^{ab}	13.50 ± 0.52 ^{ab}	92.00	13310.18	13.31
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	12.50 ± 0.62 ^{ab}	13.00 ± 0.37 ^c	16.00 ± 0.43 ^c	13.00 ± 0.63 ^{bc}	12.50 ± 0.80 ^b	11.50 ± 0.25 ^b	78.50	11357.06	11.35
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	12.00 ± 0.58 ^b	16.75 ± 0.30 ^{ab}	19.50 ± 0.26 ^{ab}	15.00 ± 0.63 ^{bc}	15.75 ± 0.88 ^{ab}	13.75 ± 0.70 ^{ab}	92.75	13418.69	13.41
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	13.00 ± 0.58 ^{ab}	14.50 ± 0.53 ^{bc}	17.50 ± 0.26 ^{bc}	14.25 ± 0.66 ^{bc}	13.50 ± 0.77 ^{ab}	12.00 ± 0.58 ^b	84.75	12261.28	12.26
Control (water)	5.75 ± 0.61 ^c	7.50 ± 0.53 ^d	8.75 ± 0.25 ^d	8.75 ± 0.34 ^c	5.25 ± 0.34 ^c	5.00 ± 0.28 ^c	41.00	5931.71	5.93
P value	0.001*	0.000**	0.000**	0.008*	0.002*	0.000**			
F value	6.723	14.128	31.204	4.520	6.100	8.607			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hecter, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant									

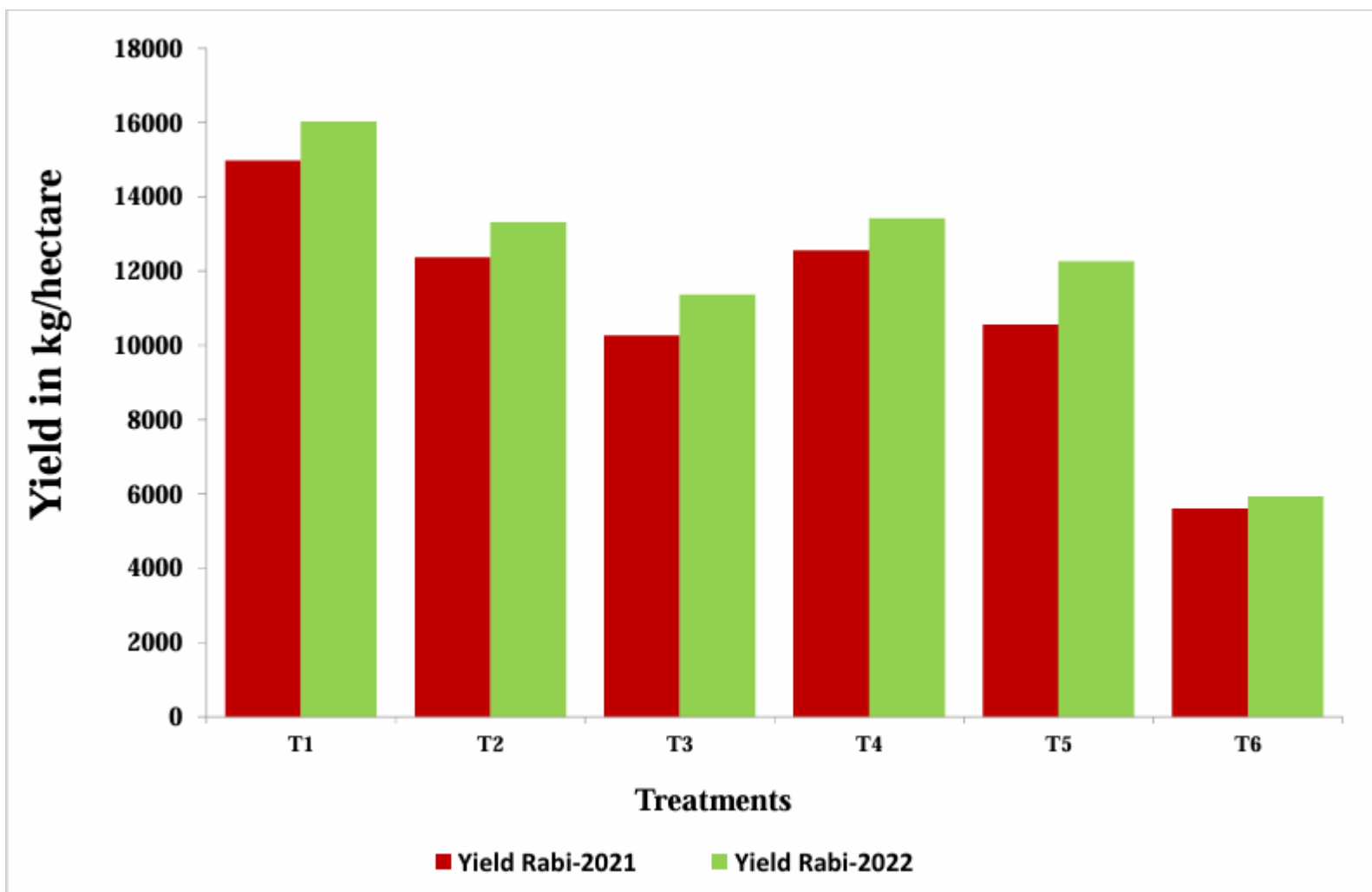


Fig. 26 Yield of different biorational insecticides against major arthropod pest of brinjal of *Rabi* season 2021 and 2022

Table 31. Yield of different biorational insecticides against major arthropod pest in brinjal of *Kharif* season 2022

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Spinosad 45% SC @ 0.4ml/l	15.50 ± 0.12 ^a	18.25 ± 0.34 ^a	23.25 ± 0.64 ^a	19.75 ± 0.66 ^{ab}	17.00 ± 0.59 ^a	11.00 ± 0.43 ^a	104.75	15154.80	15.15
NSKE 1% @ 2ml/l	11.75 ± 0.38 ^b	16.75 ± 0.41 ^{ab}	21.25 ± 0.25 ^a	20.50 ± 1.06 ^a	16.50 ± 0.84 ^a	12.50 ± 0.74 ^a	99.25	14359.08	14.35
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	11.25 ± 0.30 ^b	13.25 ± 0.55 ^b	15.25 ± 0.91 ^b	13.75 ± 0.77 ^{bc}	13.00 ± 0.59 ^{ab}	9.75 ± 0.85 ^{ab}	76.25	11031.53	11.03
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	11.75 ± 0.30 ^b	17.25 ± 0.19 ^a	19.50 ± 0.68 ^{ab}	17.75 ± 0.82 ^{ab}	14.00 ± 0.94 ^{ab}	11.25 ± 0.68 ^a	91.50	13237.84	13.23
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	12.00 ± 0.23 ^b	15.25 ± 0.34 ^{ab}	16.25 ± 0.44 ^b	13.75 ± 0.55 ^{bc}	12.25 ± 0.66 ^{ab}	8.50 ± 0.53 ^{ab}	78.00	11284.72	11.28
Control (water)	5.25 ± 0.44 ^c	8.25 ± 0.79 ^c	8.00 ± 0.52 ^c	8.75 ± 0.50 ^c	8.25 ± 0.66 ^b	5.00 ± 0.16 ^b	43.50	6293.40	6.29
P value	0.000**	0.000**	0.000**	0.003*	0.034*	0.036*			
F value	18.041	9.442	12.654	5.500	3.098	3.048			
• P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant									

Table 32. Yield of different biorational insecticides against major arthropod pest in brinjal of *Kharif* season 2023

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Spinosad 45% SC @ 0.4ml/l	16.00 ± 0.71 ^a	17.00 ± 0.71 ^{ab}	21.00 ± 0.81 ^{ab}	20.25 ± 0.34 ^a	19.00 ± 0.67 ^a	16.75 ± 0.92 ^a	110.00	15914.35	15.91
NSKE 1% @ 2ml/l	14.75 ± 0.82 ^a	18.25 ± 0.61 ^a	22.25 ± 0.59 ^a	19.50 ± 0.42 ^a	16.25 ± 0.86 ^{ab}	13.50 ± 0.62 ^{ab}	104.50	15118.63	15.11
<i>Beauveria bassiana</i> 1x10⁸ conidia/ml @ 10ml/l	10.00 ± 0.58 ^{ab}	12.00 ± 0.71 ^{bc}	15.25 ± 0.88 ^c	14.00 ± 0.37 ^b	12.50 ± 0.70 ^b	10.25 ± 0.59 ^b	74.00	10706.01	10.70
<i>Metarhizium anisopliae</i> 1x10⁸ conidia/ml @ 10ml/l	13.75 ± 1.13 ^a	14.75 ± 0.95 ^{ab}	17.50 ± 0.50 ^{bc}	16.50 ± 0.93 ^{ab}	14.75 ± 0.90 ^{ab}	13.50 ± 0.84 ^{ab}	90.75	13129.34	13.12
<i>Verticillium lecanii</i> 1x10⁸ conidia/ml @ 10ml/l	12.00 ± 0.71 ^{ab}	13.25 ± 0.50 ^{ab}	15.50 ± 0.62 ^c	17.00 ± 0.71 ^{ab}	12.00 ± 0.58 ^b	10.25 ± 0.52 ^b	80.00	11574.07	11.57
Control (water)	6.25 ± 0.62 ^b	7.50 ± 0.68 ^c	8.25 ± 0.52 ^d	7.00 ± 0.71 ^c	6.50 ± 0.41 ^c	7.75 ± 0.61 ^b	43.25	6257.23	6.25
P value	0.033*	0.006*	0.000**	0.000*	0.002*	0.027*			
F value	3.139	4.700	8.753	9.674	5.800	3.309			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT - Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

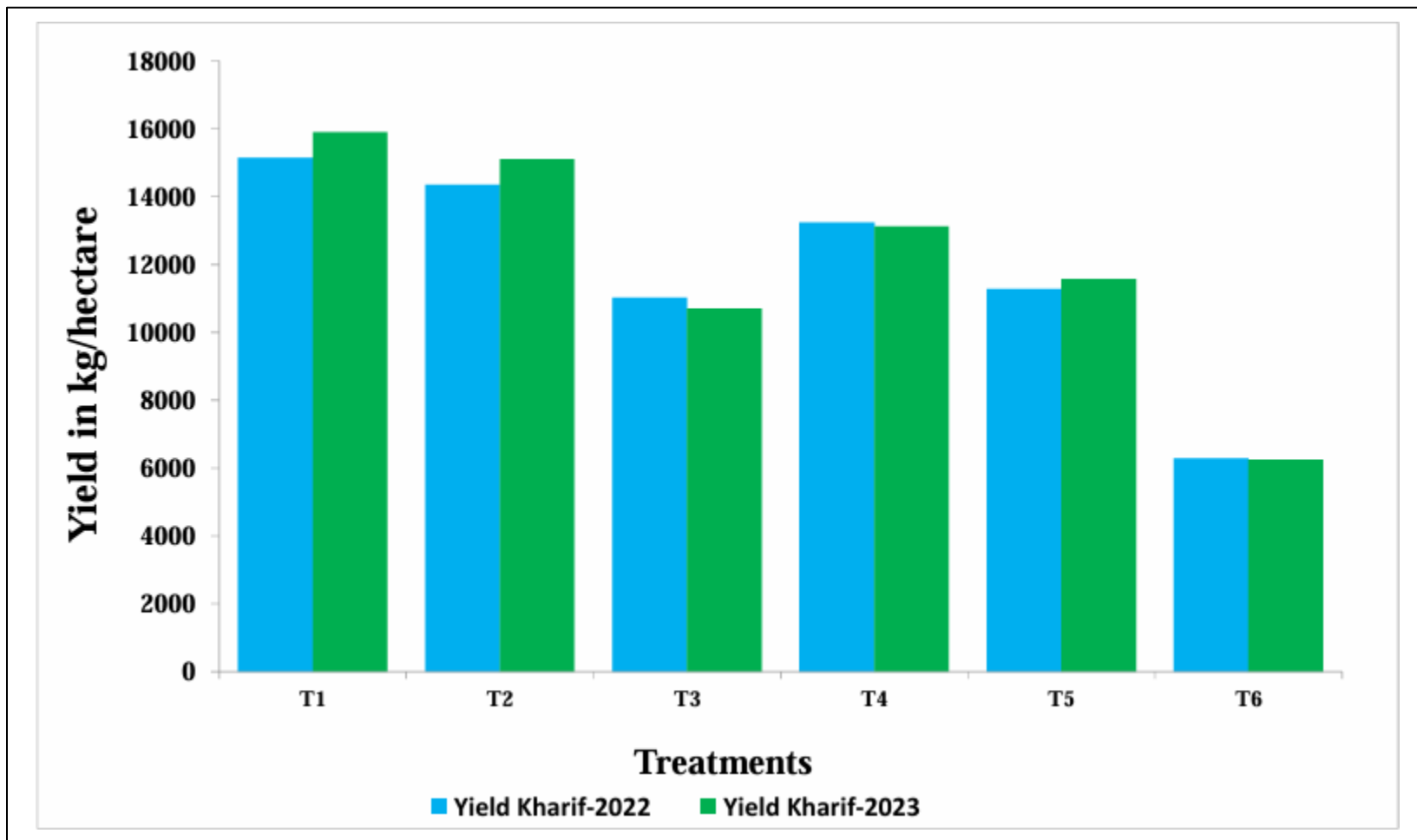


Fig. 27 Yield of different biorational insecticides against major arthropod pest in brinjal of *Kharif* season 2022 and 2023

4.3. To evaluate the efficacy of exogenous application of eco-friendly molecules eliciting host plant resistance in managing major pests of brinjal.

4.3.1. Efficacy of exogenous elicitors inducing host plant resistance in managing jassid (nymph and adult) (*Amrasca biguttula biguttula*) during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The jassid (nymph and adult) population fluctuated between figures of 15.15 and 20.80 per plant and 12.65 to 16.15 per plant observed in the *Rabi* seasons of 2021 and 2022 prior to spraying, as indicated in (Table 33, Fig. 28). All the treatments had a significant effect on the jassid (nymph and adult) population at 1 DAT ($df_{(6,4)}$; $P = 0.019$; $df_{(6,4)}$; $P = 0.000$), 3 DAT ($df_{(6,4)}$; $P = 0.002$; $df_{(6,4)}$; $P = 0.000$), 5 DAT ($df_{(6,4)}$; $P = 0.001$; $df_{(6,4)}$; $P = 0.000$), 7 DAT ($df_{(6,4)}$; $P = 0.018$; $df_{(6,4)}$; $P = 0.000$), 11 DAT ($df_{(6,4)}$; $P = 0.048$; $df_{(6,4)}$; $P = 0.000$) and 14 DAT ($df_{(6,4)}$; $P = 0.030$; $df_{(6,4)}$; $P = 0.000$) during 2021 and 2022 *Rabi* season (Table 33, Fig. 28). The jassid (nymph and adult) population in *Rabi* 2021 and 2022 reached a minimum of 4.06 and 3.74 per plant, respectively (Table 33, Fig. 28). The most significant reduction percentages compared to the control were observed in the following order: (T₂) - Jasmonic acid @ 395 mg/l offering (58.98 and 73.75 %), (T₁) - Salicylic acid @ 50 mg/l providing (46.56 and 67.08 %), (T₄) - Panchagavya 5 % solution showing reductions of (28.28 and 62.45 %), (T₃) - Acetic acid @ 0.6 ml/l with reductions of (28.28 and 57.75 %) followed by (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (11.61 and 54.73 %) (Table 33, Fig. 28). In the interaction between years and treatments, the use of exogenously applied elicitors had a significant effect on the population of jassids (nymph and adult) at 1 DAT ($df_{(6,4)}$; $P = 0.000$), 3 DAT ($df_{(6,4)}$; $P = 0.000$), 5 DAT ($df_{(6,4)}$; $P = 0.000$), 7 DAT ($df_{(6,4)}$; $P = 0.000$), 11 DAT ($df_{(6,4)}$; $P = 0.011$) and 14 DAT ($df_{(6,4)}$; $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 33, Fig. 28).

In *Kharif* season of 2022 and 2023, the population of jassid (nymph and adult) was ranged from 15.35 to 19.80 per plant and 9.85 to 12.65 per plant recorded before spraying respectively (Table 34, Fig. 29). All the treatments had a significant effect on the jassid population ($P < 0.005$) on 1 DAT, 7 DAT and 11 DAT and another days 3 DAT ($df_{(6,4)}$; $P = 0.010$; $df_{(6,4)}$; $P = 0.000$), 5 DAT ($df_{(6,4)}$; $P = 0.005$; $df_{(6,4)}$; $P = 0.000$), and 14 DAT ($df_{(6,4)}$; $P = 0.007$; $df_{(6,4)}$; $P = 0.000$) during 2022 and 2023 *Kharif* season (Table 34,

Fig. 29). The minimum jassid (nymph and adult) population (3.18 and 3.05 per plant) was recorded in *Kharif* 2022 and 2023 respectively (Table 34, Fig. 29). The most significant reduction percentages compared to the control were observed in the following order: (T₂) - Jasmonic acid @ 395 mg/l offering (72.51 and 77.08 %), (T₁) - Salicylic acid @ 50 mg/l providing (67.77 and 75.50 %), (T₃) - Acetic acid @ 0.6 ml/l with reductions of (44.42 and 68.97 %), (T₄) - Panchagavya 5 % solution showing reductions of (37.00 and 73.25 %) followed by (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (20.74 and 65.36 %) (Table 34, Fig. 29). In interaction of years and treatments, the use of exogenously applied elicitors performed significantly impact on jassid (nymph and adult) population at 1 DAT (df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during *Kharif* season 2022 and 2023 (Table 34, Fig. 29).

During the second spray of the 2023 *Kharif* season, all the treatments led to a significant reduction in the jassid (nymph and adult) population. The initial population exhibited a varied range from 6.45 to 8.00 on precount day (Table 35, Fig. 30). Each of the treatments exhibited a high level of significance in their effectiveness against the jassid (nymph and adult) population (P < 0.001) from 1 DAT till 14th DAT during in *Kharif* season 2023 (Table 35, Fig. 30). In the *Kharif* season of 2023, the lowest recorded Jassid (nymph and adult) population was 2.61 per plant (Table 35, Fig. 30). The highest percentage of reduction over the control was observed in (T₂) - Jasmonic acid @ 395 mg/l offering (77.84 %), (T₁) - Salicylic acid @ 50 mg/l providing (74.95 %), (T₄) - Panchagavya 5 % solution showing reductions of (72.32 %), (T₃) - Acetic acid @ 0.6 ml/l with reductions of (69.01 %) followed by (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (66.63 %) (Table 35, Fig. 30).

Previous studies have demonstrated that treatment with jasmonic acid (JA) and methyl jasmonate induce resistance mechanisms against insect herbivores especially for sucking pest (El-Wakeil *et al.*, 2010; El-Wakeil and Volkmar, 2012; Bayram and Tonga, 2018; Fan *et al.*, 2020). Previous research, suggests that jasmonic acid and ethylene can interact having synergetic and antagonist effect to regulate plant defense mechanisms against herbivorous insects, stimulate growth and effectively reduced oviposition and selectivity of thrips (Ma *et al.*, 2020; Bhavanam and Stout, 2021). JA and ET are crucial

plant hormones involved in plant defense mechanisms and externally spray of these plant hormones can stimulate the increase of innate hormones, thereby enhancing defense in plant responses against various stresses, including herbivory (Zhu and Lee, 2015; Saniewski *et al.*, 2020; Yang *et al.*, 2020). Indeed, as emphasized by Lortzing and Steppuhn, (2016) jasmonic acid has pivotal part in modulating plant-pest interactions and acquiring resistance to manage arthropods. Moreover, Bera *et al.*, (2020) demonstrated that not only does the exogenous application of JA affect pest behavior, but preventing the jasmonic metabolism which change pest actions. Therefore, it is crucial to investigate nature friendly control tactics that can efficiently mitigate crop yield losses by targeting the JA pathway.

Table 33. Efficacy of exogenous elicitors inducing host plant resistance in managing jassid (nymph and adult) in brinjal of Rabi season 2021 and 2022

Treatments	No. of <i>Amrasca biguttula biguttula</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> -22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Salicylic Acid @ 50 mg/l	15.55 ± 4.11 ^{ab}	14.20 ± 0.48 ^{ab}	9.85 ± 2.46 ^{ab}	8.70 ± 1.05 ^c	5.35 ± 1.33 ^{cd}	6.55 ± 2.09 ^{bc}	4.55 ± 2.62 ^{ab}	4.50 ± 0.77 ^d	5.75 ± 1.59 ^{bc}	3.85 ± 0.55 ^c	4.65 ± 1.37 ^a	2.70 ± 0.11 ^{bc}	1.60 ± 0.78 ^c	1.85 ± 0.80 ^{bc}	5.29	4.69	46.56	67.08
Jasmonic Acid @ 100 mg/l	19.45 ± 3.70 ^{ab}	12.65 ± 1.00 ^b	7.25 ± 2.39 ^b	7.90 ± 0.92 ^c	4.05 ± 1.45 ^d	5.35 ± 1.92 ^c	3.60 ± 2.23 ^c	3.75 ± 0.44 ^d	4.50 ± 1.86 ^c	2.50 ± 0.25 ^d	3.20 ± 1.39 ^b	1.85 ± 0.25 ^d	1.80 ± 0.83 ^{bc}	1.10 ± 0.25 ^c	4.06	3.74	58.98	73.75
Acetic Acid @ 0.6 ml/l	15.65 ± 3.41 ^{ab}	15.80 ± 1.24 ^a	12.70 ± 2.84 ^a	11.05 ± 0.55 ^b	8.65 ± 2.27 ^{bcd}	8.05 ± 3.45 ^{bc}	5.55 ± 1.99 ^{ab}	6.30 ± 0.34 ^b	7.00 ± 2.34 ^{bc}	5.60 ± 0.58 ^b	4.95 ± 3.16 ^b	3.05 ± 0.44 ^b	3.75 ± 0.70 ^a	2.10 ± 1.27 ^{bc}	7.10	6.02	28.28	57.75
Panchagavya @ 5% solution	20.80 ± 3.61 ^a	13.70 ± 2.54 ^{ab}	10.25 ± 2.18 ^{ab}	9.10 ± 1.31 ^c	8.95 ± 2.66 ^{bc}	7.95 ± 2.67 ^{bc}	7.70 ± 1.71 ^b	5.45 ± 0.25 ^c	6.90 ± 2.77 ^{bc}	4.95 ± 0.61 ^{bc}	6.05 ± 0.86 ^{ab}	2.70 ± 0.41 ^{bc}	2.80 ± 0.36 ^{abc}	1.95 ± 1.14 ^{bc}	7.10	5.35	28.28	62.45
Vermicompos t @ 5 tonnes/ hectare	18.80 ± 2.88 ^{ab}	16.15 ± 2.24 ^a	12.90 ± 3.03 ^a	11.60 ± 0.49 ^b	11.45 ± 3.75 ^{ab}	9.95 ± 3.20 ^b	7.10 ± 1.80 ^{ab}	6.25 ± 0.86 ^{bc}	9.35 ± 2.37 ^{ab}	5.25 ± 0.55 ^b	9.50 ± 4.80 ^a	2.40 ± 0.16 ^c	2.20 ± 1.21 ^{bc}	3.25 ± 0.64 ^b	8.75	6.45	11.61	54.73
Control (water)	15.15 ± 2.10 ^b	14.60 ± 2.56 ^{ab}	14.30 ± 3.11 ^a	17.75 ± 1.23 ^a	14.00 ± 4.80 ^a	16.90 ± 2.06 ^a	12.60 ± 3.78 ^a	14.90 ± 0.11 ^a	10.95 ± 3.41 ^a	15.35 ± 1.55 ^a	4.40 ± 1.69 ^b	12.20 ± 0.28 ^a	3.15 ± 1.32 ^{ab}	8.45 ± 1.81 ^a	9.90	14.25		
P value	0.120 ^{NS}	0.129 ^{NS}	0.019*	0.000**	0.002*	0.000**	0.001*	0.000**	0.018*	0.000**	0.048*	0.000**	0.030*	0.000**				
F value	2.052	1.990	3.611	53.406	6.179	9.742	6.788	226.442	3.666	133.106	2.814	681.571	3.222	23.866				
Year*Treatment's																		
P value	0.376 ^{NS}		0.000**		0.000**		0.000**		0.000**		0.011*		0.000**					
F value	1.100		15.903		18.237		37.259		21.741		3.496		8.065					
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Amrasca biguttula biguttula</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Amrasca biguttula</i> of per plant), PTC – Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

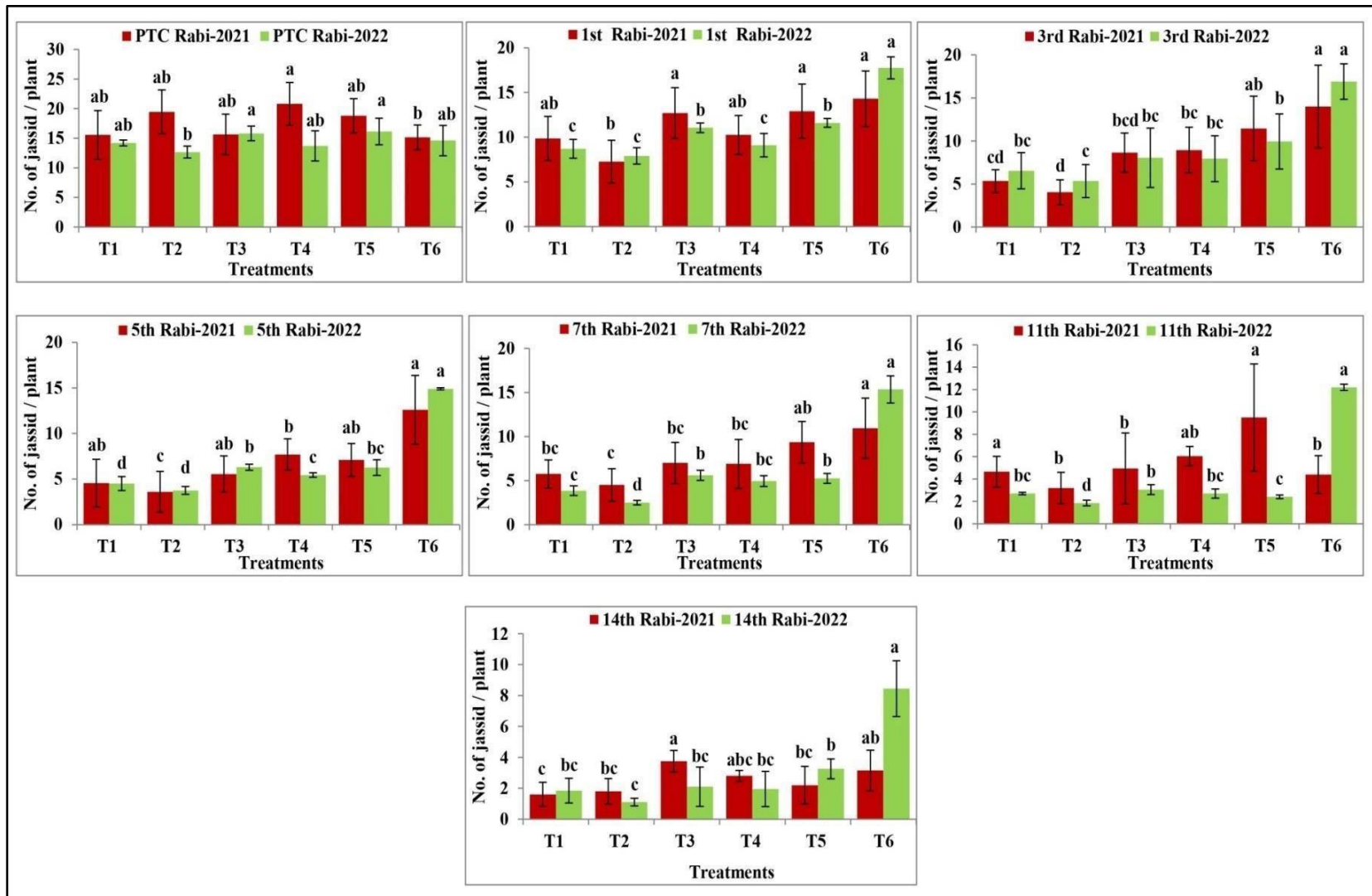


Fig. 28 Efficacy of exogenously applied elicitors against jassid (*Amrasca biguttula biguttula*) in Rabi season 2021 and 2022

Table 34. Efficacy of exogenous elicitors inducing host plant resistance in managing jassid (nymph and adult) in brinjal of Kharif season 2022 and 2023

Treatments	No. of <i>Amrasca biguttula biguttula</i> / per plant*																	
	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023
Salicylic Acid @ 50 mg/l	15.55 ± 1.19 ^b	11.15 ± 1.66 ^{ab}	7.80 ± 3.80 ^c	7.35 ± 0.34 ^{bc}	4.30 ± 1.51 ^b	4.55 ± 0.77 ^{de}	3.55 ± 0.97 ^b	3.45 ± 0.66 ^{cd}	3.05 ± 0.86 ^c	2.05 ± 0.19 ^c	1.60 ± 0.78 ^c	1.35 ± 0.19 ^c	2.10 ± 2.27 ^{bc}	0.85 ± 0.10 ^d	3.73	3.26	67.77	75.50
Jasmonic Acid @ 100 mg/l	17.40 ± 1.70 ^{ab}	12.65 ± 1.99 ^a	7.25 ± 3.92 ^c	6.90 ± 0.70 ^c	4.05 ± 1.98 ^b	4.10 ± 0.11 ^c	3.60 ± 1.84 ^b	3.30 ± 0.11 ^d	2.50 ± 0.25 ^c	2.20 ± 0.32 ^{bc}	1.20 ± 0.28 ^c	1.15 ± 0.10 ^c	0.95 ± 0.98 ^c	0.70 ± 0.12 ^d	3.18	3.05	72.51	77.08
Acetic Acid @ 0.6 ml/l	16.45 ± 2.19 ^{ab}	10.60 ± 0.96 ^{ab}	10.70 ± 1.43 ^{bc}	8.45 ± 1.65 ^b	9.65 ± 3.64 ^{ab}	5.30 ± 0.34 ^c	6.55 ± 0.80 ^{ab}	4.15 ± 0.19 ^c	5.00 ± 1.75 ^{bc}	3.30 ± 0.62 ^{bc}	3.95 ± 0.70 ^b	1.55 ± 0.19 ^c	2.75 ± 0.75 ^{abc}	2.05 ± 0.10 ^b	6.43	4.13	44.42	68.97
Panchagavya @ 5% solution	15.35 ± 0.70 ^b	9.85 ± 0.52 ^b	14.20 ± 1.43 ^{ab}	7.10 ± 0.47 ^c	8.95 ± 5.33 ^{ab}	5.15 ± 0.34 ^{cd}	6.70 ± 2.21 ^{ab}	3.65 ± 0.44 ^{cd}	5.30 ± 1.76 ^{bc}	2.65 ± 0.91 ^{bc}	4.55 ± 2.62 ^b	1.80 ± 0.16 ^{bc}	4.05 ± 1.98 ^{ab}	1.05 ± 0.19 ^d	7.29	3.56	37.00	73.25
Vermicompos t @ 5 tonnes/ hectare	19.80 ± 1.25 ^a	10.15 ± 1.66 ^{ab}	15.90 ± 1.03 ^{ab}	8.05 ± 0.52 ^{bc}	11.45 ± 5.85 ^a	6.25 ± 0.41 ^b	8.10 ± 2.19 ^a	5.45 ± 0.44 ^b	7.90 ± 3.90 ^b	3.85 ± 0.78 ^b	6.50 ± 0.73 ^a	2.50 ± 0.48 ^b	5.20 ± 1.39 ^a	1.60 ± 0.23 ^c	9.17	4.61	20.74	65.36
Control (water)	18.70 ± 4.94 ^{ab}	12.10 ± 2.20 ^{ab}	18.30 ± 6.30 ^a	15.20 ± 0.48 ^a	13.60 ± 1.17 ^a	16.30 ± 0.47 ^a	9.95 ± 3.97 ^a	15.55 ± 0.71 ^a	16.00 ± 2.18 ^a	13.60 ± 2.10 ^a	6.40 ± 0.58 ^a	10.45 ± 1.21 ^a	5.15 ± 1.67 ^a	8.80 ± 0.49 ^a	11.57	13.31		
P value	0.110 ^N _s	0.147 ^{NS}	0.001 [*]	0.000 ^{**}	0.010 [*]	0.000 ^{**}	0.005 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.007 [*]	0.000 ^{**}				
F value	2.120	1.886	6.470	59.054	4.215	416.006	4.966	392.507	21.963	74.294	13.828	172.941	4.619	644.262				
Year*Treatment's																		
P value	0.063 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}					
F value	2.315		12.039		15.454		20.128		61.291		19.391		13.040					
* P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Amrasca biguttula biguttula</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Amrasca biguttula biguttula</i> of per plant), PTC - Pre treatment count; DAT – Days after Treatment; ± Standard Deviation Values , *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

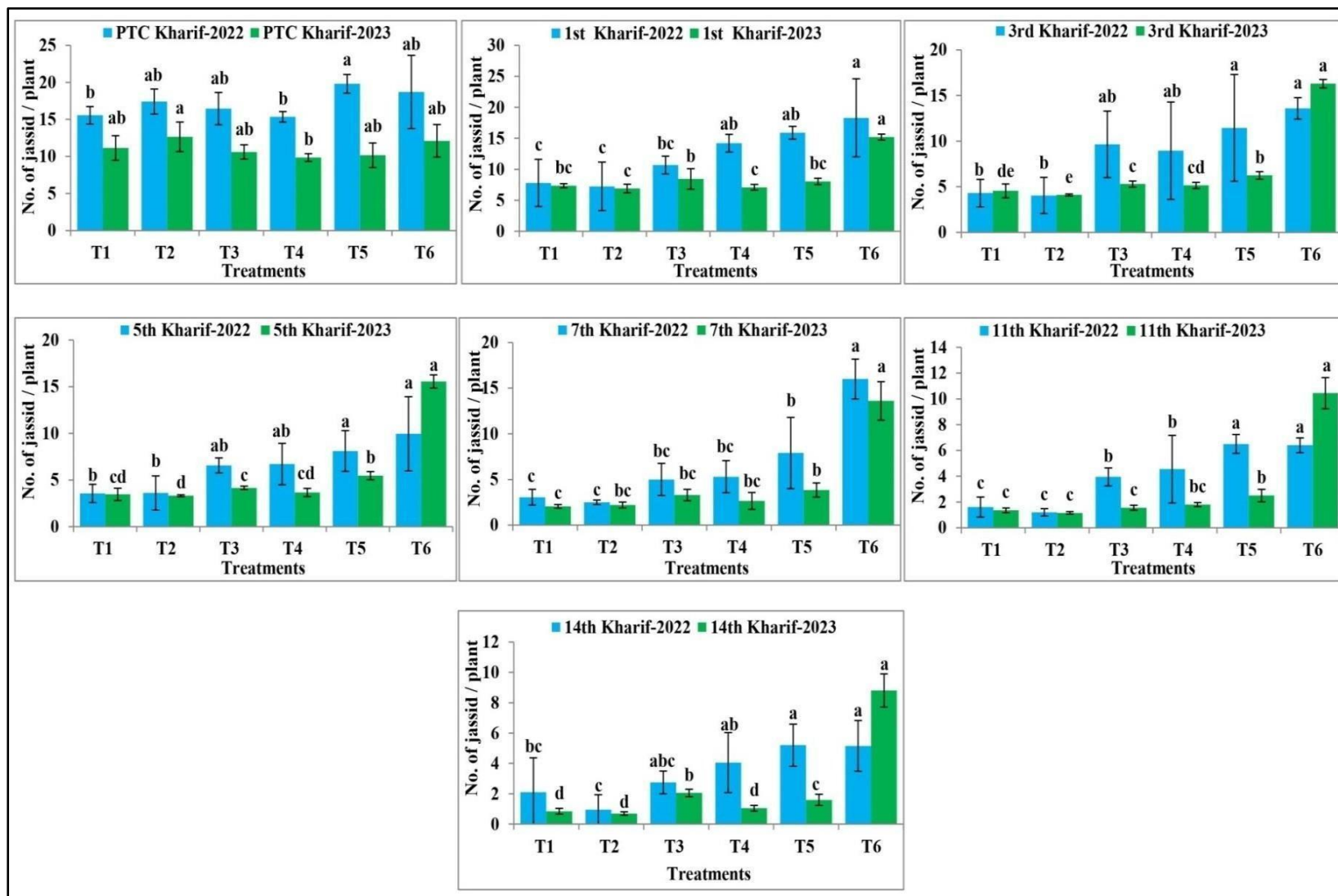


Fig. 29 Efficacy of exogenously applied elicitors against jassid (*Amrasca biguttula biguttula*) in Kharif season 2022 and 2023

Table 35. Efficacy of exogenous elicitors inducing host plant resistance in managing jassid (nymph and adult) in brinjal of Kharif season 2023 (Second Spray)

Treatments	No. of <i>Amrasca biguttula biguttula</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Salicylic Acid @ 50 mg/l	7.30 ± 0.84 ^{ab}	6.00 ± 0.16 ^c	4.55 ± 0.47 ^c	3.30 ± 0.68 ^{bc}	2.30 ± 0.68 ^{bc}	1.05 ± 0.25 ^c	0.55 ± 0.19 ^{bc}	2.95	74.95
Jasmonic Acid @ 100 mg/l	8.00 ± 0.43 ^a	5.90 ± 0.12 ^c	4.70 ± 0.60 ^c	2.90 ± 0.50 ^c	1.15 ± 0.61 ^c	0.85 ± 0.10 ^c	0.20 ± 0.23 ^c	2.61	77.84
Acetic Acid @ 0.6 ml/l	7.40 ± 0.71 ^{ab}	6.35 ± 0.19 ^b	5.85 ± 1.02 ^{bc}	4.20 ± 1.07 ^{bc}	3.10 ± 1.00 ^b	1.60 ± 0.43 ^{bc}	0.85 ± 0.19 ^{bc}	3.65	69.01
Panchagavya @ 5% solution	6.75 ± 0.75 ^{ab}	6.15 ± 0.10 ^{bc}	5.15 ± 1.18 ^{bc}	3.65 ± 1.27 ^{bc}	2.70 ± 0.90 ^b	0.75 ± 0.19 ^c	1.20 ± 0.16 ^b	3.26	72.32
Vermicompost @ 5 tonnes/ hectare	7.45 ± 0.34 ^{ab}	5.90 ± 0.20 ^c	6.45 ± 0.66 ^b	4.55 ± 0.77 ^b	3.55 ± 0.30 ^b	1.95 ± 0.71 ^b	1.20 ± 0.16 ^b	3.93	66.63
Control (water)	6.45 ± 1.36 ^b	11.05 ± 0.19 ^a	13.45 ± 0.91 ^a	14.00 ± 0.99 ^a	12.95 ± 1.02 ^a	10.50 ± 0.98 ^a	8.75 ± 0.99 ^a	11.78	
P value	0.157 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	1.833	589.922	63.994	84.775	117.758	193.118	217.892		
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Amrasca biguttula biguttula</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Amrasca biguttula biguttula</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant									

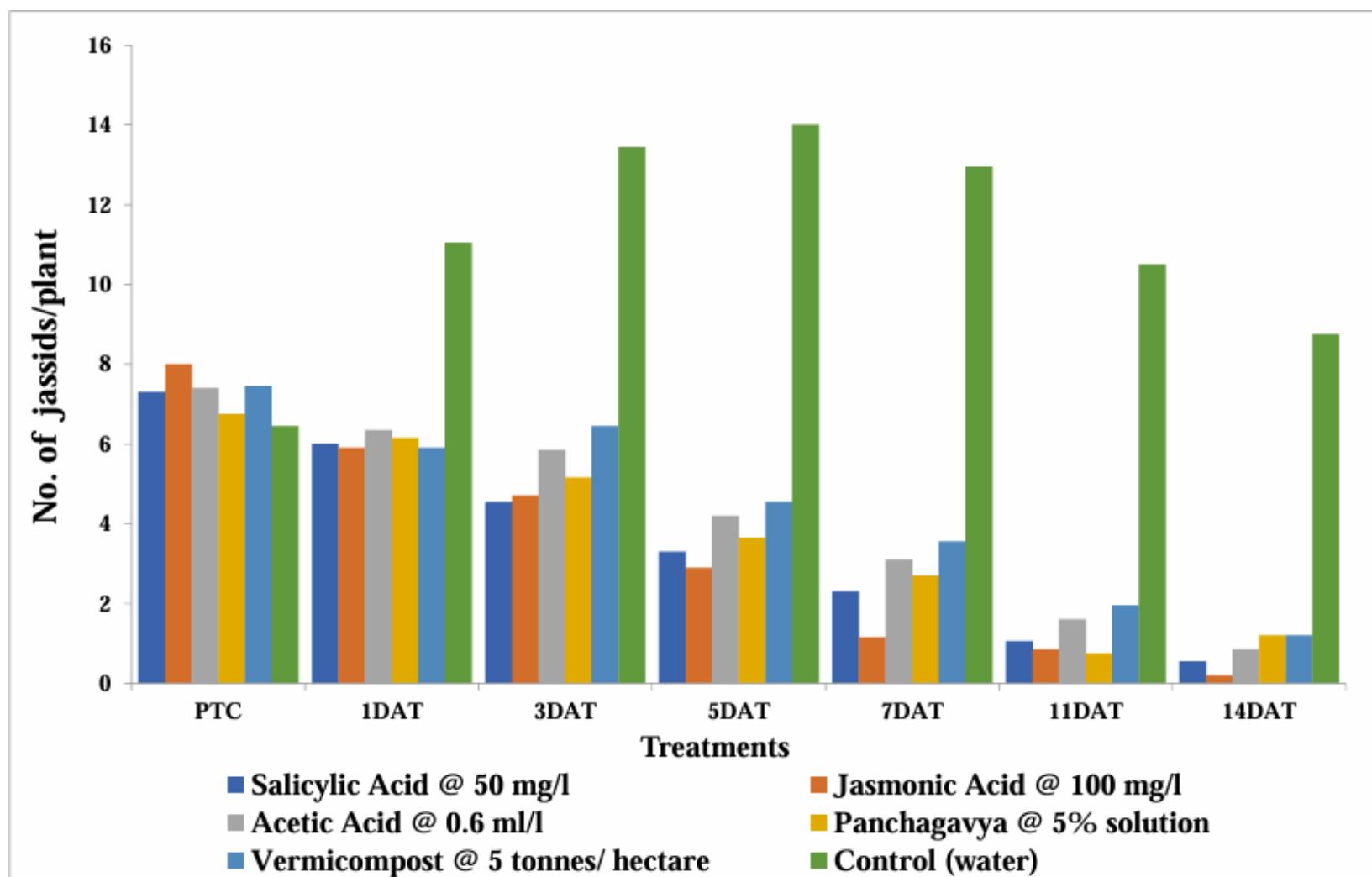


Fig. 30 Efficacy of exogenously applied elicitors against jassid (*Amrasca biguttula biguttula*) in Kharif season 2023

4.3.2. Efficacy of exogenous elicitors inducing host plant resistance in managing whitefly (adult) in brinjal during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The whitefly (adult) population fluctuated between figures of 12.25 and 13.90 per plant and 11.40 to 13.35 per plant observed in the *Rabi* seasons of 2021 and 2022 prior to spraying, as indicated in (Table 36, Fig. 31). All the treatments were performed significant impact on whitefly ($P < 0.001$) from 1 DAT till 14th DAT during 2021 and 2022 *Rabi* season (Table 36, Fig. 31). The whitefly (adult) population in *Rabi* 2021 and 2022 reached a minimum of 4.23 and 3.98 per plant, respectively (Table 36, Fig. 31). The most significant reduction percentages compared to the control were observed in the following order: (T₁) - Salicylic acid @ 50 mg/l providing (74.30 and 73.05 %), (T₄) - Panchagavya 5 % solution showing reductions of (70.71 and 70.07 %), followed by (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (65.18 and 61.74 %) continued with (T₃) - Acetic acid @ 0.6 ml/l with reductions of (63.91 and 63.64 %) and last was (T₂) - Jasmonic acid @ 395 mg/l offering (58.86 and 60.12 %) (Table 36, Fig. 31). In the interaction between year and treatments, the use of exogenously applied elicitors had a significant effect on the population of whitefly at 1 DAT (df_(6,4); $P = 0.000$), 3 DAT (df_(6,4); $P = 0.000$), 5 DAT (df_(6,4); $P = 0.000$), 7 DAT (df_(6,4); $P = 0.000$), 11 DAT (df_(6,4); $P = 0.000$) and 14 DAT (df_(6,4); $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 36, Fig. 31).

In *Kharif* season of 2022 and 2023, the whitefly (adult) occurrence was between 10.80 to 14.25 / plant and 9.85 to 12.40 per plant recorded before spraying respectively (Table 37, Fig. 32). All the treatments had a significant effect on the whitefly population at 1 DAT (df_(6,4); $P = 0.007$; df_(6,4); $P = 0.000$), 3 DAT (df_(6,4); $P = 0.045$; df_(6,4); $P = 0.000$), 5DAT (df_(6,4); $P = 0.005$; df_(6,4); $P = 0.000$), 7 DAT (df_(6,4); $P = 0.001$; df_(6,4); $P = 0.000$), 11 DAT (df_(6,4); $P = 0.000$; df_(6,4); $P = 0.000$) and 14 DAT (df_(6,4); $P = 0.004$; df_(6,4); $P = 0.000$) during 2022 and 2023 *Kharif* season (Table 37, Fig. 32). The minimum whitefly population (4.03 and 2.75 per plant) was recorded in *Kharif* 2022 and 2023 respectively (Table 37, Fig. 32). The most significant reduction percentages compared to the control were observed in the following order: (T₄) - Panchagavya 5 % solution showing

reductions of (62.92 and 78.36 %), (T₁) - Salicylic acid @ 50 mg/l providing (37.25 and 80.42 %), (T₅) - Vermicompost @ 5 tonnes/hectare offering (36.70 and 74.30 %) followed by (T₃) - Acetic acid @ 0.6 ml/l with reductions of (34.60 and 72.24 %) and least effective treatment was (T₂) - Jasmonic acid @ 395 mg/l resulting in reductions of (21.43 and 68.32 %) (Table 37, Fig. 32). In interaction of years and treatments, the use of exogenously applied elicitors performed significantly impact on whitefly population at 1 DAT (df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.000) during *Kharif* season 2022 and 2023 (Table 37, Fig. 32).

During the second spray of the 2023 *Kharif* season, all the treatments led to a noteworthy decline in the whitefly (adult) incidence. The initial population exhibited a varied range from 4.75 to 7.95 on precount day (Table 38, Fig. 33). Each of the treatments exhibited a high level of significance in their effectiveness against the whitefly population ($P < 0.005$) from 1 DAT till 14th DAT during in *Kharif* season 2023 (Table 38, Fig. 33). In the *Kharif* season of 2023, the lowest recorded whitefly population was 1.34 per plant. The highest percentage of reduction over the control was observed in (T₁) - Salicylic acid @ 50 mg/l providing (86.08 %) followed by (T₄) - Panchagavya 5 % solution showing reductions of (83.07 %), (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (79.33 %) continued with (T₃) - Acetic acid @ 0.6 ml/l with reductions of (76.01 %) and (T₂) - Jasmonic acid @ 395 mg/l offering (70.30 %) (Table 38, Fig. 33).

Initial research into the use of external applications of salicylic acid (SA)- inducing compounds focused on stimulating plant defense mechanisms, boosting resistance, and enhancing elicitors signalling. This laid the groundwork for innovative approaches to managing agricultural pests and diseases, which can lead to systemic acquired resistance and reduced pathogen loads (Faize and Faize, 2018; Tripathi *et al.*, 2019).

However, there is scanty work noted about salicylic acid (SA) in arthropod pest management. Despite this, there is evidence suggesting that whiteflies can induce response to salicylic acid in different crops (Zarate *et al.*, 2007; Rodriguez-Alvarez *et al.*, 2015). Previous studies showed important site of jasmonic and salicylic acid antipathy occurred by whitefly may present in downstream of the jasmonic pathway which helps in

signalling (Zhang *et al.*, 2013). In a study by Bhasker *et al.*, (2020), onion plants received SA use thrice shown a strong decrease in the thrips population (*Thrips tabaci*) compared to other treatments. Furthermore, exogenous application of salicylic acid reduced aphid infestation in Canola by inducing resistance, as reported by Elhamahmy *et al.*, (2016). In other studies, the combined application of salicylic acid (SA) with *Pseudomonas pudita* provided enhanced resistance to canola plants against aphids (*Brevicoryne brassicae*), as reported by Khoshfarman-Borji *et al.*, (2020). Moreover, Moran and Thompson, (2001) demonstrated that aphid feeding on Arabidopsis plants leads to the activation of genes linked to salicylic acid, which play a role in defending against pathogens.

The Russian wheat aphid, triggers the growth of salicylic acid (SA), which contributes to resistance, as observed by Mohase and Westhuizen, (2002). According to Li (2006), the Mi-1 gene-mediated resistance of tomatoes to potato aphids likewise depends on SA and provides a case study for comparable plant reactions in defenses to illnesses and sucking insects. Such responses can also alter how other plant defense pathways are activated. For instance, SA-related plant defences are induced when the jasmonic acid (JA) defense system is suppressed by the silver leaf whitefly (*Bemisia tabaci* type B), which feeds on Arabidopsis, as reported by Zarate *et al.*, (2007). In Arabidopsis plants, both egg deposition and larval feeding by *P. brassicae* can cooperate synergistically to prompt upper stages of salicylic acid (SA) (Lortzing *et al.*, 2019). As reported by Bruessow *et al.*, (2010), salicylic acid can store on site of egg laying and larval nourishing further impair this action, as observed by Lortzing *et al.*, (2019). Furthermore, Panchagavya was seen by Boomiraj *et al.*, (2004) to be efficient against okra leafhoppers and whitefly.

Absolutely, salicylic acid (SA) can have numerous effects on plant physiology throughout the entire plant. It has a function in many different elements of plant biology, such as photosynthesis, stomatal dynamics, seed germination, cell proliferation, vegetative growth, blooming, and defense responses against pests and diseases. Given its wide-ranging impact, SA application can indeed be integrated into crop protection strategies to enhance plant health and resilience against pests and diseases.

Table 36. Efficacy of exogenous elicitors inducing host plant resistance in managing whitefly (adult) in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of <i>Bemisia tabaci</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> -22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Salicylic Acid @ 50 mg/l	13.20 ± 1.14 ^{ab}	12.65 ± 0.44 ^{ab}	9.05 ± 0.41 ^d	7.10 ± 0.41 ^c	6.15 ± 0.52 ^d	5.90 ± 0.25 ^c	4.10 ± 0.25 ^c	4.40 ± 0.75 ^c	3.35 ± 0.41 ^{cd}	3.30 ± 0.34 ^c	1.75 ± 0.10 ^c	2.00 ± 0.28 ^c	1.00 ± 0.23 ^c	1.20 ± 0.36 ^d	4.23	3.98	74.30	73.05
Jasmonic Acid @ 100 mg/l	12.50 ± 1.16 ^{ab}	12.95 ± 0.72 ^{ab}	11.60 ± 1.14 ^b	10.00 ± 0.71 ^b	9.70 ± 1.10 ^b	7.70 ± 1.01 ^b	8.05 ± 1.27 ^b	6.85 ± 0.50 ^b	5.60 ± 1.09 ^b	5.50 ± 0.52 ^b	3.60 ± 0.43 ^b	2.25 ± 0.19 ^{de}	2.10 ± 0.50 ^b	3.05 ± 0.34 ^b	6.77	5.89	58.86	60.12
Acetic Acid @ 0.6 ml/l	12.25 ± 0.85 ^b	11.40 ± 0.82 ^b	10.05 ± 1.00 ^{cd}	8.20 ± 0.84 ^c	9.40 ± 0.43 ^b	7.75 ± 0.77 ^b	7.20 ± 1.23 ^{bc}	6.50 ± 1.20 ^b	4.25 ± 0.25 ^c	4.90 ± 0.47 ^b	2.85 ± 0.77 ^b	3.10 ± 0.25 ^{bc}	1.90 ± 0.54 ^{bc}	1.80 ± 0.16 ^c	5.94	5.37	63.91	63.64
Panchagavya @ 5% solution	12.85 ± 1.05 ^{ab}	12.15 ± 0.53 ^{ab}	9.45 ± 0.30 ^{cd}	7.60 ± 0.59 ^c	7.55 ± 1.11 ^c	5.95 ± 0.37 ^c	5.75 ± 0.41 ^d	4.60 ± 1.42 ^c	3.20 ± 0.48 ^d	3.80 ± 0.54 ^c	1.90 ± 0.34 ^c	2.70 ± 0.47 ^{cd}	1.10 ± 0.38 ^c	1.90 ± 0.52 ^c	4.82	4.42	70.71	70.07
Vermicompo st @ 5 tonnes/ hectare	13.90 ± 0.66 ^a	13.00 ± 1.60 ^{ab}	10.60 ± 0.87 ^{bc}	9.80 ± 0.73 ^b	8.75 ± 0.75 ^{bc}	7.85 ± 0.61 ^b	6.35 ± 1.11 ^{cd}	5.25 ± 1.03 ^{bc}	4.05 ± 0.77 ^{cd}	4.80 ± 0.50 ^b	3.05 ± 0.59 ^b	3.60 ± 0.43 ^b	1.60 ± 0.32 ^{bc}	2.65 ± 0.25 ^b	5.73	5.65	65.18	61.74
Control (water)	13.05 ± 1.00 ^{ab}	13.35 ± 1.57 ^a	19.70 ± 0.93 ^a	18.20 ± 1.32 ^a	18.20 ± 0.73 ^a	18.35 ± 0.44 ^a	18.55 ± 0.41 ^a	16.30 ± 1.01 ^a	17.70 ± 0.47 ^a	14.35 ± 0.44 ^a	14.80 ± 0.58 ^a	12.25 ± 0.52 ^a	9.85 ± 0.92 ^a	9.20 ± 0.16 ^a	16.46	14.77		
P value	0.286 ^{NS}	0.168 ^{NS}	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**				
F value	1.359	1.781	91.376	100.461	107.632	220.512	133.613	76.387	303.779	295.809	373.798	424.214	165.443	325.967				
Year*Treatment's																		
P value	0.016*		0.000**		0.000**		0.000**		0.000**		0.000**		0.000**					
F value	3.229		189.745		227.816		205.800		199.132		243.561		314.802					
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Bemisia tabaci</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Bemisia tabaci</i> of per plant), PTC – Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

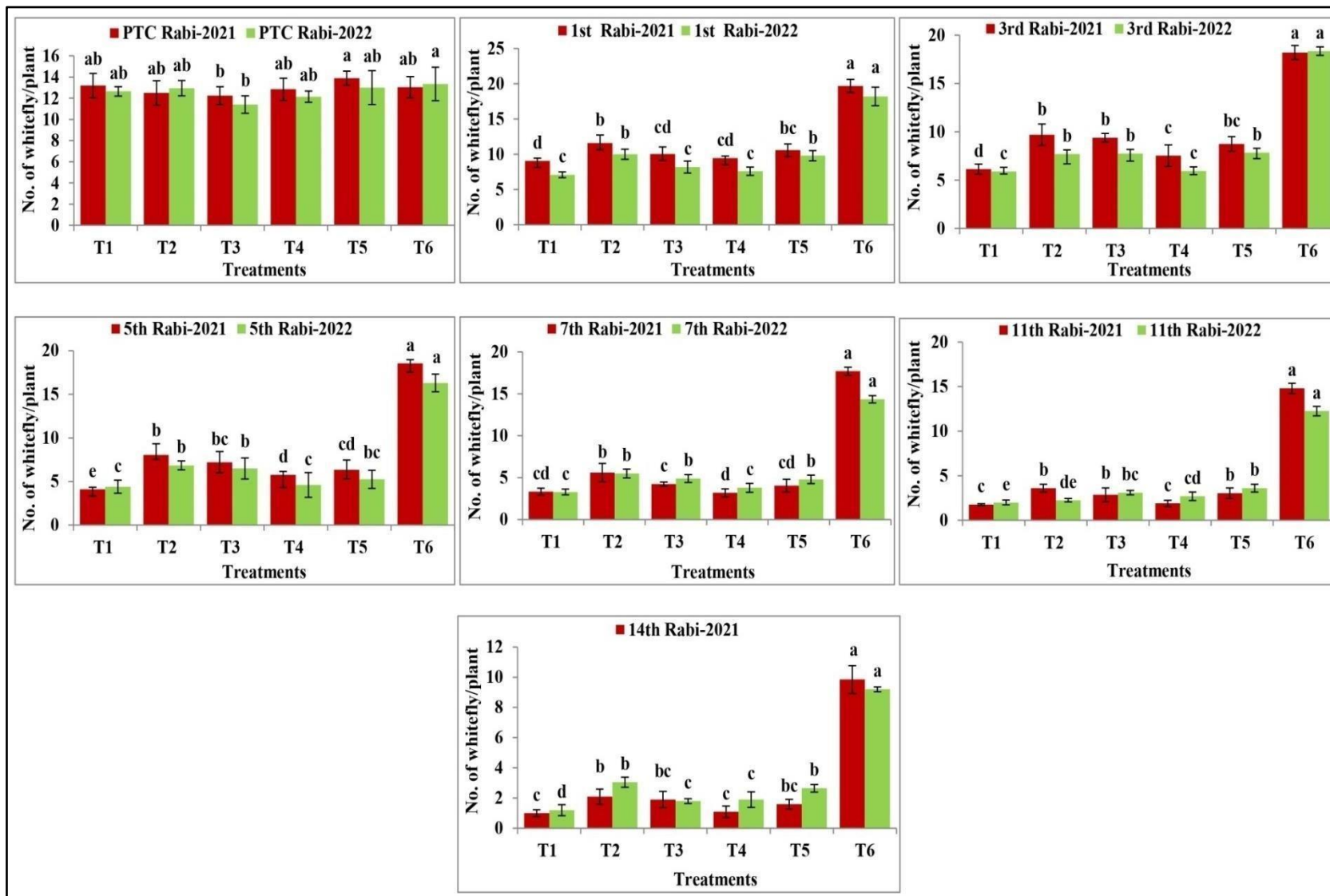


Fig. 31 Efficacy of exogenously applied elicitors against whitefly (*Bemisia tabaci*) in Rabi season 2021 and 2022

Table 37. Efficacy of exogenous elicitors inducing host plant resistance in managing whitefly (adult) in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of <i>Bemisia tabaci</i> / per plant*																	
	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023
Salicylic Acid @ 50 mg/l	13.70 ± 1.19 ^{ab}	10.05 ± 0.71 ^{ab}	9.75 ± 2.10 ^{bc}	6.50 ± 0.70 ^d	10.20 ± 1.96 ^a	4.30 ± 0.34 ^d	8.45 ± 2.24 ^b	3.00 ± 0.28 ^d	5.15 ± 1.34 ^b	1.55 ± 0.30 ^d	4.15 ± 1.96 ^c	0.85 ± 0.19 ^d	3.25 ± 1.32 ^{bc}	0.30 ± 0.11 ^d	6.82	2.75	37.25	80.42
Jasmonic Acid @ 100 mg/l	12.80 ± 2.22 ^{ab}	12.05 ± 1.42 ^{ab}	11.70 ± 0.66 ^{ab}	9.55 ± 0.91 ^b	10.40 ± 1.87 ^a	6.20 ± 0.58 ^b	9.45 ± 1.86 ^b	4.35 ± 0.34 ^b	7.80 ± 1.95 ^{ab}	3.30 ± 0.25 ^b	6.45 ± 0.66 ^b	2.10 ± 0.41 ^b	5.45 ± 1.10 ^{ab}	1.25 ± 0.34 ^b	8.54	4.45	21.43	68.32
Acetic Acid @ 0.6 ml/l	11.80 ± 1.78 ^{ab}	11.05 ± 0.75 ^{ab}	10.75 ± 1.38 ^{abc}	8.15 ± 1.30 ^c	9.15 ± 2.51 ^{ab}	5.45 ± 0.44 ^{bc}	7.90 ± 2.94 ^b	4.05 ± 0.34 ^{bc}	6.15 ± 0.59 ^b	3.10 ± 0.11 ^{bc}	4.95 ± 0.91 ^{bc}	1.65 ± 0.44 ^{bc}	3.80 ± 0.58 ^{bc}	1.05 ± 0.19 ^{bc}	7.11	3.90	34.60	72.24
Panchagavy a @ 5% solution	12.80 ± 1.09 ^{ab}	12.40 ± 1.14 ^a	8.75 ± 1.43 ^c	7.00 ± 0.63 ^{cd}	6.05 ± 0.86 ^b	4.45 ± 0.34 ^d	4.90 ± 0.93 ^c	3.15 ± 0.30 ^{cd}	2.15 ± 1.52 ^c	1.85 ± 0.19 ^d	0.40 ± 0.16 ^d	1.10 ± 0.25 ^{cd}	1.95 ± 0.95 ^c	0.70 ± 0.25 ^c	4.03	3.04	62.92	78.36
Vermicomp ost @ 5 tonnes/ hectare	10.80 ± 2.39 ^b	9.85 ± 1.06 ^b	11.85 ± 0.30 ^{ab}	7.90 ± 1.01 ^{cd}	7.15 ± 2.45 ^{ab}	5.25 ± 0.61 ^c	6.90 ± 1.16 ^{bc}	3.50 ± 0.73 ^{bcd}	6.65 ± 0.57 ^b	2.70 ± 0.11 ^c	4.95 ± 0.91 ^{bc}	1.40 ± 0.28 ^{cd}	3.80 ± 0.93 ^{bc}	0.95 ± 0.19 ^{bc}	6.88	3.61	36.70	74.30
Control (water)	14.25 ± 2.06 ^a	11.85 ± 2.79 ^{ab}	13.05 ± 1.88 ^a	16.65 ± 0.66 ^a	10.05 ± 2.66 ^a	16.30 ± 0.68 ^a	12.80 ± 0.28 ^c	15.70 ± 1.11 ^a	9.65 ± 3.64 ^a	14.65 ± 0.50 ^a	12.30 ± 1.89 ^a	11.15 ± 0.52 ^a	7.40 ± 3.38 ^a	9.90 ± 0.25 ^a	10.87	14.05		
P value	0.159 ^{NS}	0.117 ^{NS}	0.007*	0.000**	0.045*	0.000**	0.000**	0.000**	0.001*	0.000**	0.000**	0.000**	0.004*	0.000**				
F value	1.822	2.067	4.660	69.294	2.865	313.287	8.668	269.94	7.033	1280.51	37.892	461.708	5.240	980.727				
Year*Treatment's																		
P value	0.023*		0.000**		0.000**		0.000**		0.000**		0.000**		0.000**					
F value	2.967		16.005		8.853		27.827		18.855		67.521		22.018					
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Bemisia tabaci</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Bemisia tabaci</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

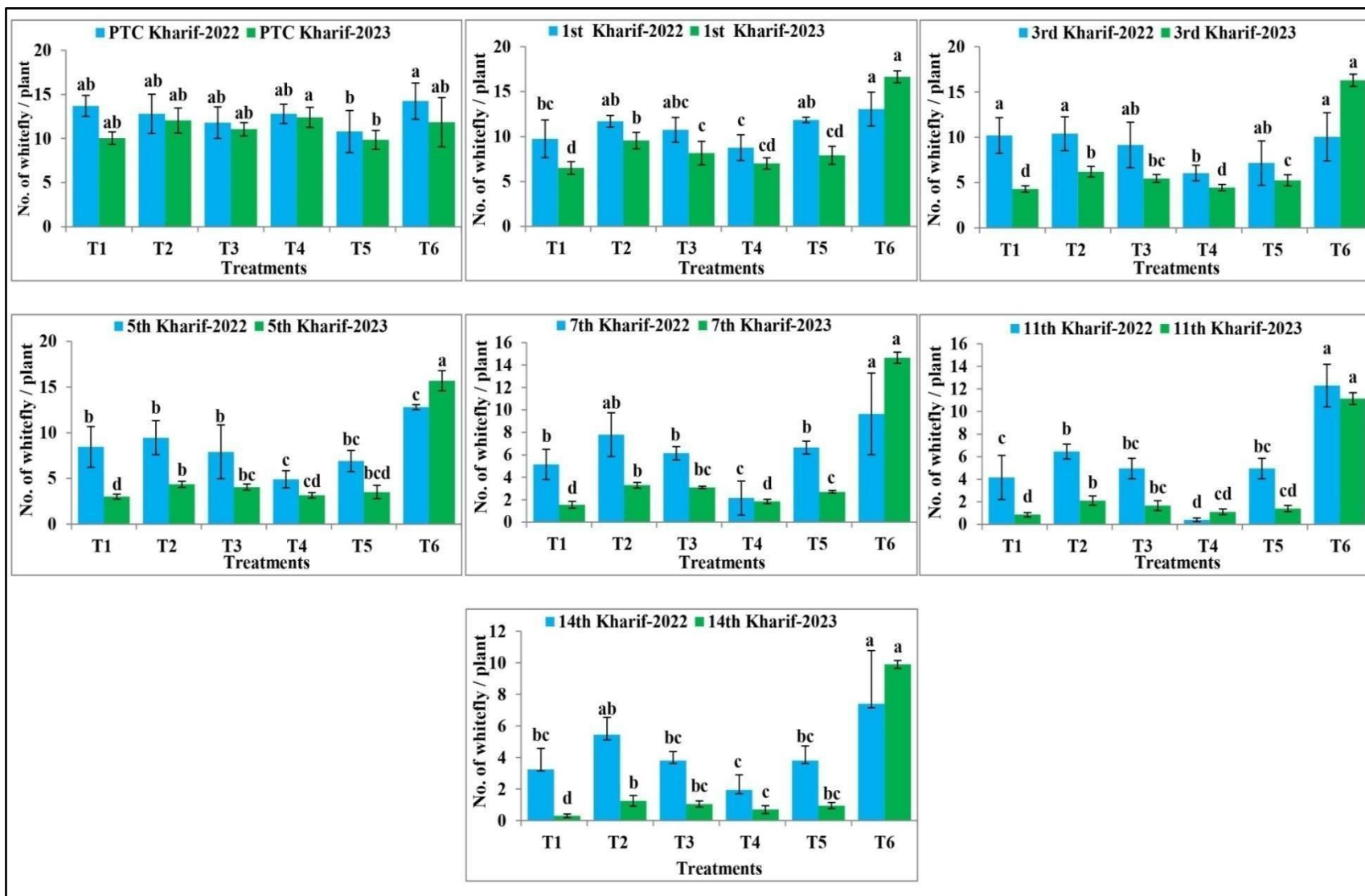


Fig. 32 Efficacy of exogenously applied elicitors against whitefly (*Bemisia tabaci*) in Kharif season 2022 and 2023

Table 38. Efficacy of exogenous elicitors inducing host plant resistance in managing whitefly (adult) in brinjal of Kharif season 2023

Treatments	No. of <i>Bemisia tabaci</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Salicylic Acid @ 50 mg/l	5.55 ± 1.14 ^{ab}	3.55 ± 1.48 ^b	2.25 ± 0.52 ^{de}	1.20 ± 0.37 ^c	0.70 ± 0.41 ^c	0.25 ± 0.10 ^c	0.10 ± 0.20 ^c	1.34	86.08
Jasmonic Acid @ 100 mg/l	6.75 ± 1.90 ^{ab}	6.45 ± 2.40 ^b	4.95 ± 1.45 ^b	2.60 ± 0.71 ^b	1.25 ± 0.30 ^b	0.95 ± 0.10 ^b	1.00 ± 0.36 ^b	2.86	70.30
Acetic Acid @ 0.6 ml/l	7.95 ± 1.57 ^a	5.25 ± 1.90 ^b	4.40 ± 0.28 ^{bc}	2.25 ± 0.52 ^{bc}	1.05 ± 0.10 ^{bc}	0.65 ± 0.10 ^{bc}	0.30 ± 0.34 ^c	2.31	76.01
Panchagavya @ 5% solution	5.25 ± 1.22 ^b	4.05 ± 1.54 ^b	1.45 ± 0.44 ^c	2.75 ± 0.25 ^b	0.85 ± 0.10 ^{bc}	0.50 ± 0.41 ^{bc}	0.20 ± 0.16 ^c	1.63	83.07
Vermicompost @ 5 tonnes/ hectare	4.75 ± 1.48 ^b	4.40 ± 2.08 ^b	3.25 ± 1.26 ^{cd}	1.95 ± 0.34 ^{bc}	1.20 ± 0.28 ^b	0.75 ± 0.52 ^{bc}	0.40 ± 0.28 ^c	1.99	79.33
Control (water)	6.05 ± 1.73 ^{ab}	11.60 ± 3.35 ^a	12.85 ± 1.34 ^a	10.15 ± 1.36 ^a	7.70 ± 0.11 ^a	8.45 ± 0.44 ^a	7.05 ± 0.66 ^a	9.63	
P value	0.107 ^{NS}	0.001 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	2.141	7.192	67.215	88.544	478.051	364.389	214.291		
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Bemisia tabaci</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Bemisia tabaci</i> of per plant), PTC - Pre treatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

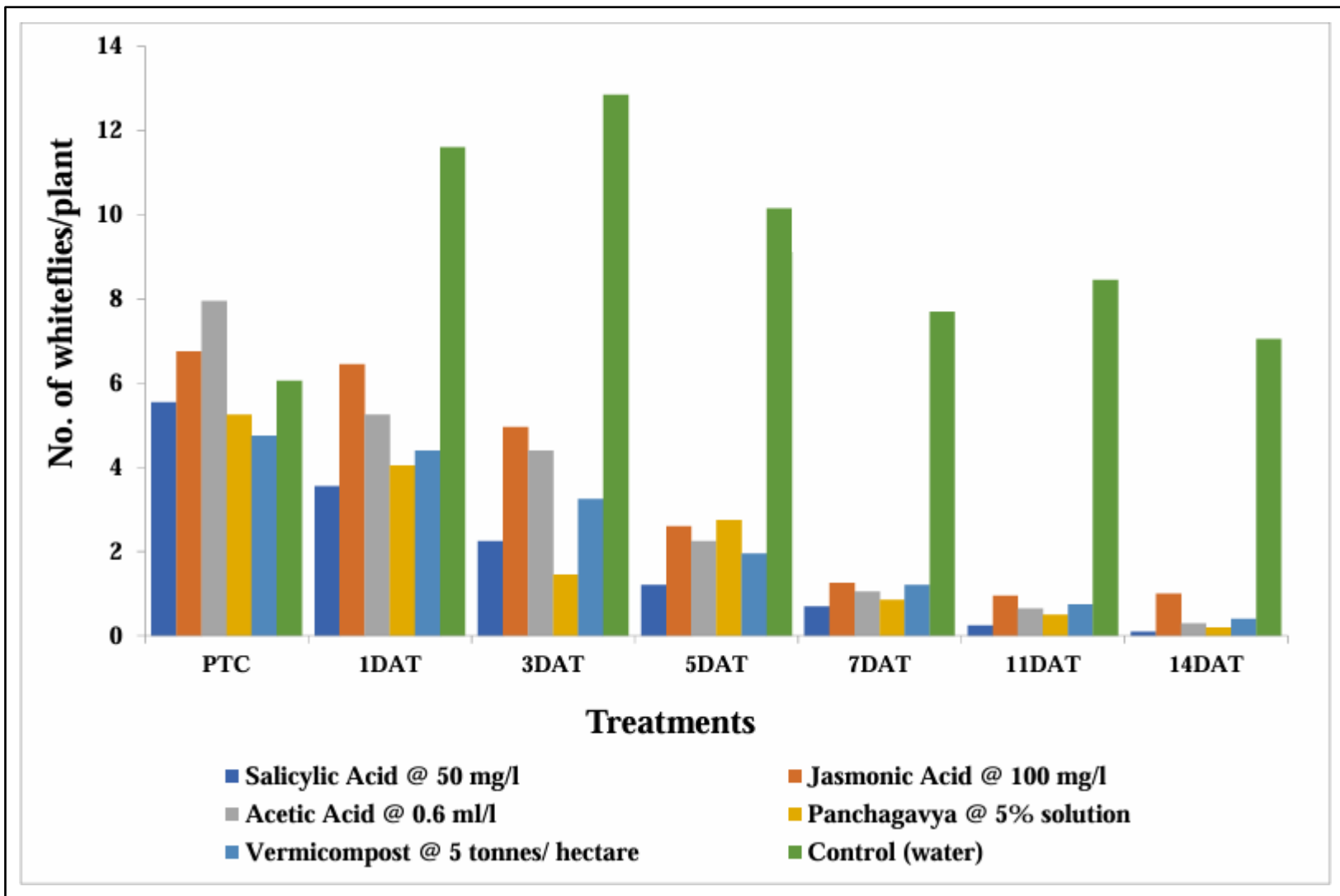


Fig. 33 Efficacy of exogenously applied elicitors against whitefly (*Bemisia tabaci*) in Kharif season 2023

4.3.3. Efficacy of exogenous elicitors inducing host plant resistance in managing hadda beetle (grub & adult) in brinjal during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The hadda beetle (grub and adult) population fluctuated between figures of 1.85 and 2.50 per plant and 1.90 to 3.25 per plant observed in the *Rabi* seasons of 2021 and 2022 prior to spraying, as indicated in (Table 39, Fig. 34). All the treatments had a significant effect on the hadda beetle population ($P < 0.001$) from 1 DAT till 14th DAT at 1 DAT during 2021 and 2022 *Rabi* season (Table 39, Fig. 34). Hadda beetle (grub and adult) population in *Rabi* 2021 and 2022 reached a minimum of 0.61 and 0.82 per plant, respectively (Table 39, Fig. 34). The most significant reduction percentages compared to the control were observed in the following order: (T₂) - Jasmonic acid @ 395 mg/l offering (81.51 and 84.04 %) followed by (T₄) - Panchagavya 5 % solution showing reductions of (79.69 and 82.10 %), (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (73.03 and 77.62 %) continued with (T₃) - Acetic acid @ 0.6 ml/l with reductions of (71.21 and 73.34 %) and last was (T₁) - Salicylic acid @ 50 mg/l providing (62.12 and 72.17 %). In the interaction between year and treatments, the use of exogenously applied elicitors had a significant effect on the population of hadda beetle at 1 DAT (df_(6,4); $P = 0.000$), 3 DAT (df_(6,4); $P = 0.000$), 5 DAT (df_(6,4); $P = 0.000$), 7 DAT (df_(6,4); $P = 0.000$), 11 DAT (df_(6,4); $P = 0.000$) and 14 DAT (df_(6,4); $P = 0.000$) during *Rabi* season 2021 and 2022 (Table 39, Fig. 34).

In *Kharif* season of 2022 and 2023, the population of hadda beetle (grub and adult) was ranged from 0.75 to 3.75 per plant and 1.30 to 2.20 per plant recorded before spraying respectively (Table 40, Fig. 35). All the treatments had a significant impact on the hadda beetle population ($P < 0.001$) from 3 DAT till 14th DAT except 1 DAT (df_(6,4); $P = 0.029$; df_(6,4); $P = 0.000$), during 2022 and 2023 *Kharif* season (Table 40, Fig. 35). The minimum hadda beetle population (0.18 and 0.45 per plant) was recorded in *Kharif* 2022 and 2023 respectively (Table 40, Fig. 35). The most significant reduction percentages compared to the control were observed in the following order: (T₄) - Panchagavya 5 % solution showing reductions of (89.78 and 82.43 %) followed by (T₂) - Jasmonic acid @ 395 mg/l resulting

in reductions of (82.38 and 83.87 %), (T₅) - Vermicompost @ 5 tonnes / hectare offering (80.68 and 78.13 %) followed by (T₃) - Acetic acid @ 0.6 ml/l with reductions of (73.29 and 74.19 %) and least effective treatment was (T₁) - Salicylic acid @ 50 mg/l providing (72.15 and 67.74 %) (Table 40, Fig. 35). In interaction of years and treatments, the use of exogenously applied elicitors performed significantly impact on hadda beetle population. All the treatments were performed significant impact on whitefly ($P < 0.001$) from 1 DAT till 14th DAT during *Kharif* season 2022 and 2023 (Table 40, Fig. 35).

During the second spray of the 2023 *Kharif* season, all the treatments led to a significant reduction in hadda beetle (grub and adult) population. The initial population exhibited a varied range from 1.15 to 1.45 on precount day (Table 41, Fig. 36). Each of the treatments exhibited a high level of significance in their effectiveness against hadda beetle (grub and adult) population. All the treatments were performed significant impact on whitefly ($P < 0.001$) from 1 DAT till 14th during in *Kharif* season 2023 (Table 41, Fig. 36). In the *Kharif* season of 2023, the lowest recorded hadda beetle (grub and adult) population was 0.40 per plant (Table 41, Fig. 36). The highest percentage of reduction over the control was observed in (T₂) - Jasmonic acid @ 395 mg/l offering (85.96 %), followed by (T₄) - Panchagavya 5 % solution showing reductions of (82.45 %), (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (79.64 %) continued with (T₃) - Acetic acid @ 0.6 ml/l with reductions of (79.29 %) and least effective was (T₁) - Salicylic acid @ 50 mg/l providing (78.24 %) (Table 41, Fig. 36).

Research on utilizing elicitors for managing hadda beetle through host plant resistance has been limited. However, there have been numerous investigations into the efficacy of elicitors, particularly for controlling chewing pests in various crops. For instance, Bruinsma *et al.*, (2007) found that female cabbage butterfly species on plants of brassica family crops treated with jasmonic acid decreased their oviposition. Furthermore, it was shown that the *M. brassicae* is incapable of laying eggs when exposed to methyl salicylate, indicating that herbivores are able to recognize and react to methyl salicylate (Ulland *et al.*, 2008).

The exogenous application of jasmonic acid has been shown to trigger systemic defense mechanisms in oilseed rape against *Plutella xylostella*, as demonstrated by Nouri-Ganbalani *et al.*, (2018). Similarly, the treatment of paddy seeds with a derivative of jasmonic acid, namely Methyl Jasmonate (MeJA), has been found to reduce damage caused by the rice water weevil (RWW), *Lissorhoptrus oryzophilus*, as evidenced by Kraus and Stout, (2019). Moreover, Puentes *et al.*, (2021) reported that MeJA has been effective in inducing resistance to pine weevils, specifically *Hylobius abietis*, in Norway spruce.

A different investigation on cotton revealed that JA treatment greatly reduced American bollworm development (Yang *et al.*, 2013). In another study, it was discovered that rice plants treated with ethephon perished more quickly than those treated with water, were less resistant to *N. lugens*, and that ethephon treatments caused the brown plant hopper body weight to rise (Ma *et al.*, 2020). Senthilkumar *et al.*, (2015), using panchagavya given hundred per cent prevention rate of hadda beetles and ground hoppers.

Currently, use of jasmonic acid to increase productivity in agriculture remain limited. The synthesis of JA within plants is influenced by environmental factors present during growth. Additionally, exogenous application of JA is commonly employed to bolster plant resistance as anti-stress protective agents. Consequently, there is a pressing need for additional research on JA in economically significant plants. Such studies represent fundamental research essential for developing practical strategies to combat various plant stressors. Overall, JA exhibit considerable potential in agriculture and forestry for enhancing defensive resistance and stress tolerance, thus positioning them as valuable anti-stress protective agents with broad applicability.

Table 39. Efficacy of exogenous elicitors inducing host plant resistance in managing hadda beetle (grub and adult) in brinjal of Rabi season 2021 and 2022

Treatments	No. of <i>Henosepilachna vigintioctopunctata</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> -22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Salicylic Acid @ 50 mg/l	2.30 ± 0.25 ^{ab}	1.90 ± 0.73 ^b	2.05 ± 0.19 ^b	2.35 ± 0.34 ^b	1.80 ± 0.16 ^b	1.95 ± 0.55 ^b	1.25 ± 0.25 ^b	1.50 ± 0.12 ^b	0.95 ± 0.34 ^b	1.20 ± 0.16 ^b	0.85 ± 0.19 ^b	0.75 ± 0.10 ^b	0.60 ± 0.16 ^b	0.85 ± 0.19 ^b	1.25	1.43	62.12	72.17
Jasmonic Acid @ 100 mg/l	2.15 ± 0.41 ^{ab}	3.20 ± 0.90 ^{ab}	1.10 ± 0.34 ^d	1.80 ± 0.32 ^c	0.95 ± 0.19 ^c	1.10 ± 0.25 ^d	0.75 ± 0.19 ^d	0.90 ± 0.48 ^d	0.45 ± 0.19 ^c	0.50 ± 0.25 ^c	0.30 ± 0.25 ^c	0.40 ± 0.16 ^c	0.15 ± 0.19 ^c	0.25 ± 0.19 ^c	0.61	0.82	81.51	84.04
Acetic Acid @ 0.6 ml/l	2.10 ± 0.11 ^{ab}	2.95 ± 0.90 ^{ab}	1.75 ± 0.41 ^{bc}	2.25 ± 0.25 ^{bc}	1.20 ± 0.28 ^c	1.80 ± 0.28 ^b	1.10 ± 0.25 ^{bc}	1.40 ± 0.30 ^{bc}	0.70 ± 0.11 ^{bc}	1.25 ± 0.30 ^b	0.40 ± 0.28 ^c	0.60 ± 0.16 ^{bc}	0.60 ± 0.16 ^b	0.95 ± 0.19 ^b	0.95	1.37	71.21	73.34
Panchagavy a @ 5% solution	2.50 ± 0.34 ^a	2.75 ± 0.44 ^{ab}	1.35 ± 0.19 ^{cd}	1.85 ± 0.30 ^{bc}	1.05 ± 0.19 ^c	1.30 ± 0.11 ^{cd}	0.80 ± 0.16 ^{cd}	0.85 ± 0.10 ^d	0.50 ± 0.11 ^c	0.65 ± 0.10 ^c	0.25 ± 0.19 ^c	0.55 ± 0.19 ^{bc}	0.10 ± 0.20 ^c	0.35 ± 0.19 ^c	0.67	0.92	79.69	82.10
Vermicomp ost @ 5 tonnes/ hectare	1.95 ± 0.91 ^b	1.95 ± 0.71 ^{ab}	1.50 ± 0.25 ^{cd}	2.20 ± 0.49 ^{bc}	1.35 ± 0.34 ^c	1.60 ± 0.32 ^{bc}	1.00 ± 0.16 ^{bcd}	1.05 ± 0.19 ^{cd}	0.65 ± 0.10 ^{bc}	0.80 ± 0.16 ^c	0.35 ± 0.10 ^c	0.75 ± 0.10 ^b	0.50 ± 0.11 ^b	0.50 ± 0.25 ^c	0.89	1.15	73.03	77.62
Control (water)	1.85 ± 0.34 ^b	3.25 ± 1.01 ^a	4.50 ± 0.47 ^a	6.40 ± 0.16 ^a	3.75 ± 0.30 ^a	7.15 ± 0.19 ^a	4.05 ± 0.19 ^a	5.70 ± 0.28 ^a	3.40 ± 0.43 ^a	4.80 ± 0.16 ^a	2.25 ± 0.30 ^a	3.95 ± 0.38 ^a	1.90 ± 0.34 ^a	2.85 ± 0.34 ^a	3.30	5.14		
P value	0.066 ^{NS}	0.097 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}				
F value	2.541	2.220	56.921	117.342	69.124	210.646	150.117	177.394	82.285	257.805	44.900	177.789	39.046	67.958				
Year*Treatment's																		
P value	0.150 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}					
F value	1.735		98.015		44.178		135.043		131.346		59.919		70.034					
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Henosepilachna vigintioctopunctata</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Henosepilachna vigintioctopunctata</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																		

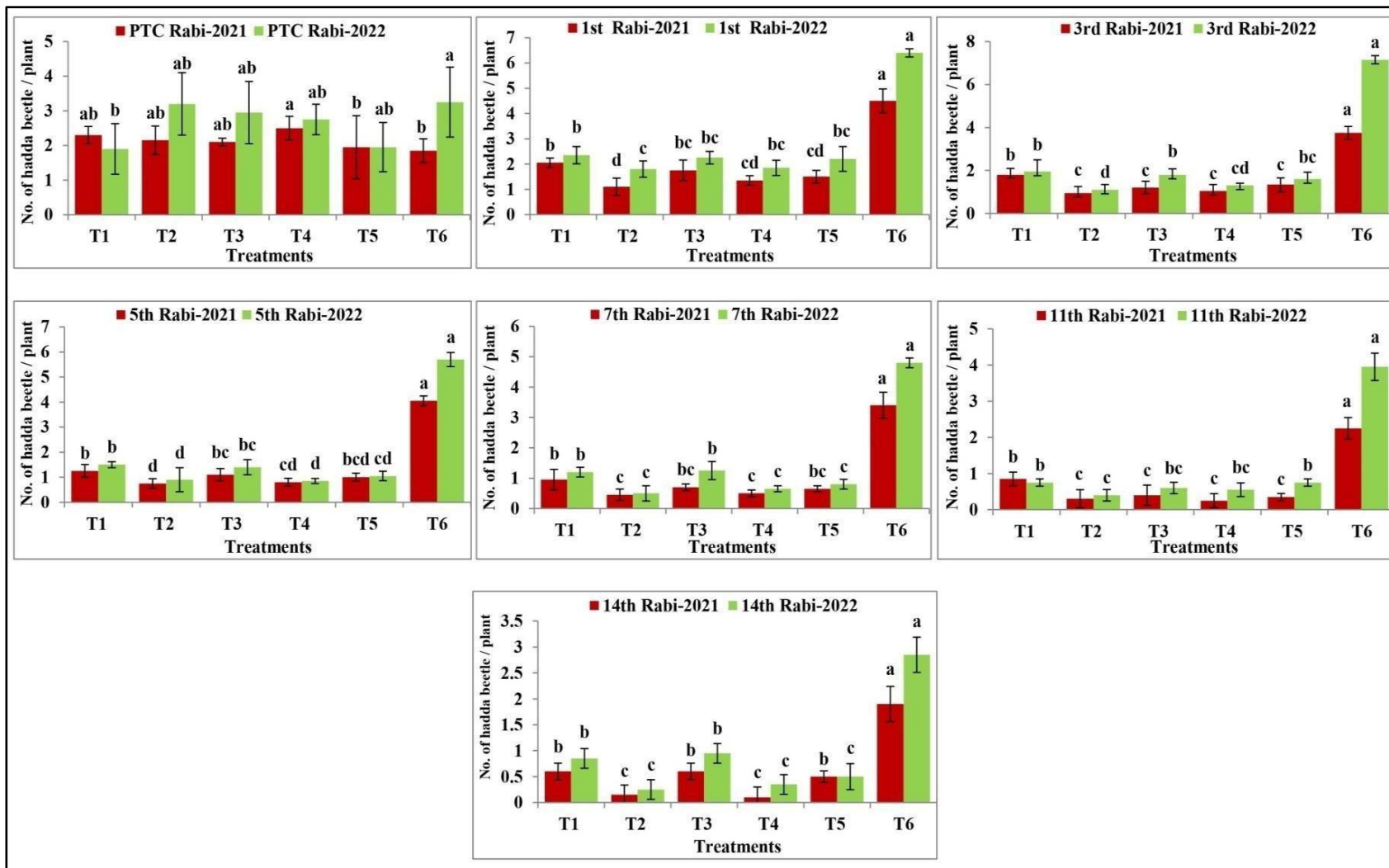


Fig. 34 Efficacy of exogenously applied elicitors against hadda beetle (*Henosepilachna vigintioctopunctata*) in Rabi season 2021 and 2022

Table 40. Efficacy of exogenous elicitors inducing host plant resistance in managing hadda beetle (grub and adult) in brinjal of Kharif season 2022 and 2023

Treatments	No. of <i>Henosepilachna vigintioctopunctata</i> / per plant*																	
	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Kharif</i> 2022	<i>Kharif</i> 2023	<i>Kharif</i> 2022	<i>Kharif</i> 2023
Salicylic Acid @ 50 mg/l	1.50 ± 1.24 ^b	2.15 ± 0.19 ^a	1.00 ± 0.28 ^b	1.50 ± 0.35 ^b	0.75 ± 0.19 ^{bc}	1.25 ± 0.19 ^b	0.50 ± 0.38 ^{bc}	1.10 ± 0.11 ^b	0.35 ± 0.19 ^b	0.70 ± 0.34 ^b	0.25 ± 0.19 ^b	0.40 ± 0.16 ^{bc}	0.10 ± 0.11 ^b	0.50 ± 0.11 ^b	0.49	0.90	72.15	67.74
Jasmonic Acid @ 100 mg/l	2.05 ± 1.26 ^{ab}	1.55 ± 0.34 ^{ab}	0.50 ± 0.38 ^b	0.95 ± 0.19 ^c	0.25 ± 0.10 ^c	0.60 ± 0.16 ^c	0.75 ± 0.34 ^b	0.50 ± 0.10 ^c	0.25 ± 0.10 ^{bc}	0.30 ± 0.11 ^c	0.15 ± 0.10 ^{bc}	0.25 ± 0.10 ^c	0.00 ± 0.00 ^b	0.15 ± 0.19 ^c	0.31	0.45	82.38	83.87
Acetic Acid @ 0.6 ml/l	1.55 ± 1.43 ^b	1.75 ± 0.19 ^{ab}	1.25 ± 0.34 ^{ab}	1.20 ± 0.16 ^{bc}	0.70 ± 0.11 ^{bc}	1.05 ± 0.19 ^{bc}	0.40 ± 0.16 ^{bc}	0.60 ± 0.23 ^c	0.35 ± 0.10 ^b	0.70 ± 0.11 ^b	0.05 ± 0.10 ^{bc}	0.45 ± 0.10 ^b	0.10 ± 0.11 ^b	0.35 ± 0.19 ^{bc}	0.47	0.72	73.29	74.19
Panchagavya @ 5% solution	0.75 ± 1.03 ^b	1.30 ± 0.74 ^b	0.50 ± 0.38 ^b	1.00 ± 0.19 ^c	0.25 ± 0.10 ^c	0.75 ± 0.19 ^{dc}	0.15 ± 0.10 ^c	0.45 ± 0.10 ^c	0.15 ± 0.10 ^{bc}	0.40 ± 0.16 ^{bc}	0.00 ± 0.00 ^c	0.25 ± 0.10 ^c	0.05 ± 0.10 ^b	0.10 ± 0.11 ^c	0.18	0.49	89.78	82.43
Vermicompos t @ 5 tonnes/ hectare	1.35 ± 1.11 ^b	2.20 ± 0.28 ^a	0.75 ± 0.34 ^b	1.05 ± 0.19 ^c	1.00 ± 0.16 ^b	0.95 ± 0.19 ^{cd}	0.15 ± 0.10 ^c	0.60 ± 0.16 ^c	0.10 ± 0.11 ^b	0.45 ± 0.19 ^{bc}	0.05 ± 0.10 ^{bc}	0.35 ± 0.10 ^{bc}	0.00 ± 0.00 ^b	0.30 ± 0.11 ^{bc}	0.34	0.61	80.68	78.13
Control (water)	3.75 ± 2.03 ^a	1.55 ± 0.87 ^{ab}	2.20 ± 1.55 ^a	4.10 ± 0.34 ^a	3.15 ± 0.86 ^a	3.60 ± 0.16 ^a	1.50 ± 0.25 ^a	3.15 ± 0.34 ^a	1.65 ± 0.19 ^a	2.30 ± 0.25 ^a	1.00 ± 0.16 ^a	1.90 ± 0.12 ^a	1.05 ± 0.10 ^a	1.70 ± 0.25 ^a	1.76	2.79		
P value	0.101 ^{NS}	0.133 ^{NS}	0.029*	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**				
F value	2.184	1.968	3.257	96.338	33.178	149.840	16.359	113.191	70.303	48.614	36.771	123.600	86.743	47.556				
Year*Treatment's																		
P value	0.158 ^{NS}		0.000**		0.000**		0.000**		0.000**		0.000**		0.000**					
F value	1.700		18.207		105.328		31.903		116.416		57.760		69.976					
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Henosepilachna vigintioctopunctata</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Henosepilachna vigintioctopunctata</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																		

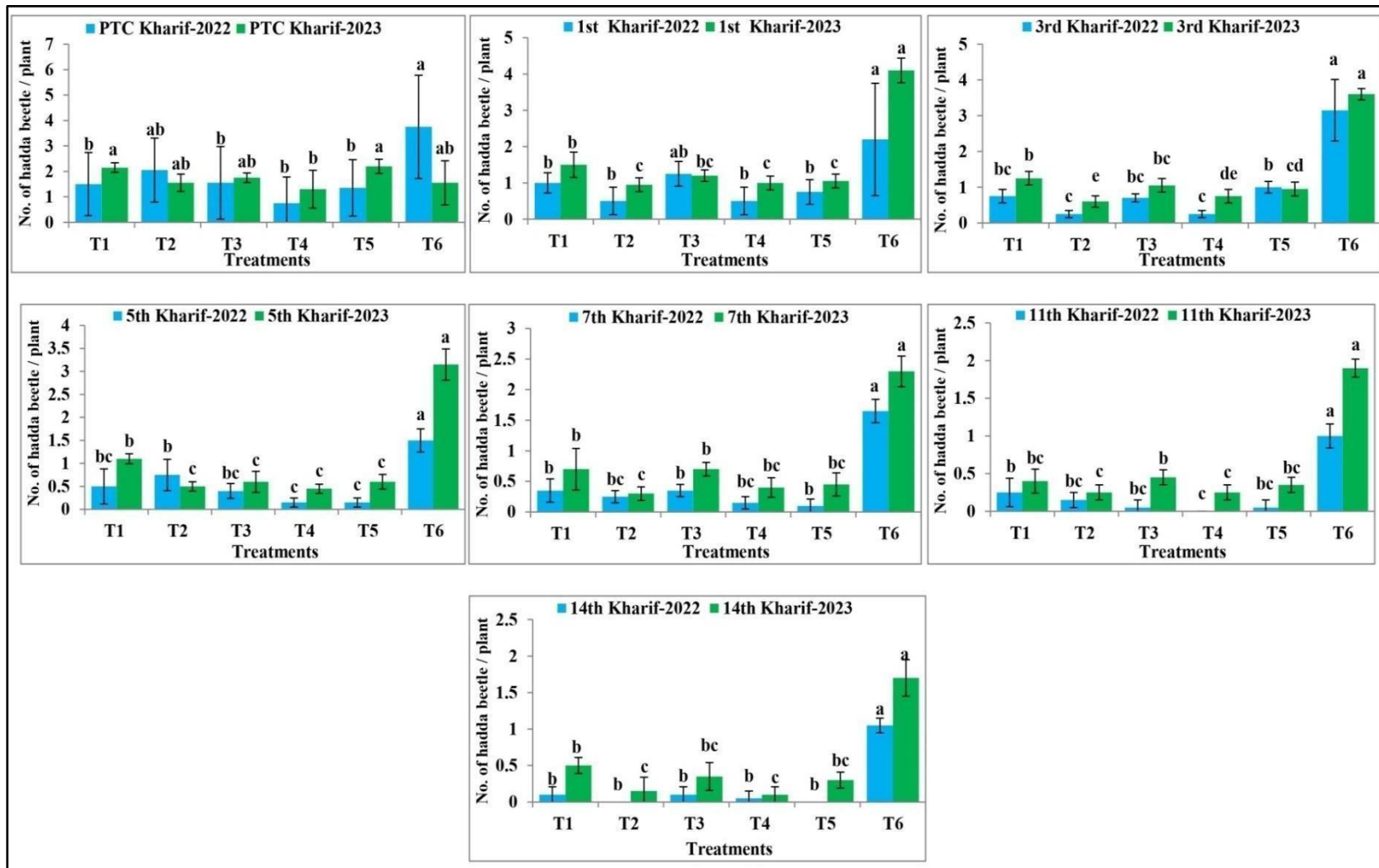


Fig. 35 Efficacy of exogenously applied elicitors against hadda beetle (*Henosepilachna vigintioctopunctata*) in Kharif season 2022 and 2023

Table 41. Efficacy of exogenous elicitors inducing host plant resistance in managing hadda beetle (grub and adult) in brinjal of Kharif season 2023

Treatments	No. of <i>Henosepilachna vigintioctopunctata</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Salicylic Acid @ 50 mg/l	1.35 ± 0.19 ^{ab}	1.20 ± 0.16 ^b	1.00 ± 0.00 ^b	0.85 ± 0.19 ^b	0.40 ± 0.16 ^{ab}	0.20 ± 0.00 ^{bc}	0.10 ± 0.12 ^b	0.62	78.24
Jasmonic Acid @ 100 mg/l	1.40 ± 0.16 ^{ab}	0.95 ± 0.19 ^c	0.65 ± 0.10 ^d	0.45 ± 0.19 ^c	0.25 ± 0.10 ^c	0.10 ± 0.12 ^c	0.00 ± 0.00 ^b	0.40	85.96
Acetic Acid @ 0.6 ml/l	1.15 ± 0.10 ^b	1.05 ± 0.10 ^{bc}	0.95 ± 0.10 ^b	0.75 ± 0.26 ^{bc}	0.55 ± 0.19 ^b	0.20 ± 0.00 ^{bc}	0.05 ± 0.10 ^b	0.59	79.29
Panchagavya @ 5% solution	1.25 ± 0.25 ^{ab}	1.10 ± 0.12 ^{bc}	0.75 ± 0.10 ^{cd}	0.65 ± 0.19 ^{bc}	0.35 ± 0.10 ^{ab}	0.15 ± 0.10 ^{bc}	0.00 ± 0.00 ^b	0.50	82.45
Vermicompost @ 5 tonnes/ hectare	1.25 ± 0.10 ^{ab}	1.15 ± 0.10 ^{bc}	0.85 ± 0.10 ^{bc}	0.70 ± 0.26 ^{bc}	0.35 ± 0.10 ^{ab}	0.30 ± 0.12 ^b	0.15 ± 0.10 ^b	0.58	79.64
Control (water)	1.45 ± 0.19 ^a	2.75 ± 0.19 ^a	4.80 ± 0.16 ^a	3.95 ± 0.19 ^a	2.85 ± 0.19 ^a	1.20 ± 0.16 ^a	1.60 ± 0.23 ^a	2.85	
P value	0.204 ^{NS}	0.000*	0.000**	0.000**	0.000**	0.000**	0.000**		
F value	1.625	84.000	946.800	155.114	189.492	66.095	110.400		
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Henosepilachna vigintioctopunctata</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Henosepilachna vigintioctopunctata</i> of per plant), PTC – Pre treatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

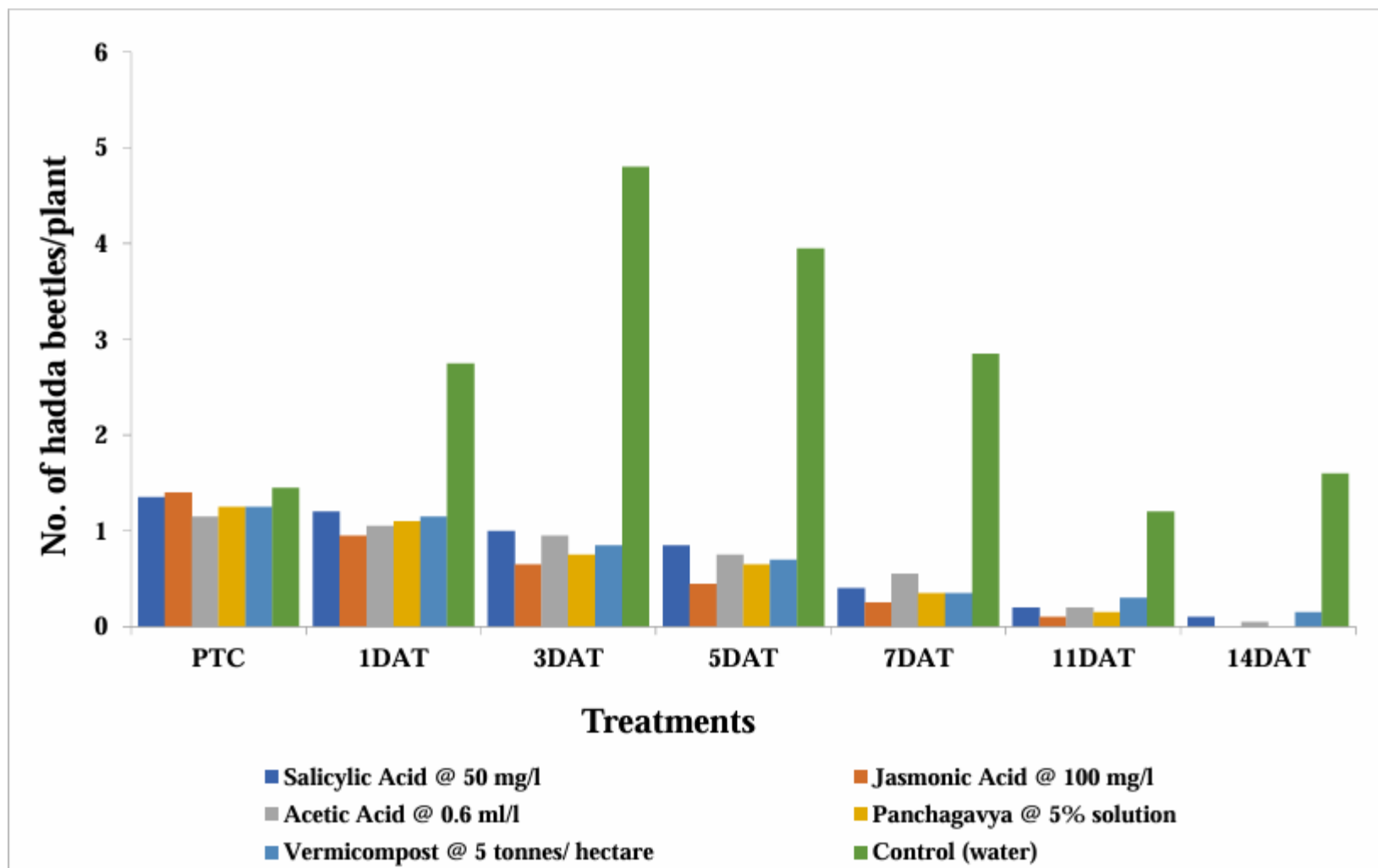


Fig. 36 Efficacy of exogenously applied elicitors against hadda beetle (*Henosepilachna vigintioctopunctata*) in Kharif season 2023

4.3.4. Efficacy of exogenous elicitors inducing host plant resistance in managing shoot and fruit borer (larva) in brinjal during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The shoot borer damage (larva) population fluctuated between figures of 2.35 and 3.50 per plant and 3.10 to 5.50 per plant observed in the *Rabi* seasons of 2021 and 2022 prior to spraying, as indicated in (Table 42, Fig. 37). All the treatments had a significant effect on the shoot borer damage population ($P < 0.001$) from 1 DAT till 14th DAT during 2021 and 2022 *Rabi* season (Table 42, Fig. 37). The shoot borer damage population in *Rabi* 2021 and 2022 reached a minimum of 1.00 and 1.05 per plant, respectively (Table 42, Fig. 37). The most significant reduction percentages compared to the control were observed in the following order: (T₄) - Panchagavya 5 % solution showing reductions of (83.05 and 80.18 %) followed by (T₂) - Jasmonic acid @ 395 mg/l offering (81.35 and 77.35 %), (T₅) - Vermicompost @ 5 tonnes / hectare resulting in reductions of (73.38 and 72.07 %) continued with (T₃) - Acetic acid @ 0.6 ml/l with reductions of (65.59 and 66.79 %) and last was (T₁) - Salicylic acid @ 50 mg/l providing (63.22 and 67.16 %) (Table 42, Fig. 37). In the interaction between year and treatments, the use of exogenously applied elicitors had a significant effect on the population of shoot borer damage and all the treatments performed significant impact on shoot borer damage ($P = 0.000$) from 1 DAT till 14th DAT during *Rabi* season 2021 and 2022 (Table 42, Fig. 37).

In *Kharif* season of 2022 and 2023, the shoot borer damage population was ranged from 0.75 to 2.75 per plant and 2.30 to 3.25 per plant recorded before spraying respectively (Table 43, Fig. 38). All the treatments had a significant impact on the hadda beetle population ($P < 0.001$) from 1 DAT till 14th DAT during 2022 and 2023 *Kharif* season (Table 43, Fig. 38). The minimum shoot borer damage population (0.18 and 0.85 per plant) was recorded in *Kharif* 2022 and 2023 respectively (Table 43, Fig. 38). The most significant reduction percentages compared to the control were observed in the following order: (T₄) - Panchagavya 5 % solution showing reductions of (87.05 and 82.40 %) followed by (T₂) - Jasmonic acid @ 395 mg/l resulting in reductions of (73.38 and 79.71), (T₅) - Vermicompost @ 5 tonnes/hectare offering (71.22 and 78.67 %) followed by

(T₃) - Acetic acid @ 0.6 ml/l with reductions of (68.34 and 75.56 %) and least effective treatment was (T₁) - Salicylic acid @ 50 mg/l providing (60.43 and 74.94 %), (Table 43, Fig. 38). In interaction of years and treatments, the use of exogenously applied elicitors performed significantly impact on shoot borer damage population at 1 DAT (df_(6,4); P = 0.000), 3 DAT (df_(6,4); P = 0.000), 5 DAT (df_(6,4); P = 0.000), 7 DAT (df_(6,4); P = 0.000), 11 DAT (df_(6,4); P = 0.000) and 14 DAT (df_(6,4); P = 0.003) during *Kharif* season 2022 and 2023 (Table 43, Fig. 38).

During the second spray of the 2023 *Kharif* season, all the treatments led to a significant reduction in shoot borer damage population. The initial population exhibited a varied range from 1.05 to 2.10 on precount day (Table 44, Fig. 39). Each of the treatments exhibited a high level of significance in their effectiveness against the shoot borer damage population (P < 0.001) from 1 DAT till 14th DAT during in *Kharif* season 2023 (Table 44, Fig. 39). In the *Kharif* season of 2023, the lowest recorded shoot borer damage population was 0.39 per plant (Table 44, Fig. 39). The highest percentage of reduction over the control was observed in (T₄) - Panchagavya 5 % solution showing reductions of (83.95 %) followed by (T₂) - Jasmonic acid @ 395 mg/l offering (83.53 %), (T₅) - Vermicompost @ 5 tonnes/hectare resulting in reductions of (79.01 %) continued with (T₃) - Acetic acid @ 0.6 ml/l with reductions of (75.30 %) and least effective was (T₁) - Salicylic acid @ 50 mg/l providing (71.60 %) (Table 44, Fig. 39).

In the study of HPR, research on utilizing elicitors spray for managing shoot and fruit borers has been limited. However, various studies have explored the effectiveness of different approaches in controlling chewing-type pests in diverse crops. For instance, Sowmiya *et al.*, (2020) conducted leaf disc experiments employing a no-choice method to evaluate the antifeedant activity and mortality rate of a botanical mixture combined with panchagavya against *Leucinodes orbonalis* in brinjal. Their findings indicated that the highest antifeedant activity was observed in the combination of cow urine fermented cashew leaves (CLE) with panchagavya, while neem oil exhibited the highest mortality rate. Following these, the combination of other botanical mixtures such as olive oil (OLE) with panchagavya and sesame oil (SLE) with panchagavya showed progressively lower

antifeedant activity and mortality rates at 72 hours after treatment (HAT), respectively. Additionally, Sood *et al.*, (2023) found that cow urine, a component of panchagavya, was helpful in reduction of shoot infestation caused through *L. orbonalis* in brinjal. Furthermore, Ghosh and Negi, (2020) demonstrated that panchagavya combined with fermented cashew leaves or aged karanj leaves, both containing cow urine, resulted in reduced shoot damage by *L. orbonalis* in eggplant. These treatments were found to be more effective compared to insecticidal treatments and untreated controls.

Panchagavya also reported to contain pesticidal and pest repellent activity (Natarajan, 2002; Selvaraj, 2004; Belina *et al.*, 2005). According to research by Shrinivas *et al.*, (2009), panchagavya, cow urine, and neem seed kernel extract worked well together to suppress sorghum shoot fly. In, Tamil Nadu, panchagavya was shown to be more successful at controlling the three main pests of teak: papaya mealybug, teak defoliator moth, and teakskeletonizer, at different concentrations (Senthilkumar *et al.*, 2015). In Meghalaya, Derisom in addition with Panchgavya and cow urine mixture reduced the population of grey weevil and leaf folders in soybeans (Das *et al.*, 2018). Under laboratory circumstances, the combination of neem oil and Panchagavya showed the highest death rate of *S. litura* (Sathya *et al.*, 2019).

Table. 42 Efficacy of exogenous elicitors inducing host plant resistance in managing shoot borer damage (larva) in brinjal of Rabi season 2021 and 2022

Treatments	No. of <i>Leucinodes orbonalis</i> / per plant*																	
	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	<i>Rabi</i> 2021	<i>Rabi</i> 2022	Mean		% Reduction over control	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		<i>Rabi</i> -21	<i>Rabi</i> -22	<i>Rabi</i> - 21	<i>Rabi</i> - 22
Salicylic Acid @ 50 mg/l	3.25 ± 0.19 ^{ab}	5.35 ± 1.52 ^{ab}	3.10 ± 0.26 ^b	3.25 ± 0.37 ^{bc}	2.85 ± 0.25 ^b	2.50 ± 0.25 ^b	2.60 ± 0.43 ^b	1.90 ± 0.19 ^c	2.20 ± 0.28 ^b	1.40 ± 0.28 ^b	1.40 ± 0.36 ^b	0.80 ± 0.16 ^b	0.90 ± 0.11 ^b	0.60 ± 0.28 ^b	2.17	1.74	63.22	67.16
Jasmonic Acid @ 100 mg/l	2.35 ± 0.61 ^b	4.80 ± 1.00 ^{ab}	1.80 ± 0.16 ^c	2.85 ± 0.41 ^{bc}	1.65 ± 0.19 ^c	1.85 ± 0.52 ^c	1.35 ± 0.19 ^c	1.15 ± 0.19 ^c	0.90 ± 0.38 ^c	0.80 ± 0.16 ^c	0.60 ± 0.16 ^{cd}	0.40 ± 0.16 ^c	0.35 ± 0.30 ^{cd}	0.20 ± 0.16 ^c	1.10	1.20	81.35	77.35
Acetic Acid @ 0.6 ml/l	3.30 ± 0.11 ^{ab}	3.50 ± 1.07 ^{ab}	3.15 ± 0.60 ^b	3.30 ± 0.26 ^b	2.75 ± 0.80 ^b	2.75 ± 0.25 ^b	2.50 ± 0.25 ^b	1.85 ± 0.30 ^b	1.85 ± 0.93 ^{bc}	1.35 ± 0.19 ^b	1.25 ± 0.25 ^b	0.85 ± 0.37 ^b	0.70 ± 0.25 ^{bc}	0.50 ± 0.11 ^{bc}	2.03	1.76	65.59	66.79
Panchagavya @ 5% solution	3.00 ± 0.36 ^{ab}	4.60 ± 0.71 ^{ab}	1.65 ± 0.19 ^c	2.45 ± 0.44 ^c	1.50 ± 0.47 ^c	1.65 ± 0.19 ^c	1.45 ± 0.10 ^c	1.10 ± 0.25 ^c	0.80 ± 0.43 ^c	0.65 ± 0.19 ^c	0.45 ± 0.10 ^d	0.30 ± 0.11 ^c	0.20 ± 0.16 ^d	0.15 ± 0.10 ^c	1.00	1.05	83.05	80.18
Vermicompost @ 5 tonnes/ hectare	2.85 ± 0.30 ^{ab}	3.10 ± 1.35 ^b	2.50 ± 0.96 ^{bc}	3.00 ± 0.37 ^{bc}	2.40 ± 0.16 ^{bc}	2.55 ± 0.41 ^b	1.50 ± 0.73 ^c	1.40 ± 0.16 ^{bc}	1.30 ± 0.62 ^{bc}	0.90 ± 0.12 ^{bc}	1.00 ± 0.58 ^{bc}	0.75 ± 0.10 ^b	0.75 ± 0.25 ^{bc}	0.30 ± 0.11 ^{bc}	1.57	1.48	73.38	72.07
Control (water)	3.50 ± 1.32 ^a	5.50 ± 2.30 ^a	7.50 ± 1.08 ^a	7.45 ± 0.92 ^a	6.95 ± 1.14 ^a	6.75 ± 0.44 ^a	6.70 ± 0.25 ^a	5.70 ± 0.62 ^a	5.75 ± 0.83 ^a	5.40 ± 0.68 ^a	4.65 ± 0.25 ^a	3.75 ± 0.19 ^a	3.90 ± 0.41 ^a	2.75 ± 0.44 ^a	5.90	5.30		
P value	0.192 ^{NS}	0.132 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 [*]				
F value	1.672	1.969	43.151	52.469	41.624	105.020	109.699	120.376	34.618	122.029	90.556	157.410	105.545	69.882				
Year*Treatment's																		
P value	0.106 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}					
F value	1.964		106.069		117.459		194.122		119.127		184.462		118.671					
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Leucinodes orbonalis</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Leucinodes orbonalis</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																		

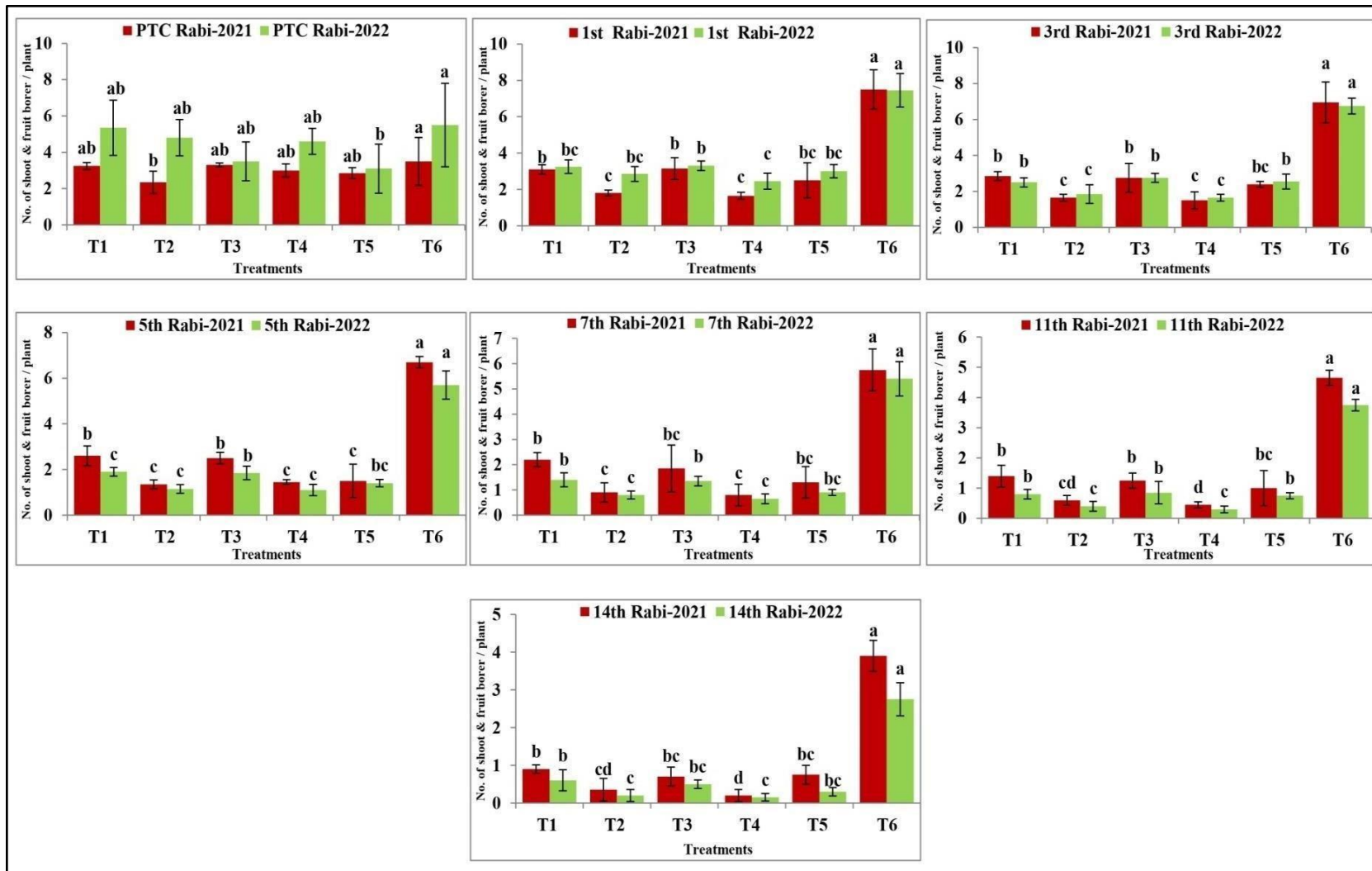


Fig. 37 Efficacy of exogenously applied elicitors against shoot borer (*Leucinodes orbonalis*) in Rabi season 2021 and 2022

Table 43. Efficacy of exogenous elicitors inducing host plant resistance in managing shoot and fruit borer (larva) in brinjal of Kharif season 2022 and 2023

Treatments	No. of <i>Leucinodes orbonalis</i> / per plant*																Mean		% Reduction over control	
	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023						
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Kharif 2022	Kharif 2023				
Salicylic Acid @ 50 mg/l	1.70 ±	3.05 ±	1.50 ±	2.10 ±	0.75 ±	1.75 ±	0.50 ±	1.35 ±	0.25 ±	1.05 ±	0.20 ±	0.70 ±	0.15 ±	0.35 ±	0.55	1.21	60.43	74.94		
	1.63 ^{ab}	0.19 ^{ab}	0.30 ^b	0.41 ^b	0.19 ^b	0.19 ^b	0.20 ^b	0.19 ^c	0.10 ^b	0.19 ^b	0.00 ^a	0.12 ^b	0.10 ^b	0.10 ^{bc}						
Jasmonic Acid @ 100 mg/l	1.75 ±	2.30 ±	1.00 ±	1.75 ±	0.50 ±	1.55 ±	0.15 ±	1.10 ±	0.25 ±	0.80 ±	0.20 ±	0.40 ±	0.15 ±	0.30 ±	0.37	0.98	73.38	79.71		
	1.56 ^{ab}	0.26 ^b	0.28 ^{bc}	0.30 ^{bc}	0.11 ^{bc}	0.19 ^{bc}	0.10 ^c	0.11 ^c	0.10 ^b	0.28 ^{bc}	0.00 ^a	0.16 ^c	0.10 ^b	0.12 ^{bc}						
Acetic Acid @ 0.6 ml/l	1.55 ±	2.90 ±	1.50 ±	2.15 ±	0.50 ±	1.80 ±	0.25 ±	1.25 ±	0.15 ±	0.90 ±	0.10 ±	0.60 ±	0.15 ±	0.40 ±	0.44	1.18	68.34	75.56		
	0.25 ^{ab}	0.74 ^{ab}	0.26 ^b	0.25 ^b	0.11 ^{bc}	0.23 ^b	0.10 ^{bc}	0.19 ^c	0.19 ^b	0.11 ^{bc}	0.11 ^b	0.16 ^{bc}	0.10 ^b	0.16 ^b						
Panchagavya @ 5% solution	0.75 ±	3.20 ±	0.50 ±	1.60 ±	0.25 ±	1.25 ±	0.20 ±	1.05 ±	0.10 ±	0.65 ±	0.05 ±	0.40 ±	0.00 ±	0.20 ±	0.18	0.85	87.05	82.40		
	0.34 ^b	0.19 ^{ab}	0.38 ^c	0.16 ^c	0.19 ^c	0.25 ^c	0.00 ^c	0.19 ^b	0.11 ^b	0.19 ^c	0.10 ^b	0.16 ^c	0.00 ^c	0.00 ^c						
Vermicompost @ 5 tonnes/hectare	1.35 ±	2.55 ±	1.50 ±	1.90 ±	0.25 ±	1.50 ±	0.50 ±	1.20 ±	0.10 ±	0.75 ±	0.05 ±	0.50 ±	0.00 ±	0.35 ±	0.40	1.03	71.22	78.67		
	0.91 ^{ab}	0.61 ^{ab}	0.26 ^b	0.11 ^{bc}	0.10 ^c	0.26 ^{bc}	0.25 ^b	0.16 ^c	0.11 ^b	0.19 ^{bc}	0.10 ^b	0.12 ^{bc}	0.00 ^c	0.10 ^{bc}						
Control (water)	2.75 ±	3.25 ±	2.70 ±	7.00 ±	1.75 ±	6.65 ±	1.50 ±	5.30 ±	1.65 ±	4.65 ±	0.20 ±	3.15 ±	0.50 ±	2.25 ±	1.39	4.83				
	0.75 ^a	0.77 ^a	0.81 ^a	0.43 ^a	0.28 ^a	0.19 ^a	0.25 ^a	0.25 ^a	0.25 ^a	0.19 ^a	0.00 ^a	0.25 ^a	0.11 ^a	0.10 ^a						
P value	0.180 ^{NS}	0.133 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.012 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}						
F value	1.726	1.968	11.625	189.889	42.789	355.064	31.614	295.689	60.491	245.067	4.080	164.671	18.508	214.429						
Year*Treatment's																				
P value	0.076 ^{NS}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.000 ^{**}		0.003 [*]							
F value	2.186		21.597		21.656		22.649		35.359		8.333		4.452							
* P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Leucinodes orbonalis</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Leucinodes orbonalis</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant																				

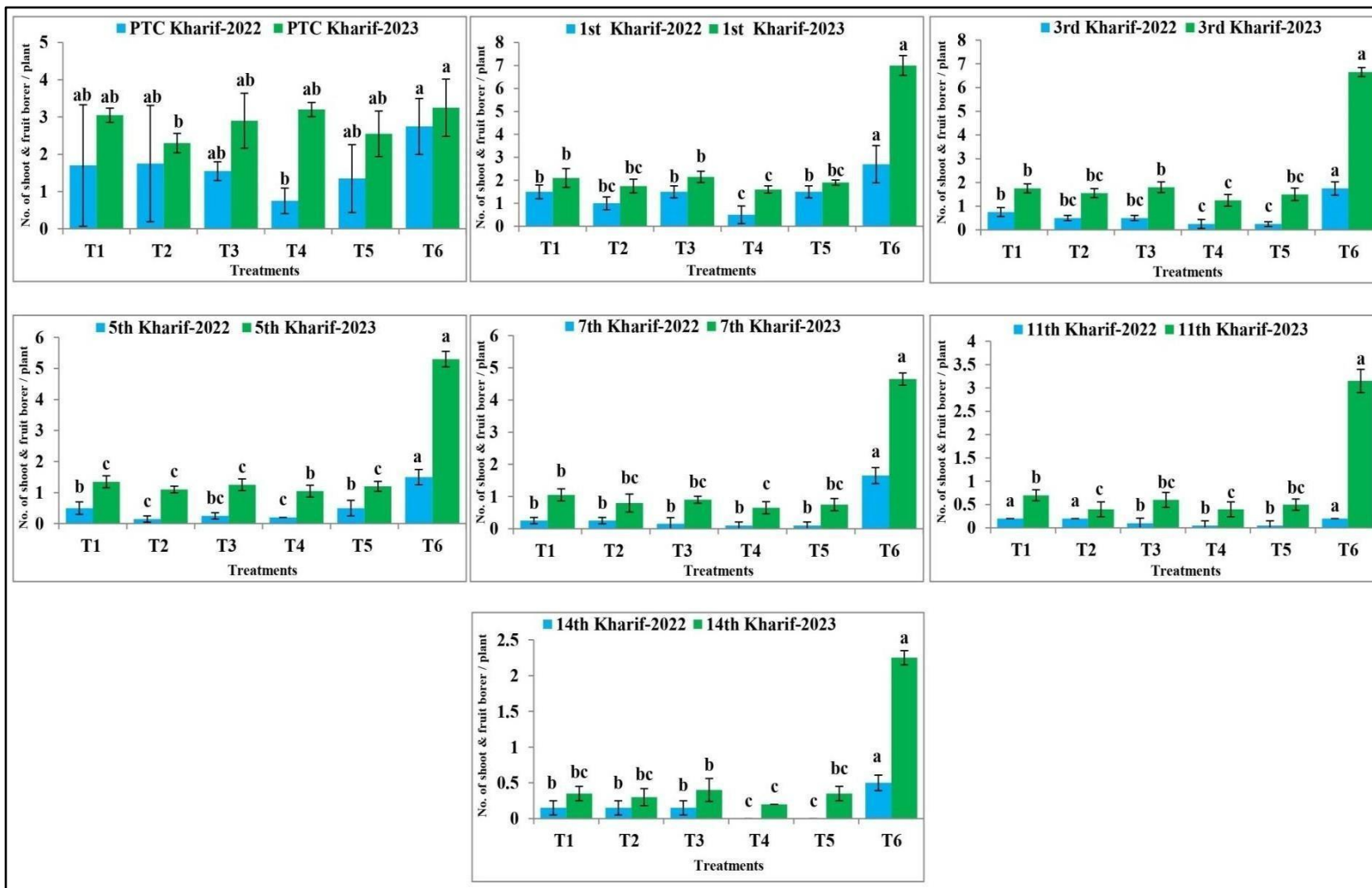


Fig. 38 Efficacy of exogenously applied elicitors against shoot and fruit borer (*Leucinodes orbonalis*) in Kharif season 2022 and 2023

Table. 44 Efficacy of exogenous elicitors inducing host plant resistance in managing shoot borer damage (larva) brinjal of Kharif season 2023

Treatments	No. of <i>Leucinodes orbonalis</i> / per plant*								% Reduction over control
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean	
Salicylic Acid @ 50 mg/l	1.25 ± 0.25 ^{ab}	1.15 ± 0.10 ^b	0.90 ± 0.11 ^{bc}	0.85 ± 0.25 ^b	0.70 ± 0.12 ^b	0.20 ± 0.00 ^b	0.35 ± 0.10 ^b	0.69	71.60
Jasmonic Acid @ 100 mg/l	1.10 ± 0.68 ^b	0.85 ± 0.10 ^{cd}	0.65 ± 0.44 ^c	0.45 ± 0.19 ^c	0.35 ± 0.19 ^{cd}	0.10 ± 0.12 ^{bc}	0.05 ± 0.10 ^c	0.40	83.53
Acetic Acid @ 0.6 ml/l	1.35 ± 0.70 ^{ab}	1.20 ± 0.16 ^b	1.10 ± 0.20 ^b	0.55 ± 0.30 ^{ab}	0.60 ± 0.16 ^{bc}	0.15 ± 0.10 ^{bc}	0.05 ± 0.10 ^c	0.60	75.30
Panchagavya @ 5% solution	1.05 ± 0.60 ^b	0.75 ± 0.19 ^d	0.65 ± 0.19 ^c	0.50 ± 0.11 ^{ab}	0.30 ± 0.12 ^d	0.00 ± 0.00 ^c	0.15 ± 0.19 ^{bc}	0.39	83.95
Vermicompost @ 5 tonnes/ hectare	1.25 ± 0.80 ^{ab}	1.05 ± 0.19 ^{bc}	0.80 ± 0.16 ^{bc}	0.55 ± 0.19 ^{ab}	0.40 ± 0.16 ^{cd}	0.20 ± 0.16 ^b	0.10 ± 0.11 ^c	0.51	79.01
Control (water)	2.10 ± 0.26 ^a	3.15 ± 0.25 ^a	2.80 ± 0.23 ^a	2.85 ± 0.30 ^a	2.50 ± 0.26 ^a	1.85 ± 0.10 ^a	1.45 ± 0.19 ^a	2.43	
P value	0.189 ^{NS}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}		
F value	1.685	104.782	44.640	63.885	93.000	199.467	61.389		
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (<i>Leucinodes orbonalis</i> were counted on 5 randomly selected plants per replication and was expressed as no. <i>Leucinodes orbonalis</i> of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

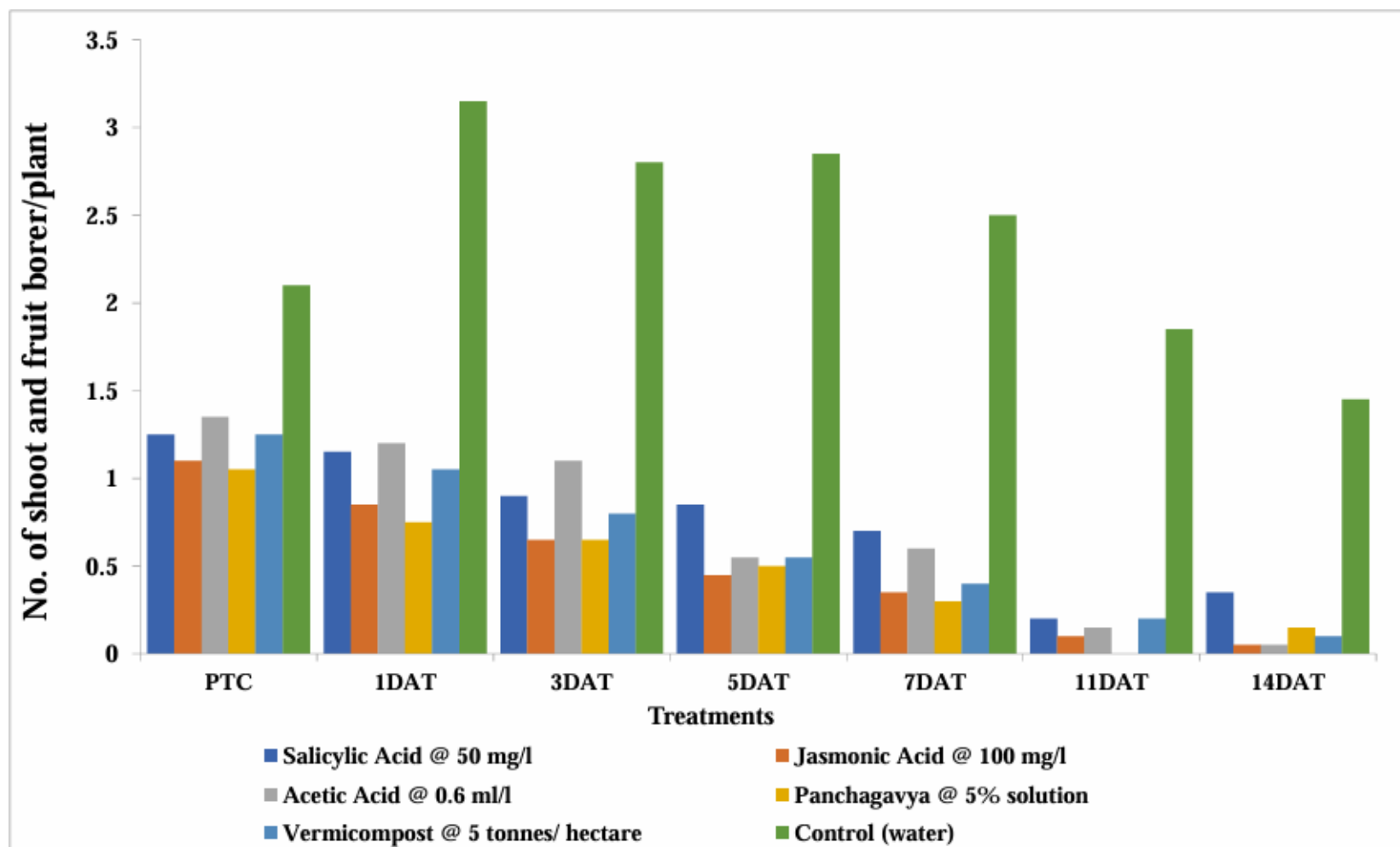


Fig. 39 Efficacy of exogenously applied elicitors against shoot borer damage (*Leucinodes orbonalis*) in Kharif season 2023

4.3.5. Effect of exogenously applied elicitors on predatory coccinellids during *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023 seasons.

The initial population of predatory coccinellid beetles on precount day ranged from 0.15 to 0.55 coccinellid beetles per plant and 0.40 to 0.95 coccinellid beetles per plant during *Rabi* 2021 and 2022 and *Kharif* season 2022 and 2023 (Table 45 and 46, Fig. 40 and 41). However, at the end of 14 DAT the population ranged between mean 0.00 to 0.15 coccinellid / plant (Table 45, Fig. 40) and 0.10 to 0.45 coccinellid beetles per plant (Table 46, Fig. 41) during both seasons. The populations of predatory coccinellid beetles were observed with no significant difference on pretreatment count day during *Rabi* season of 2021 and 2022 with ($df_{(6,4)}$; $P>0.428$) (Table 45, Fig. 40) and while found significant in *Kharif* season of 2022 and 2023 with ($df_{(6,4)}$; $P<0.046$) (Table 46, Fig. 41). Predatory coccinellid populations fluctuated as they increased and decreased until 14 DAT during *Rabi* season of 2021 and 2022 and *Kharif* season 2022 and 2023 (Table 45 and 46, Fig. 40 and 41).

During second spray of *Kharif* season 2023, the initial population of predatory coccinellid beetles on precount day lie between 0.35 to 0.90 coccinellid beetles per plant (Table 47, Fig. 42). However, at the end of 14 DAT the population ranged between mean 0.05 to 0.35 coccinellid per plant *Kharif* seasons 2023 (Table 47, Fig. 42). The populations of predatory coccinellid beetles were observed with no significant difference on precount day ($df_{(6,4)}$; $P>0.108$) as well as at 1 DAT ($df_{(6,4)}$; $P>0.160$), 3 DAT ($df_{(6,4)}$; $P>0.101$), 5 DAT ($df_{(6,4)}$; $P>0.206$), 7 DAT ($df_{(6,4)}$; $P>0.125$), 11 DAT ($df_{(6,4)}$; $P>0.179$) and 14 DAT ($df_{(6,4)}$; $P>0.216$) during *Kharif* season of 2023 (Table 47, Fig. 42). Predatory coccinellid populations fluctuated as they increased and decreased until 14 DAT during *Kharif* season 2023 (Table 47, Fig. 42). In this study, elicitors demonstrated a positive response in attracting natural enemies and effectively controlling eggplant sap sucking pests. Presence of predatory coccinellids indicates their potential for safe integration into integrated pest management (IPM) programs. This suggests that incorporating elicitors into pest management techniques is better way to pests controlling and to promote beneficial organism's presence, thereby enhancing the sustainability and effectiveness of pest control

efforts in brinjal cultivation.

Additionally, olfactometer trials revealed that cis-jasmone was a direct attractant to the predatory beetle *C. septempunctata*. Similarly, in wind tunnel studies, cis-jasmone was also observed to attract the aphid parasitoid *Aphidius ervi*. These findings suggest that cis-jasmone holds promise as a potential tool for attracting beneficial insects, thereby contributing to the biological control of pests in agricultural ecosystems (Birkett *et al.*, 2000). In the current study, elicitors were found to be safe and effective in managing pests while also attracting natural enemies. Jayasimha *et al.*, (2017), who demonstrated synthetic elicitors like Linalool acted as attractants for predators of *N. lugens*. These results suggest that elicitors have the potential to serve as semiochemicals for the sustainable management of pests such as the brown planthopper in rice cultivation. This highlights the promising role of elicitors in integrated pest management strategies, where they can contribute to both pest control and the conservation of natural enemy populations. Alborn *et al.*, (2000), said as elicitors serve as attractants for pests' natural enemies. Instead of employing elicitor lures, an alternative approach involves applying exogenous elicitors to plants in the field. This application induces the production and release of a unique mix of volatiles by the plants themselves, thereby attracting natural enemies (Rohwer and Erwin, 2008). Additionally, other elicitors such as acetic acid, panchagavya, and vermicompost have been found to be safer for natural enemies, as there are no reports indicating any side effects on them.

Currently, elicitors represent the most effective method for augmenting the attractiveness of cultivated plants to biological control agents (Sobhy *et al.*, 2012). SA compounds indirectly enhance biological control by augmenting the attractiveness of plants damaged by herbivores to parasitic wasps. This enhancement occurs through qualitative and quantitative alterations in the emissions of induced volatiles (Sobhy *et al.*, 2012; Sobhy *et al.*, 2014; Moreno-Delafuente *et al.*, 2020). BTH effectively enhances the short-term suppression of *A. gossypii* without exerting any adverse effects on predatory larva *C. carnea*. Similar to the findings mentioned the behavior of green lacewings was unaffected by the treatment of jasmonate in tomato seeds and helps to decrease pest incidence, pinworm (Strapasson *et al.*, 2014).

Indeed, Ishiwari *et al.*, (2007) found that MeSA (methyl salicylate) is a common herbivore- induced plant volatile (HIPV) helps to attract predators of herbivores. These natural enemies rely on a variety of HIPVs to locate their prey or hosts, and the specific blend of chemicals emitted by plants can vary depending on the herbivore species present. MeSA, identified as a significant HIPV according to Ozawa *et al.*, (2000), has been recognized for its role in attracting predators across various taxa. James, (2003) observed that sticky traps lured predators from families such as Chrysopidae, Miridae, Geocoridae, Anthocoridae, Syrphidae, and Coccinellidae when baited with MeSA. Additionally, MeSA has been documented as an attractant for *Erigonidium graminicolum* and *Orius similis* within the cotton ecosystem (Yu *et al.*, 2008). The orientation behavior of coccinellids was notably heightened when exposed to MeSA-treated rice leaves, as observed by Indhumathi *et al.*, (2019). Moreover, MeSA has demonstrated its attractiveness not only to predators but also to parasitoids such as Mymaridae and Encyrtidae, as noted by James and Grasswitz, (2005). Additionally, the application of salicylic acid has been found to deter herbivory in wheat while simultaneously increasing the foraging activity of both parasitoids and predators, as documented by Mahmoud and Mahfouz, (2015). Furthermore, Gokila *et al.*, (2021) found that methyl salicylate attracted a larger population of coccinellids compared to salicylic acid.

Jasmonic acid and MeJA treatment have been recognized for their ability to elicit emissions similar to those triggered by herbivore feeding. This characteristic suggests that treated plants have the potential to attract natural enemies even before actual herbivore infestation occurs on cultivated plants, as noted by Thaler (1999). Growth stimulants given externally to rice, such as 2,4-D, methyl jasmonate, and jasmonic, aid in luring the brown plant hopper parasitoid (Cheng *et al.*, 2007; Xin *et al.*, 2012). Likewise, Sobhy *et al.*, (2014) have demonstrated that applying benzo (1,2,3) thiadiazole-7-carbothioic acid salicylic-methyl ester to cotton increases the release of homoterpenes, which in turn increases the attraction of three hymenopteran parasitoids: *C. marginiventris*, *C. sonorensis*, and *M. rufiventris*.

Phytohormone mimics hold promise for future agricultural practices by eliciting plant resistance to pests and diseases. However, their adoption will necessitate comprehensive safety testing similar to that required for pesticides due to their synthetic nature. The successful utilization of commercial products like BTH, MeSA, MeJA, and synthetic elicitors in plant pathogen control has already demonstrated the potential of elicitors to replace more toxic fungicides in the future. Nevertheless, extensive research is still required to develop practical applications of elicitors in managing pests and diseases in conifers.

Table 45. Effect of exogenous elicitors inducing plant resistance on predatory coccinellids in brinjal of *Rabi* season 2021 and 2022

Treatments	No. of Coccinellids / per plant*															
	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Rabi 2021	Rabi 2022	Mean	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Rabi - 21	Rabi - 22
Salicylic Acid @ 50 mg/l	0.30 ± 0.34 ^{ab}	0.35 ± 0.19 ^a	0.30 ± 0.26 ^{ab}	0.20 ± 0.00 ^a	0.35 ± 0.10 ^a	0.30 ± 0.11 ^a	0.15 ± 0.10 ^b	0.10 ± 0.12 ^b	0.10 ± 0.11 ^{ab}	0.15 ± 0.10 ^{ab}	0.15 ± 0.30 ^a	0.00 ± 0.00 ^b	0.00 ± 0.00 ^a	0.05 ± 0.10 ^{ab}	0.17	0.13
Jasmonic Acid @ 100 mg/l	0.25 ± 0.25 ^{ab}	0.25 ± 0.10 ^a	0.25 ± 0.19 ^b	0.25 ± 0.25 ^a	0.40 ± 0.00 ^a	0.20 ± 0.00 ^a	0.20 ± 0.00 ^{ab}	0.05 ± 0.10 ^b	0.15 ± 0.19 ^{ab}	0.15 ± 0.10 ^{ab}	0.00 ± 0.00 ^b	0.05 ± 0.10 ^{ab}	0.05 ± 0.12 ^a	0.00 ± 0.00 ^b	0.17	0.11
Acetic Acid @ 0.6 ml/l	0.15 ± 0.19 ^b	0.35 ± 0.10 ^a	0.40 ± 0.28 ^{ab}	0.25 ± 0.10 ^a	0.40 ± 0.16 ^a	0.25 ± 0.10 ^a	0.20 ± 0.10 ^{ab}	0.35 ± 0.10 ^a	0.15 ± 0.10 ^{ab}	0.20 ± 0.16 ^a	0.10 ± 0.20 ^{ab}	0.00 ± 0.00 ^b	0.10 ± 0.12 ^a	0.05 ± 0.10 ^{ab}	0.22	0.18
Panchagavy a @ 5% solution	0.55 ± 0.19 ^a	0.20 ± 0.00 ^a	0.40 ± 0.16 ^{ab}	0.35 ± 0.10 ^a	0.25 ± 0.10 ^a	0.15 ± 0.19 ^a	0.35 ± 0.10 ^a	0.20 ± 0.16 ^{ab}	0.00 ± 0.00 ^b	0.00 ± 0.00 ^b	0.15 ± 0.19 ^a	0.15 ± 0.10 ^a	0.10 ± 0.12 ^a	0.10 ± 0.12 ^{ab}	0.20	0.15
Vermicompo st @ 5 tonnes/ hectare	0.55 ± 0.19 ^a	0.30 ± 0.12 ^a	0.50 ± 0.26 ^a	0.35 ± 0.10 ^a	0.30 ± 0.11 ^a	0.30 ± 0.11 ^a	0.20 ± 0.16 ^{ab}	0.15 ± 0.19 ^{ab}	0.30 ± 0.20 ^a	0.05 ± 0.10 ^{ab}	0.05 ± 0.10 ^{ab}	0.10 ± 0.12 ^{ab}	0.00 ± 0.00 ^a	0.15 ± 0.10 ^a	0.22	0.18
Control (water)	0.35 ± 0.19 ^{ab}	0.25 ± 0.10 ^a	0.40 ± 0.37 ^{ab}	0.30 ± 0.11 ^a	0.25 ± 0.10 ^a	0.25 ± 0.25 ^a	0.30 ± 0.11 ^{ab}	0.15 ± 0.19 ^{ab}	0.10 ± 0.11 ^{ab}	0.20 ± 0.16 ^a	0.00 ± 0.00 ^b	0.10 ± 0.12 ^{ab}	0.10 ± 0.12 ^a	0.00 ± 0.00 ^b	0.19	0.16
P value	0.141 ^{NS}	0.394 ^{NS}	0.212 ^{NS}	0.548 ^{NS}	0.203 ^{NS}	0.701 ^{NS}	0.152 ^{NS}	0.141 ^{NS}	0.120 ^{NS}	0.137 ^{NS}	0.059 ^{NS}	0.147 ^{NS}	0.366 ^{NS}	0.146 ^{NS}		
F value	1.921	1.110	1.594	0.825	1.629	0.600	1.857	1.920	2.047	1.944	2.631	1.886	1.160	1.892		
Year*Treatment's																
P value	0.428 ^{NS}		0.059 ^{NS}		0.375 ^{NS}		0.048*		0.064 ^{NS}		0.195 ^{NS}		0.516 ^{NS}			
F value	1.005		2.349		1.102		2.487		2.302		1.559		0.862			
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (Coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. Coccinellids of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																

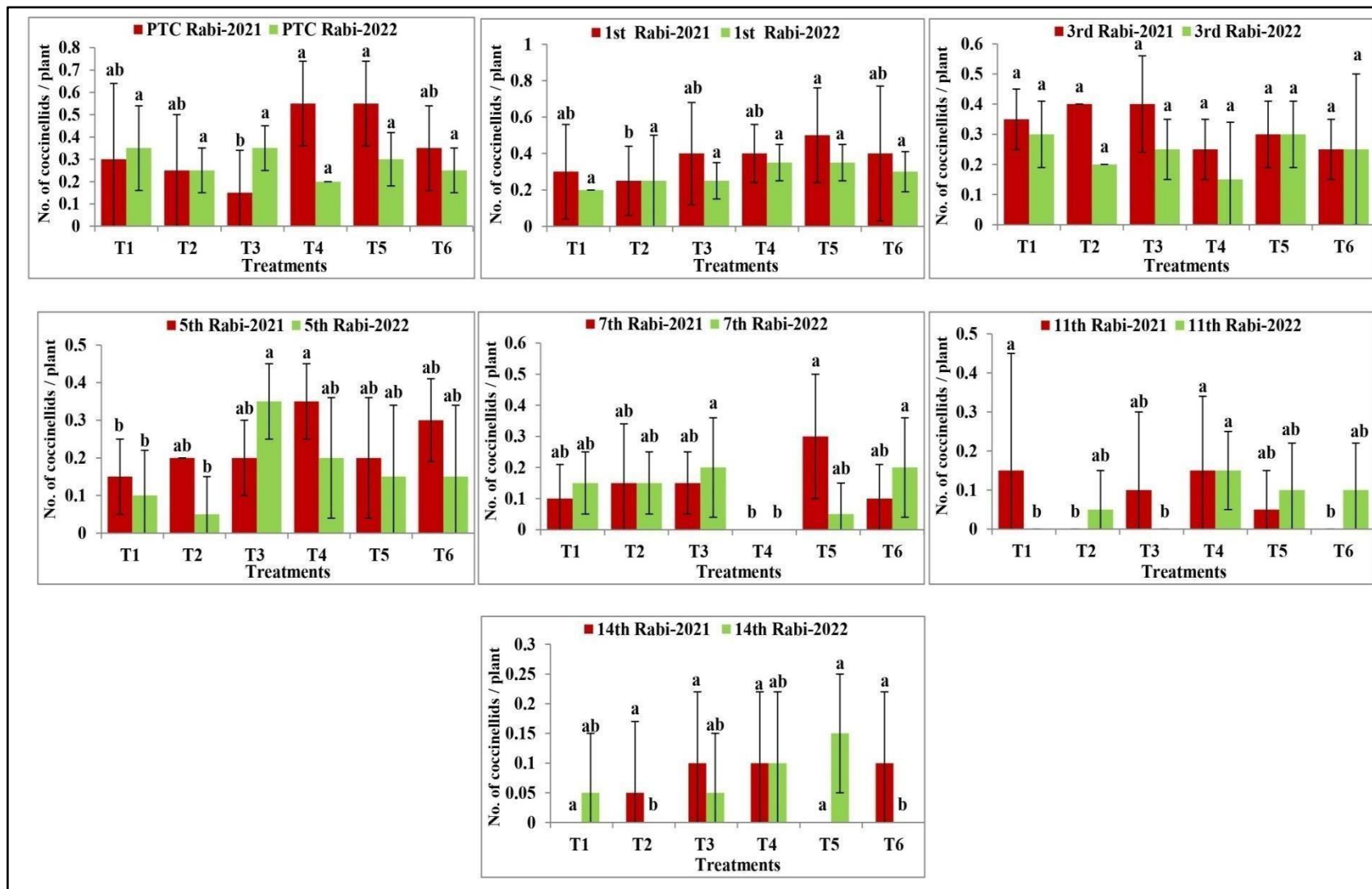


Fig. 40 Efficacy of exogenously applied elicitors on predatory coccinellids in *Rabi* season 2021 and 2022

Table 46. Effect of exogenous elicitors inducing plant resistance on predatory coccinellids in brinjal of *Kharif* season 2022 and 2023

Treatments	No. of Coccinellids / per plant*															
	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023	Mean	
	PTC		1DAT		3DAT		5DAT		7DAT		11DAT		14DAT		Kharif 2022	Kharif 2023
Salicylic Acid @ 50 mg/l	0.40 ± 0.16 ^b	0.75 ± 0.19 ^{ab}	0.40 ± 0.32 ^{ab}	0.65 ± 0.10 ^a	0.70 ± 0.11 ^{ab}	0.55 ± 0.10 ^{ab}	0.60 ± 0.16 ^{ab}	0.75 ± 0.30 ^a	0.40 ± 0.28 ^b	0.35 ± 0.10 ^b	0.55 ± 0.19 ^{ab}	0.15 ± 0.10 ^b	0.25 ± 0.10 ^b	0.10 ± 0.12 ^a	0.48	0.42
Jasmonic Acid @ 100 mg/l	0.75 ± 0.10 ^a	0.85 ± 0.19 ^{ab}	0.45 ± 0.34 ^{ab}	0.70 ± 0.12 ^a	0.70 ± 0.11 ^{ab}	0.45 ± 0.19 ^b	0.80 ± 0.16 ^a	0.55 ± 0.19 ^{ab}	0.60 ± 0.16 ^{ab}	0.40 ± 0.00 ^{ab}	0.45 ± 0.34 ^{ab}	0.35 ± 0.10 ^a	0.30 ± 0.12 ^{ab}	0.10 ± 0.12 ^a	0.55	0.42
Acetic Acid @ 0.6 ml/l	0.70 ± 0.12 ^{ab}	0.95 ± 0.19 ^a	0.50 ± 0.47 ^{ab}	0.75 ± 0.19 ^a	0.50 ± 0.11 ^b	0.65 ± 0.10 ^{ab}	0.50 ± 0.11 ^b	0.50 ± 0.11 ^{ab}	0.60 ± 0.32 ^{ab}	0.45 ± 0.10 ^{ab}	0.25 ± 0.19 ^b	0.25 ± 0.10 ^{ab}	0.30 ± 0.12 ^{ab}	0.25 ± 0.25 ^a	0.88	0.47
Panchagav ya @ 5% solution	0.65 ± 0.10 ^{ab}	0.60 ± 0.16 ^b	0.40 ± 0.36 ^{ab}	0.65 ± 0.19 ^a	0.75 ± 0.10 ^a	0.60 ± 0.16 ^{ab}	0.80 ± 0.16 ^a	0.40 ± 0.16 ^b	0.40 ± 0.16 ^b	0.50 ± 0.12 ^{ab}	0.60 ± 0.28 ^{ab}	0.30 ± 0.12 ^{ab}	0.35 ± 0.10 ^{ab}	0.20 ± 0.00 ^a	0.55	0.44
Vermicom post @ 5 tonnes/ hectare	0.65 ± 0.34 ^{ab}	0.70 ± 0.12 ^{ab}	0.95 ± 0.19 ^a	0.85 ± 0.25 ^a	0.60 ± 0.16 ^{ab}	0.50 ± 0.11 ^{ab}	0.55 ± 0.19 ^{ab}	0.70 ± 0.11 ^{ab}	0.75 ± 0.10 ^a	0.55 ± 0.19 ^a	0.45 ± 0.44 ^{ab}	0.25 ± 0.10 ^{ab}	0.45 ± 0.10 ^a	0.15 ± 0.19 ^a	0.62	0.50
Control (water)	0.45 ± 0.30 ^{ab}	0.70 ± 0.12 ^{ab}	0.35 ± 0.34 ^b	0.85 ± 0.30 ^a	0.55 ± 0.19 ^{ab}	0.70 ± 0.11 ^a	0.65 ± 0.19 ^{ab}	0.60 ± 0.16 ^{ab}	0.70 ± 0.12 ^{ab}	0.50 ± 0.12 ^{ab}	0.80 ± 0.16 ^a	0.20 ± 0.16 ^{ab}	0.45 ± 0.10 ^a	0.25 ± 0.10 ^a	0.58	0.51
P value	0.164 ^{NS}	0.092 ^{NS}	0.208 ^{NS}	0.559 ^{NS}	0.120 ^{NS}	0.143 ^{NS}	0.088 ^{NS}	0.138 ^{NS}	0.130 ^{NS}	0.222 ^{NS}	0.201 ^{NS}	0.239 ^{NS}	0.067 ^{NS}	0.542 ^{NS}		
F value	1.800	2.265	1.610	0.808	2.047	1.909	2.304	1.935	1.982	1.560	1.638	1.500	2.520	0.834		
Year*Treatment's																
P value	0.046*		0.100 ^{NS}		0.622 ^{NS}		0.549 ^{NS}		0.030*		0.371 ^{NS}		0.085 ^{NS}			
F value	2.512		2.008		0.707		0.812		2.809		1.110		2.116			
P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (Coccinellids were counted on 5 randomly selected plants per replication and was expressed as no coccinellids of per plant, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed), NS - Non Significant																

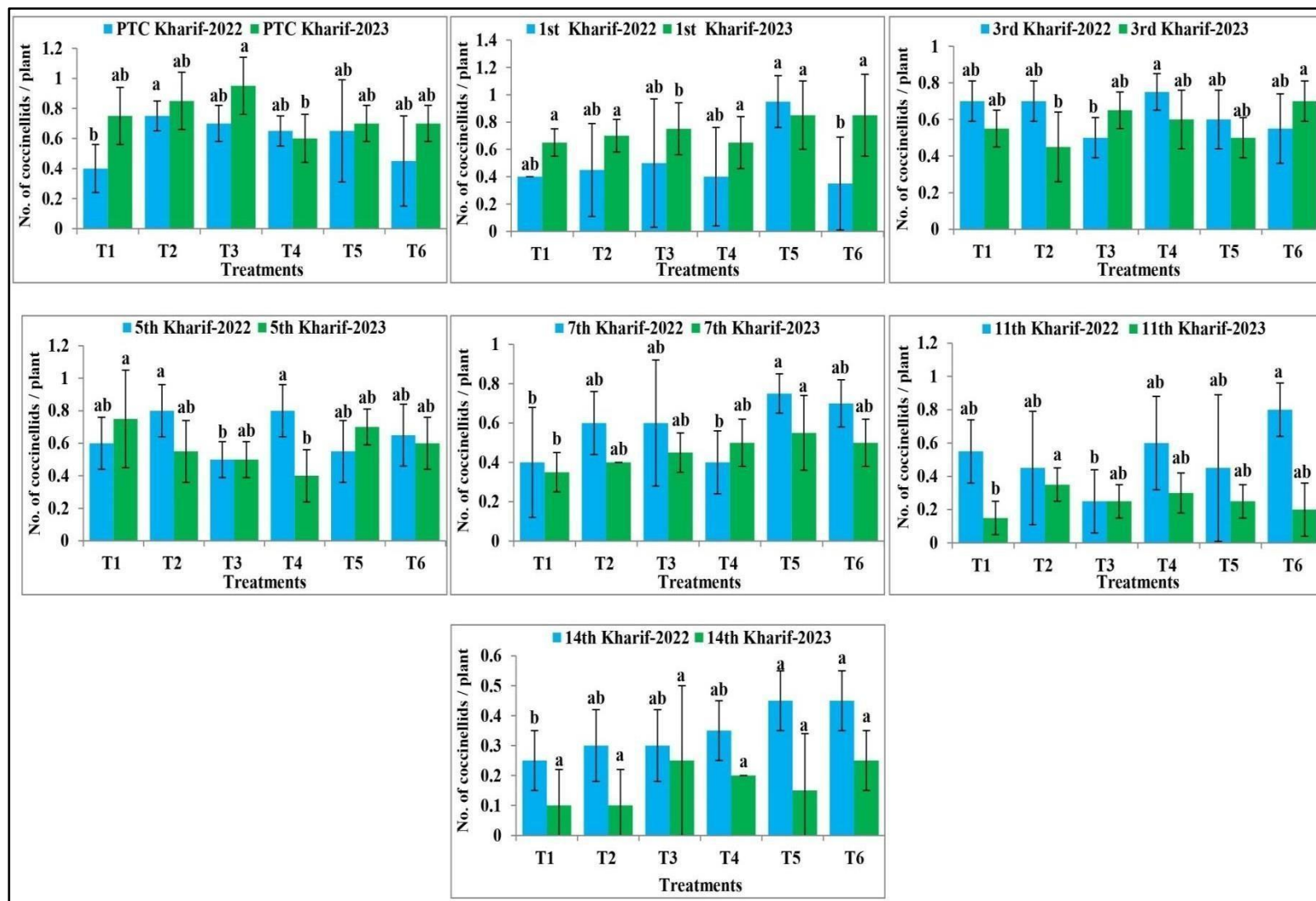


Fig. 41 Efficacy of exogenously applied elicitors on predatory coccinellids in *Kharif* season 2022 and 2023

Table 47. Effect of exogenous elicitors inducing plant resistance on predatory coccinellids in brinjal of *Kharif* season 2023

Treatments	No. of Coccinellids / per plant*							
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean
Salicylic Acid @ 50 mg/l	0.35 ± 0.19 ^b	0.40 ± 0.16 ^b	0.65 ± 0.19 ^{ab}	0.70 ± 0.68 ^{ab}	0.55 ± 0.19 ^{ab}	0.25 ± 0.19 ^{ab}	0.15 ± 0.19 ^{ab}	0.45
Jasmonic Acid @ 100 mg/l	0.55 ± 0.25 ^{ab}	0.50 ± 0.26 ^{ab}	0.55 ± 0.19 ^{ab}	0.30 ± 0.20 ^b	0.45 ± 0.10 ^b	0.55 ± 0.34 ^a	0.05 ± 0.10 ^b	0.40
Acetic Acid @ 0.6 ml/l	0.60 ± 0.28 ^{ab}	0.75 ± 0.19 ^a	0.40 ± 0.23 ^b	0.95 ± 0.19 ^a	0.70 ± 0.12 ^{ab}	0.15 ± 0.10 ^b	0.20 ± 0.16 ^{ab}	0.52
Panchagavya @ 5% solution	0.35 ± 0.19 ^b	0.55 ± 0.26 ^{ab}	0.60 ± 0.16 ^{ab}	0.80 ± 0.16 ^{ab}	0.45 ± 0.19 ^b	0.35 ± 0.30 ^{ab}	0.15 ± 0.10 ^{ab}	0.48
Vermicompost @ 5 tonnes/ hectare	0.45 ± 0.44 ^{ab}	0.60 ± 0.16 ^{ab}	0.40 ± 0.16 ^b	0.55 ± 0.10 ^{ab}	0.75 ± 0.19 ^a	0.40 ± 0.11 ^{ab}	0.20 ± 0.16 ^{ab}	0.48
Control (water)	0.90 ± 0.26 ^a	0.75 ± 0.19 ^a	0.80 ± 0.28 ^a	0.40 ± 0.56 ^{ab}	0.60 ± 0.23 ^{ab}	0.45 ± 0.25 ^{ab}	0.35 ± 0.19 ^a	0.55
P value	0.108 ^{NS}	0.160 ^{NS}	0.101 ^{NS}	0.206 ^N _s	0.125 ^N _s	0.179 ^{NS}	0.216 ^{NS}	
F value	2.133	1.816	2.185	1.618	2.014	1.727	1.582	
• P Value- Probability, F Value - Ratio of two variances, Mean of four replicates (Coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. Coccinellids of per plant), PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant								

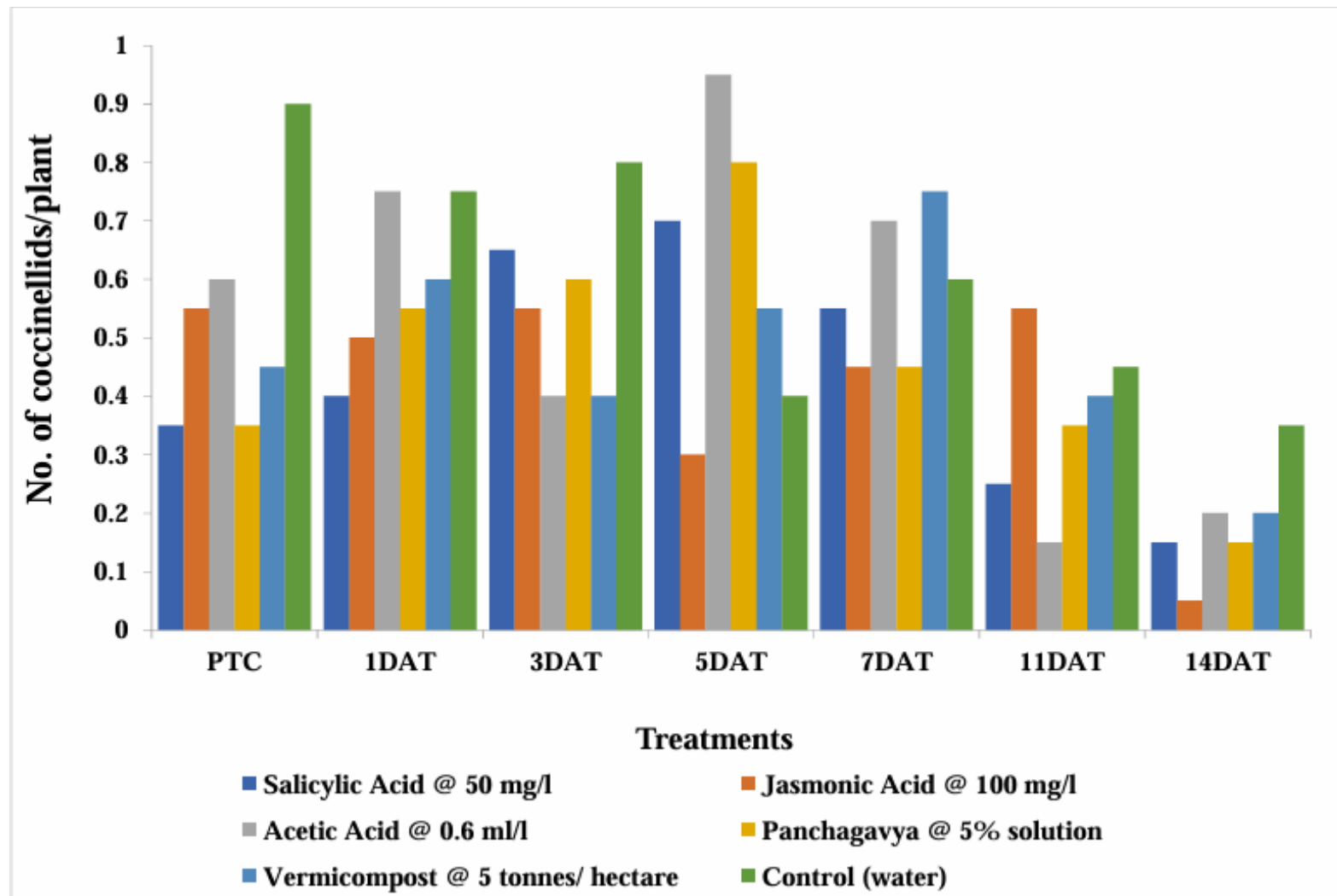


Fig. 42 Efficacy of exogenously applied elicitors on predatory coccinellids in *Kharif* season 2023

4.3.6. Yield of different exogenously applied elicitors against major arthropod pest of brinjal in *Rabi* 2021 and 2022 and *Kharif* 2022 and 2023.

In *Rabi* season 2021 and 2022, all the treatments had significant difference in yield. All the treatments showed significant impact on yield at 1st picking ($df_{(8,3)}$; $P = 0.011$; $df_{(8,3)}$; $P = 0.001$), 2nd picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.001$), 3rd picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.000$), 4th picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.000$), 5th picking ($df_{(8,3)}$; $P = 0.010$; $df_{(8,3)}$; $P = 0.002$) and 6th picking ($df_{(8,3)}$; $P = 0.013$; $df_{(8,3)}$; $P = 0.001$) during *Rabi* season 2021 and 2022 (Table 48 and 49, Fig. 43 and 44).

In *Rabi* season 2021 and 2022, all the treatments significantly increased in yield over the control. The maximum fruit yield of (14973.95 and 16022.85 kg ha⁻¹) was recorded from the fields treated with followed by those treated with (T₄) - Panchagavya 5 % solution (16095.19 and 15661.16 kg ha⁻¹), (T₂) - Jasmonic acid @ 395 mg/l offering (14105.90 and 14359.08 kg ha⁻¹), (T₅) - Vermicompost @ 5 tonnes/hectare offering (12261.28 and 12261.28 kg ha⁻¹), (T₃) - Acetic acid @ 0.6 ml/l (12116.60 and 11754.91 kg ha⁻¹), (T₁) - Salicylic acid @ 50 mg/l (11754.91 and 11284.72 kg ha⁻¹) and last was (T₆) - untreated plots with yield of (6438.07 and 5750.86 kg ha⁻¹) (Table 48 and 49, Fig. 43 and 44).

In *Kharif* season 2022 and 2023, all the treatments had significant difference in yield. All the treatments showed significant impact on yield at 1st picking ($df_{(8,3)}$; $P = 0.003$; $df_{(8,3)}$; $P = 0.000$), 2nd picking ($df_{(8,3)}$; $P = 0.003$; $df_{(8,3)}$; $P = 0.000$), 3rd picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.006$), 4th picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.000$), 5th picking ($df_{(8,3)}$; $P = 0.000$; $df_{(8,3)}$; $P = 0.000$) and 6th picking ($df_{(8,3)}$; $P = 0.027$; $df_{(8,3)}$; $P = 0.026$) during *Kharif* season 2022 and 2023 (Table 50 and 51, Fig. 43 and 44).

In *Kharif* season 2022 and 2023, all the treatments significantly increased in yield over the control. The maximum fruit yield of (16493.05 and 16239.87 kg ha⁻¹) was recorded from the fields treated with (T₂) - Jasmonic acid @ 395 mg/l followed by those treated with offering (T₄) - Panchagavya 5 % solution (16276.04 and 15950.52 kg ha⁻¹), (T₅) - Vermicompost @ 5 tonnes/hectare offering (13925.05 and 14322.91 kg ha⁻¹), (T₃) - Acetic acid @ 0.6 ml/l (13671.87 and 14033.56 kg ha⁻¹), (T₁) - Salicylic acid @ 50 mg/l

(12876.15 and 13454.86 kg ha⁻¹) and last was (T₆) - untreated plots with yield of (6474.24 and 7233.79 kg ha⁻¹) (Table 50 and 51, Fig. 43 and 44).

Similar findings were observed in the present study, where higher levels of growth-promoting chemicals, greater levels of chlorophyll synthesis, and the availability of plant nutrients, Panchagavya improved the biological efficiency of plants. This resulted in increased fruit yield in brinjal, aligning with observations in other crops as reported by Kumawat *et al.*, (2009). Cumin and cluster beans produced more when neem in addition with panchagavya were applied topically (Kumawat *et al.*, 2010; Mahajan *et al.*, 2012). Various researchers reported that application of panchagavya with different concentration in liquid spray show increased in yield and yield contributing attributes like Kumar *et al.*, (2011a) in groundnut, Vimalendran and Wahab, (2013) show increased yield in baby corn, Sakhubai *et al.*, (2014) in buck- wheat, Waghmode *et al.*, (2015) in crop sweet corn, Boraiah *et al.*, (2018) in capsicum, Kumar *et al.*, (2011b) and Choudhary *et al.*, (2017) in black gram, Rakesh *et al.*, (2017) in okra.

According to Swarnam *et al.*, (2016), the utilization of panchagavya resulted in enhancements such as increased plant height, branch count, fruit quantity, and individual fruit weight. Tharmaraj *et al.*, (2011) noted used of panchagavya, which contains plant growth regulators, leads to rapid alterations in plant phenotypes, ultimately improving crop growth and productivity. According to research by Vijayakumari *et al.*, (2012), soaking seeds in a panchagavya and humic acid solution for eight hours increased the amount of protein and ascorbic acid in harvested soybean seeds when compared to other treatments. Similar to this, using panchagavya was shown to boost yields in a number of crops, including French beans (Selvaraj, 2004), green gram (Somasundaram *et al.*, 2004), moringa (Beaulah *et al.*, 2001).

Awang *et al.*, (2015) suggested that utilizing jasmonic acid in chilli plants could serve as a potential substitute for pesticide application. Their research indicated that applying jasmonic acid through exogenous spray twice was helpful in managing both, percentage of disease occurrence and damaged, and promoting growth and yield characteristics of chilli plants. Applying salicylic acid topically has been shown to

preserve plant-water associations and photosynthesis (Habibi, 2012; Nazar *et al.*, 2015). Studies noted, foliar salicylic acid application increases the yield of brinjal (Gawade and Sirohi, 2011), tomatoes (Afsana *et al.*, 2017), and garlic (Bideshki and Arvin, 2010) and soyabean (Nasrin *et al.*, 2017). Vermicompost is a rich source of micro- and macronutrients, enzymes, and growth regulators, according to their research, using vermicompost reduced biotic stress and increased plant growth and output claim by (Sundararasu and Jeyasankar, 2014).

Table 48. Yield of different exogenously applied elicitors against major arthropod pest in brinjal of *Rabi* season 2021

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Salicylic Acid @ 50 mg/l	12.50 ± 0.52 ^a	15.25 ± 0.91 ^b	17.50 ± 0.38 ^b	16.75 ± 0.34 ^b	10.00 ± 0.52 ^c	9.25 ± 0.55 ^{abc}	81.25	11754.91	11.75
Jasmonic Acid @ 100 mg/l	11.25 ± 0.50 ^{ab}	16.25 ± 0.30 ^b	21.00 ± 0.16 ^a	21.50 ± 0.25 ^a	16.25 ± 0.53 ^{ab}	11.25 ± 0.60 ^{ab}	97.50	14105.90	14.10
Acetic Acid @ 0.6 ml/l	10.50 ± 0.47 ^{ab}	15.00 ± 0.67 ^b	18.50 ± 0.30 ^{ab}	20.50 ± 0.11 ^a	11.25 ± 0.70 ^{bc}	8.00 ± 0.37 ^{bc}	83.75	12116.60	12.11
Panchagavya @ 5% solution	15.00 ± 1.14 ^a	22.25 ± 0.19 ^a	20.75 ± 0.57 ^a	22.50 ± 0.26 ^a	17.50 ± 0.74 ^a	13.25 ± 0.72 ^a	111.25	16095.19	16.09
Vermicompost @ 5 tonnes/ hectare	7.50 ± 0.41 ^b	12.50 ± 0.48 ^b	19.00 ± 0.46 ^{ab}	21.25 ± 0.34 ^a	13.75 ± 1.12 ^{abc}	10.75 ± 0.66 ^{ab}	84.75	12261.28	12.26
Control (water)	6.25 ± 0.25 ^b	7.50 ± 0.26 ^c	8.50 ± 0.26 ^c	9.00 ± 0.94 ^c	8.00 ± 0.52 ^c	5.25 ± 0.34 ^c	44.50	6438.07	6.43
P value	0.011 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.010 [*]	0.013 [*]			
F value	4.151	13.073	23.441	19.784	4.209	4.015			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT - Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

Table 49. Yield of different exogenously applied elicitors against major arthropod pest in brinjal of *Rabi* season 2022

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Salicylic Acid @ 50 mg/l	12.00 ± 0.43 ^{abc}	15.25 ± 0.52 ^{ab}	16.25 ± 0.19 ^b	15.25 ± 0.25 ^c	10.75 ± 0.61 ^{bc}	8.50 ± 0.42 ^{bc}	78.00	11284.72	11.28
Jasmonic Acid @ 100 mg/l	13.25 ± 0.86 ^{ab}	16.50 ± 0.57 ^{ab}	19.00 ± 0.33 ^{ab}	21.50 ± 0.62 ^a	17.00 ± 0.71 ^a	12.00 ± 0.59 ^{ab}	99.25	14359.08	14.35
Acetic Acid @ 0.6 ml/l	10.50 ± 0.80 ^{bc}	14.50 ± 0.68 ^{ab}	16.25 ± 0.25 ^b	16.25 ± 0.72 ^{bc}	13.50 ± 0.62 ^{ab}	10.25 ± 0.68 ^b	81.25	11754.91	11.75
Panchagavya @ 5% solution	16.00 ± 0.36 ^a	18.50 ± 0.68 ^a	20.50 ± 0.41 ^a	20.75 ± 0.77 ^{ab}	16.75 ± 0.66 ^a	15.75 ± 0.70 ^a	108.25	15661.16	15.66
Vermicompost @ 5 tonnes/ hectare	8.25 ± 0.34 ^{cd}	11.75 ± 0.66 ^b	19.00 ± 0.28 ^{ab}	18.25 ± 0.82 ^{abc}	15.25 ± 0.68 ^{ab}	12.25 ± 0.50 ^{ab}	84.75	12261.28	12.26
Control (water)	5.50 ± 0.47 ^d	6.75 ± 0.50 ^c	8.00 ± 0.59 ^c	7.50 ± 0.42 ^d	6.75 ± 0.66 ^c	5.25 ± 0.30 ^c	39.75	5750.86	5.75
P value	0.001*	0.001*	0.000**	0.000**	0.002*	0.001*			
F value	6.397	7.391	24.010	10.240	5.792	6.812			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

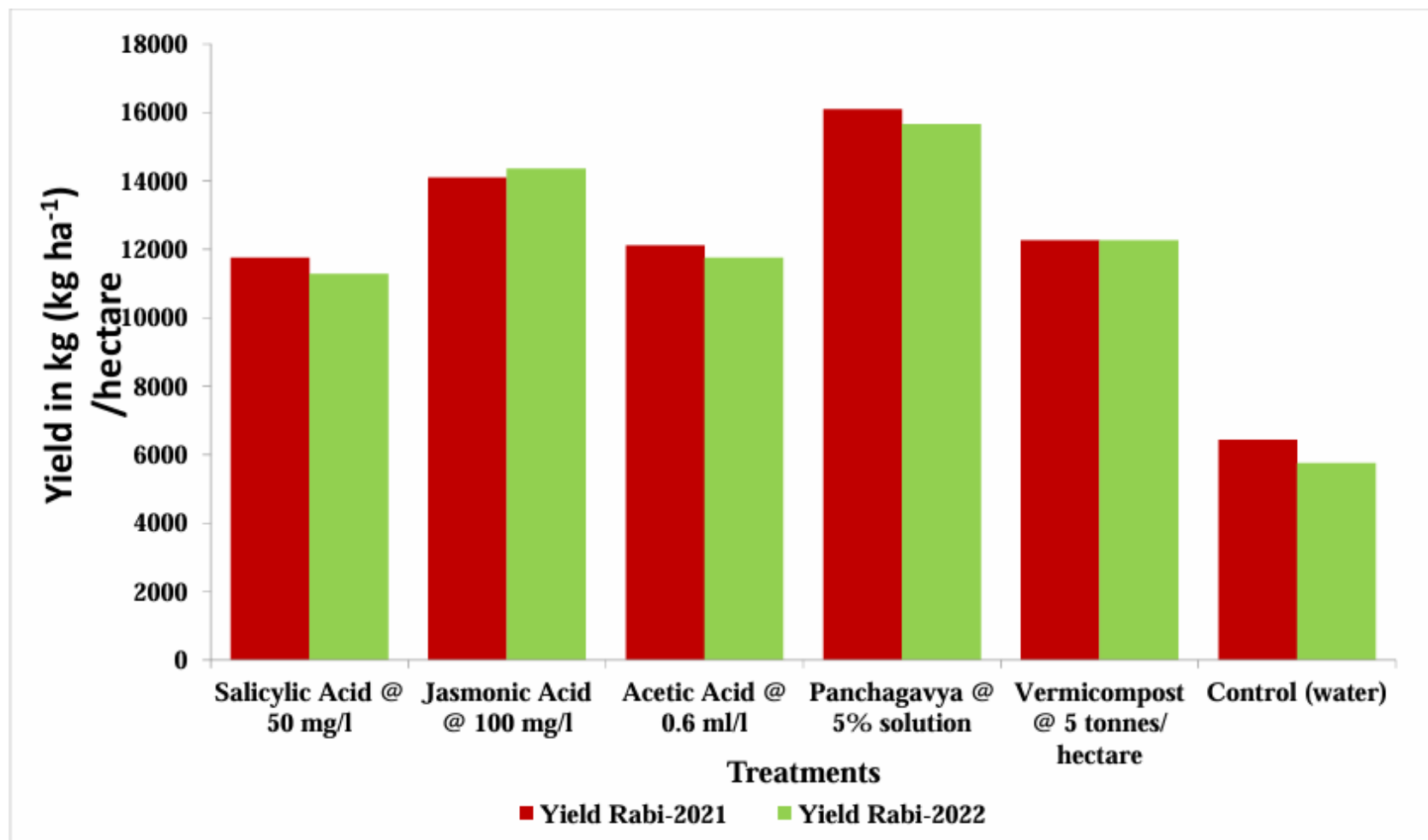


Fig. 43 Yield of different elicitors against major arthropod pest of brinjal of *Rabi* season 2021 and 2022

Table 50. Yield of different exogenously applied elicitors against major arthropod pest in brinjal of *Kharif* season 2022

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Salicylic Acid @ 50 mg/l	9.25 ± 0.44 ^b	17.50 ± 0.62 ^{ab}	20.25 ± 0.44 ^b	21.25 ± 0.55 ^c	12.50 ± 0.48 ^{ab}	8.25 ± 0.19 ^{ab}	89.00	12876.15	12.87
Jasmonic Acid @ 100 mg/l	13.75 ± 0.44 ^a	20.00 ± 0.43 ^a	26.75 ± 0.66 ^a	30.00 ± 0.23 ^a	13.75 ± 0.44 ^{ab}	9.75 ± 0.34 ^a	114.00	16493.05	16.49
Acetic Acid @ 0.6 ml/l	10.00 ± 0.78 ^{ab}	15.00 ± 0.28 ^{ab}	24.25 ± 0.55 ^a	25.25 ± 0.62 ^b	12.50 ± 0.26 ^{ab}	7.50 ± 0.26 ^a	94.50	13671.87	13.67
Panchagavya @ 5% solution	12.25 ± 0.50 ^{ab}	18.75 ± 0.44 ^{ab}	26.00 ± 0.48 ^a	31.00 ± 0.49 ^a	14.75 ± 0.19 ^a	9.75 ± 0.25 ^a	112.50	16276.04	16.27
Vermicompost @ 5 tonnes/ hectare	11.25 ± 0.53 ^{ab}	14.25 ± 0.97 ^{bc}	24.75 ± 0.53 ^a	27.25 ± 0.72 ^{ab}	11.25 ± 0.25 ^b	7.50 ± 0.26 ^b	96.25	13925.05	13.92
Control (water)	5.00 ± 0.28 ^c	10.00 ± 0.74 ^c	9.50 ± 0.42 ^c	7.25 ± 0.34 ^d	7.00 ± 0.37 ^c	6.00 ± 0.52 ^b	44.75	6474.24	6.47
P value	0.003*	0.003*	0.000*	0.000*	0.000**	0.027*			
F value	5.460	5.371	25.557	45.769	9.735	3.298			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

Table 51. Yield of different exogenously applied elicitors against major arthropod pest in brinjal of *Kharif* season 2023

Treatments	No. of Pickings Kg/Plot*						Total (kg/plot)	Yield (kg ha ⁻¹)	Yield (ton ha ⁻¹)
	1 st picking	2 nd picking	3 rd picking	4 th picking	5 th picking	6 th picking			
Salicylic Acid @ 50 mg/l	11.50 ± 0.26 ^b	14.00 ± 0.16 ^c	16.50 ± 0.53 ^{bc}	16.75 ± 0.66 ^b	16.25 ± 0.19 ^{ab}	14.75 ± 0.77 ^a	93.00	13454.86	13.45
Jasmonic Acid @ 100 mg/l	17.25 ± 0.55 ^a	18.50 ± 0.12 ^a	22.25 ± 0.60 ^a	21.75 ± 0.44 ^a	18.25 ± 0.61 ^a	14.25 ± 0.84 ^a	112.25	16239.87	16.23
Acetic Acid @ 0.6 ml/l	11.50 ± 0.42 ^b	16.25 ± 0.25 ^b	20.25 ± 0.38 ^{ab}	19.75 ± 0.50 ^{ab}	17.75 ± 0.19 ^a	11.50 ± 0.53 ^{ab}	97.00	14033.56	14.03
Panchagavya @ 5% solution	16.00 ± 0.43 ^a	17.75 ± 0.30 ^{ab}	20.00 ± 0.67 ^{ab}	21.75 ± 0.55 ^a	18.75 ± 0.30 ^a	16.00 ± 0.78 ^a	110.25	15950.52	15.95
Vermicompost @ 5 tonnes/ hectare	14.50 ± 0.48 ^{ab}	17.25 ± 0.41 ^{ab}	19.75 ± 1.11 ^{ab}	19.50 ± 0.74 ^{ab}	14.75 ± 0.19 ^b	13.25 ± 0.81 ^a	99.00	14322.91	14.32
Control (water)	6.25 ± 0.50 ^c	8.00 ± 0.23 ^d	12.00 ± 0.52 ^c	9.00 ± 0.43 ^c	8.00 ± 0.49 ^c	6.75 ± 0.55 ^b	50.00	7233.79	7.23
P value	0.000**	0.000**	0.006*	0.000**	0.000**	0.026*			
F value	12.603	34.987	4.731	11.596	18.765	3.333			
P Value- Probability, F Value - Ratio of two variances, Yield was expressed in kg per hector, PTC - Pretreatment count; DAT – Days after Treatment; ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant									

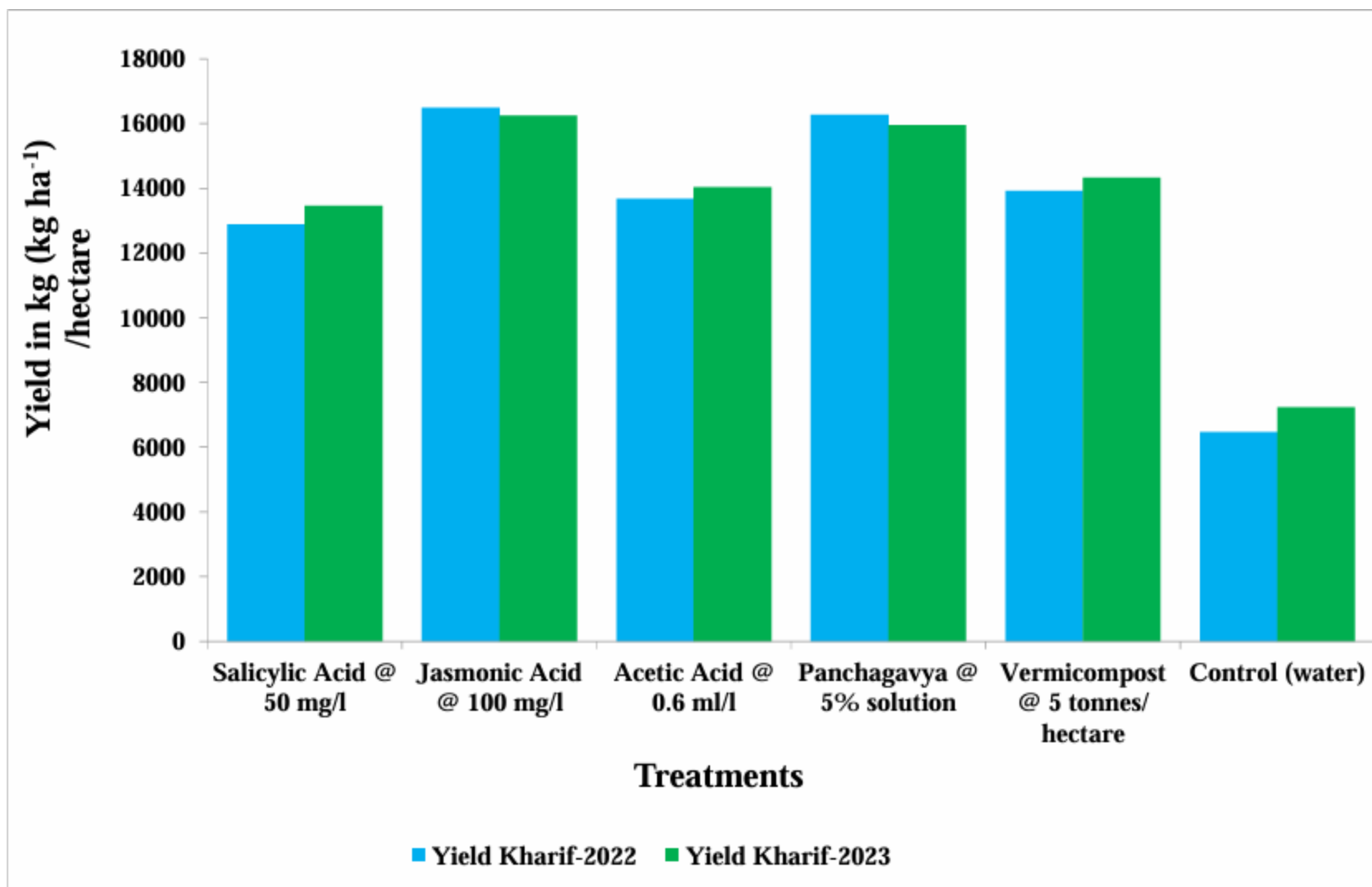


Fig. 44 Yield of different elicitors against major arthropod pest of brinjal of *Kharif* season 2022 and 2023

4.3.7. Biochemical analysis of exogenously applied elicitors against major arthropod pest of brinjal in *Kharif* season 2022.



Plate 7A Lab Chemicals



Plate 7B Plant Samples



Plate 7C Sample Crushing



Plate 7D Extracted Samples

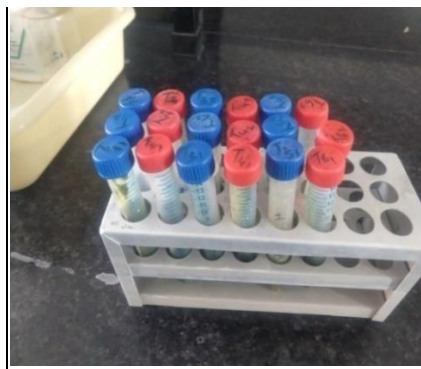


Plate 7E Treatment Labels



Plate 7F pH Adjustment



Plate 7G Centrifuging Samples

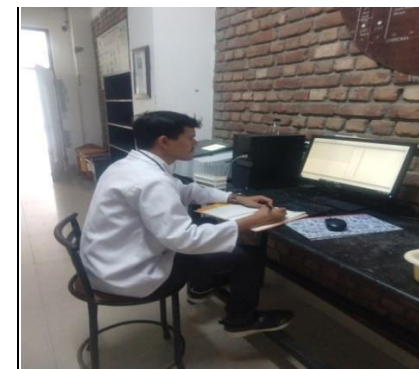


Plate 7H Spectrophotometer Reading

Plate 6. Biochemicals characterization of exogenously applied elicitors

4.3.7.1 Phenol activity

The phenol activity in elicitors of six treatments was differed significantly ($df_{(6,4)}$; $F = 585.476$; $P = 0.000$) during *Kharif* 2022 season. The phenol activity ranged between 80.56 and 105.56 (mg/100g). The data revealed that minimum phenol activity was observed in treatments (T_6) - untreated plots (80.56 ± 0.32 mg/100g) followed by (T_5) - Vermicompost @ 5 tonnes/hectare offering (91.81 ± 0.94 mg/100g). The maximum phenol activity was recorded in treatments (T_4) - Panchagavya 5 % solution (105.56 ± 0.32 mg/100g) which differed significantly with (T_2) - Jasmonic acid @ 395 mg/l (100.98 ± 0.78 mg/100g). The phenol activity was more in high effective treatments as compared to low effective treatments. The sequence of all the treatments from minimum to maximum were (T_6) - untreated plots < (T_5) - Vermicompost @ 5 tonnes/hectare < (T_3) - Acetic acid @ 0.6 ml/l < (T_1) - Salicylic acid @ 50 mg/l < (T_2) - Jasmonic acid @ 395 mg/l < (T_4) - Panchagavya 5 % solution (Table 52, Fig. 45; Plate 7).

4.3.7.2 Protein activity

The protein activity in elicitors of six treatments was differed significantly ($df_{(6,4)}$; $F = 1568.278$; $P = 0.000$) during *Kharif* 2022 season. The protein activity ranged between 88.97 and 118.25 (mg/100g). The data revealed that minimum protein activity was observed in treatments (T_6) - untreated plots (88.97 ± 0.53 mg/100g) which differed significantly with (T_2) - Jasmonic acid @ 395 mg/l (94.72 ± 0.35 mg/100g). The maximum protein activity was recorded in treatments (T_5) - Vermicompost @ 5 tonnes/hectare offering (118.25 ± 0.17 mg/100g) followed by (T_3) - Acetic acid @ 0.6 ml/l (114.27 ± 0.41 mg/100g). The protein activity was more in low effective treatments as compared to high effective treatments. The sequence of all the treatments from minimum to maximum was (T_6) - untreated plots < (T_2) - Jasmonic acid @ 395 mg/l < (T_4) - Panchagavya 5 % solution < (T_1) - Salicylic acid @ 50 mg/l < (T_3) - Acetic acid @ 0.6 ml/l < (T_5) - Vermicompost @ 5 tonnes/hectare (Table 52, Fig. 45; Plate 7).

4.3.7.3 Proline activity

The proline activity in elicitors of six treatments was differed significantly ($df_{(6,4)}$; $F = 186.639$; $P = 0.000$) during *Kharif* 2022 season. The proline activity ranged between

2.10 and 4.89 $\mu\text{moles/g}$. The data revealed that minimum proline activity was observed in treatments (T₆) - untreated plots ($2.10 \pm 0.09 \mu\text{moles/g}$) followed by (T₅) - Vermicompost @ 5 tonnes/hectare ($3.10 \pm 0.12 \mu\text{moles/g}$). The maximum proline activity was recorded in treatments (T₄) - Panchagavya 5 % solution ($4.89 \pm 0.11 \mu\text{moles/g}$) followed by (T₂) - Jasmonic acid @ 395 mg/l ($4.16 \pm 0.08 \mu\text{moles/g}$). The proline activity was more in high effective treatments as compared to low effective treatments. The sequence of all the treatments from minimum to maximum was (T₆) - untreated plots < (T₅) - Vermicompost @ 5 tonnes/hectare < (T₃) - Acetic acid @ 0.6 ml/l < (T₁) - Salicylic acid @ 50 mg/l < (T₂) - Jasmonic acid @ 395 mg/l < (T₄) - Panchagavya 5 % solution (Table 52, Fig. 45; Plate 7).

4.3.7.4 Peroxidase activity

The peroxidase activity in elicitors of six treatments was differed significantly ($df_{(6,4)}$; $F = 126.885$; $P = 0.000$) during *Kharif* 2022 season. The peroxidase activity ranged between 0.90 and 1.31 $\mu\text{M/min/g}$ proteins. The data revealed that minimum peroxidase activity was observed in treatments (T₆) - untreated plots ($0.90 \pm 0.00 \mu\text{M/min/g}$ protein) followed by (T₃) - Acetic acid @ 0.6 ml/l ($0.98 \pm 0.00 \mu\text{M/min/g}$ protein). The maximum peroxidase activity was recorded in treatments (T₂) - Jasmonic acid @ 395 mg/l ($1.31 \pm 0.03 \mu\text{M/min/g}$ protein) which differed significantly with (T₄) - Panchagavya 5 % solution ($1.27 \pm 0.03 \mu\text{M/min/g}$ protein). The peroxidase activity was more in high effective treatments as compared to low effective treatments. The sequence of all the treatments from minimum to maximum were (T₆) - untreated plots < (T₃) - Acetic acid @ 0.6 ml/l < (T₅) - Vermicompost @ 5 tonnes/hectare < (T₁) - Salicylic acid @ 50 mg/l < (T₄) - Panchagavya 5 % solution < (T₂) - Jasmonic acid @ 395 mg/l (Table 52, Fig. 45; Plate 7).

4.3.7.5 Phenylalanine ammonia lyase activity

The PAL activity in elicitors of six treatments was differed significantly ($df_{(6,4)}$; $F = 13160.513$; $P = 0.000$) during *Kharif* 2022 season. The phenylalanine ammonia lyase activity ranged between 20.04 and 38.79 μM cinnamic acid/min/g. The data revealed that minimum phenylalanine ammonia lyase activity was observed in treatments (T₆) - untreated plots ($20.04 \pm 0.06 \mu\text{M}$ cinnamic acid/min/g) followed by (T₃) - Acetic acid @ 0.6 ml/l ($24.13 \pm 0.08 \mu\text{M}$ cinnamic acid/min/g). The maximum phenylalanine ammonia

lyase activity was recorded in treatments (T₂) - Jasmonic acid @ 395 mg/l (38.79 ± 0.03 μ M cinnamic acid/min/g) which differed significantly with (T₄) - Panchagavya 5 % solution (32.17 ± 0.02 μ M cinnamic acid/min/g). The phenylalanine ammonia lyase activity was more in high effective treatments as compared to low effective treatments. The sequence of all the treatments from minimum to maximum were (T₆) - untreated plots < (T₃) - Acetic acid @ 0.6 ml/l < (T₅) - Vermicompost @ 5 tonnes/hectare < (T₁) - Salicylic acid @ 50 mg/l < (T₄) - Panchagavya 5 % solution < (T₂) - Jasmonic acid @ 395 mg/l (Table 52, Fig. 45; Plate 7).

Salicylic acid (SA), ethylene, and jasmonic acid (JA) are three examples of plant hormones that are the primary mediators of herbivore-induced defense. In order to ascertain the mechanism of induced resistance in plants, other related chemicals such as methyl jasmonate, cis-jasmone, and methyl salicylate are used nowadays (Smith *et al.*, 2009, Wu and Baldwin, 2009; Matthes *et al.*, 2010; Venu *et al.*, 2010). Biochemicals such as superoxide dismutase, phenylalanine ammonia lyase, phenol, lipoxygenase, catalase, peroxidase, and ascorbate peroxidase are among the main oxidative enzymes that plants activate in response to insect herbivory, according to studies by (Zhao *et al.*, 2009; War *et al.*, 2012).

The findings complement those of others who have reported increases in phenolic content, indole acetic acid, cytokinin, and macro-micronutrients following panchagavya application. This may be because more nitrogen is allocated to the production of secondary metabolites like phenols, which are the plant's natural defense mechanism (Somasundaram *et al.*, 2004; Zambrano-Moreno *et al.*, 2015).

Recently, 2-hydroxybenzoic acid or salicylic acid was added to the group of plant growth hormones. This significant signal molecule is a member of an exceptionally broad class of plant phenolic compounds that are produced in brinjal and other crops in response to several biotic and abiotic stressors (Bideshki and Arvin, 2010; Miura and Tada, 2014; Shama *et al.*, 2016). Through cell lignifications, wound healing, and the synthesis of secondary metabolites, higher levels of POD activity in response to JA and SA application and/or insect attack will protect plants from the insects, pathogens, and other stresses (Heng-Moss *et al.*, 2004; Rangasamy *et al.*, 2009; Matthes *et al.*, 2010;).

Polyphenol oxidase induction is mediated by increased messenger RNA accumulation, which is characteristic of a number of induced defense proteins. Its systemic purpose is to reduce subsequent herbivore damage rather than wound healing (Constabel *et al.*, 2000; Haruta *et al.*, 2001). Within 10–20 minutes of the isoflavonoids biosynthesis pathway being elicited, the genes encoding L-phenylalanine ammonia-lyase, chalcone synthase, and chalcone reductase were the most quickly active (Salles *et al.*, 2002).

By mediating the octadecanoid and phenylpropanoid pathways, respectively, jasmonic acid and salicylic acid contribute to the defence mechanisms of plants by increasing the concentration of total carotenoids, ascorbic acid, phenolic, polyphenol oxidase and peroxidase, which in turn causes resistant characters in specific varieties (Ranmalbhai, 2014; Gurve, 2016; Swarnam *et al.*, 2016; Kadu, 2018).

Lima *et al.*, (2008) similarly found that organic brinjal plants showed elevated levels of polyphenols and flavonoids. Additionally, it is noted that panchagavya contains calcium and silica derived from cow dung and urine, which are crucial for chlorophyll synthesis. These elements contribute to increased formation of protein and division of cell within the leaves, as highlighted by Natarajan, (2002).

Vermicompost's microbial metabolite provides bioavailable nutrients that foster the growth of these microorganisms in the perfect environment (Nadana *et al.*, 2020). The humoral immune system is made up of a variety of substances that aid in the lysis and clotting processes, including cytokines, cytotoxic proteins, and antibacterial compounds (Cooper *et al.*, 2006).

In breeding programs for brinjal, it is important to not only focus on yield and other traditional attributes but also consider the biochemical compounds present in different genotypes. These genotypes may possess traits that make them resistant to major pests affecting brinjal. By utilizing such genotypes in breeding programs, it becomes possible to develop new varieties of brinjal with enhanced resistance to pests and potentially other desirable traits. Brinjal exhibits varied responses to infestations by its major pests and treatment with elicitors, as reflected activities of defensive enzymes include phenol, L-phenylalanine ammonia-lyase, peroxidase, and proline. These enzymes, along with other defensive components, contribute to the plant's defense opposite to ecological factors.

Brinjal varieties with higher biochemical compounds poses resistance traits. Induced resistance mechanisms help in managing pests, strengthening the plant's defense mechanisms to resist pests. In addition to providing insight on the basic principles of chemical communication and plant-animal co-evolution, a greater comprehension of plant immunity against arthropod herbivores creates new opportunities for crop protection and promotion.

Table 52. Effect of exogenous elicitors inducing plant resistance of healthy leaves of different brinjal treatments

Brinjal Treatments	Phenol content (mg/100g)	Protein content (mg/100g)	Proline content (μmoles/g)	Peroxidase content (μM/min/g protein)	Phenylalanine ammonia-lyase content (μM cinnamic acid/min/g)
Salicylic Acid @ 50 mg/l	98.06 ± 0.63 ^c	104.22 ± 0.10 ^c	3.81 ± 0.11 ^c	1.21 ± 0.04 ^b	31.74 ± 0.21 ^c
Jasmonic Acid @ 100 mg/l	100.98 ± 0.78 ^b	94.72 ± 0.35 ^e	4.16 ± 0.08 ^b	1.31 ± 0.03 ^a	38.79 ± 0.03 ^a
Acetic Acid @ 0.6 ml/l	95.04 ± 0.47 ^d	114.27 ± 0.41 ^b	3.44 ± 0.19 ^d	0.98 ± 0.00 ^d	24.13 ± 0.08 ^e
Panchagavya @ 5% solution	105.56 ± 0.32 ^a	101.62 ± 0.91 ^d	4.89 ± 0.11 ^a	1.27 ± 0.03 ^a	32.17 ± 0.02 ^b
Vermicompost @ 5 tonnes/ hectare	91.81 ± 0.94 ^e	118.25 ± 0.17 ^a	3.10 ± 0.12 ^e	1.06 ± 0.03 ^c	29.21 ± 0.06 ^d
Control (water)	80.56 ± 0.32 ^f	88.97 ± 0.53 ^f	2.10 ± 0.09 ^f	0.90 ± 0.00 ^e	20.04 ± 0.06 ^f
P value	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}
F value	585.476	1568.278	186.639	126.885	13160.513
• Mean of three replicates of each treatment were taken and expressed as per their units • P Value- Probability, F Value - Ratio of two variances, ± Standard Deviation Values, *Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed), NS - Non Significant					

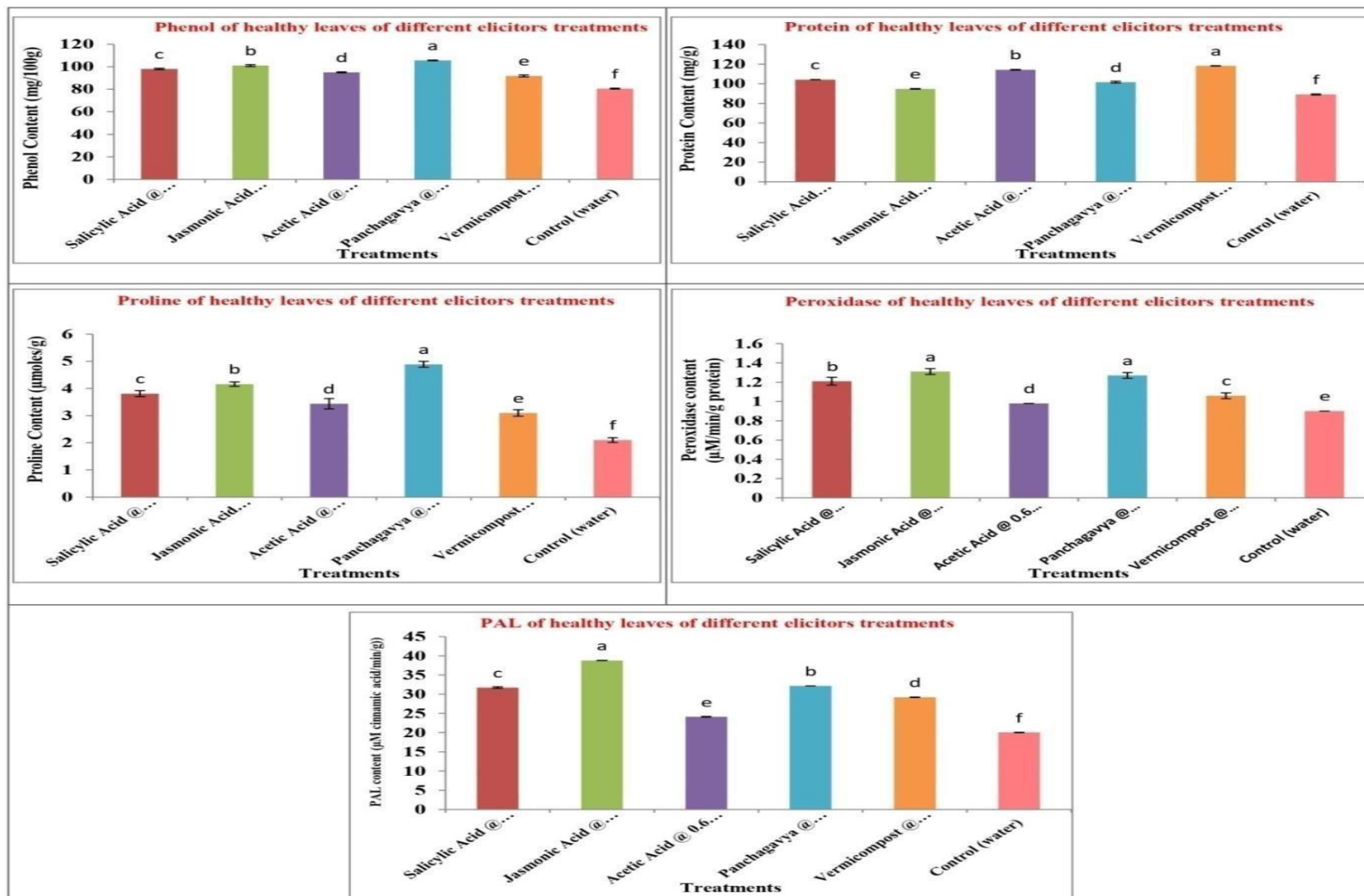


Fig. 45 Biochemical analysis of exogenously applied elicitors

Results of the investigations carried out to study the pest and natural enemy complex of cauliflower, identify the pest incidence on different brinjal varieties and management of major pests are summarized below.

- Data recorded from eight brinjal varieties revealed the presence of four insect pests: jassids (*Amrasca biguttula biguttula*), whitefly (*Bemisia tabaci*), hadda beetle (*Henosepilachna vigintioctopunctata*), and shoot and fruit borer (*Leucinodes orbonalis*) in the brinjal crops grown at the research farm of Lovely Professional University. Among these, Jassid (*Amrasca biguttula biguttula*) and Whitefly (*Bemisia tabaci*) were identified as the major sucking pests, while the chewing pests, *Henosepilachna vigintioctopunctata* and *Leucinodes orbonalis*, occurred at moderate levels. The incidence of aphids (*Aphis gossypii*) was observed at a minor and negligible level.
- Natural enemies found in the ecosystem included predators belonging to Coccinellidae namely *Coccinella septempunctata*, *Brumoides suturalis*, *Menochilus sexmaculatus* and *Hippodamia variegata* species were major natural enemies and minor green lacewings species were observed. Coccinellids effectively predated upon jassid and whitefly (Kumar *et al.*, 2018a; Borkakati *et al.*, 2019).
- Eight brinjal varieties were screened namely (Manjushree, NBH-214, Ajay, Punjab Bharpur, MAHY-91, Navkiran, Nishant and VNR-51C) for their degrees of resistance to insect pests' infestation. Highest infestation was noted on VNR-51C followed by Navkiran was higher as compared to all other varieties which showed varied levels of pest infestation.
- All the eight varieties showed varied levels of pest infestation and VNR-51C showed increased levels of infestation by all four major pest as average mean population of jassid (22.16 jassid/plant), whitefly (23.15 whitefly/ plant), hadda beetle (8.04 hadda beetle/plant) and shoot borer damage (5.21 shoot borer damage/plant) compared to other varieties while NBH-1214 was found resistance as average mean population of jassid (nymph and adult - 9.36 jassid/plant), hadda beetle (grub and adult - 2.72 hadda beetle/plant) and shoot & fruit borer (0.77

- shoot borer damage/plant) while Ajay found resistance for whitefly (adult - 9.13 whitefly/plant).
- Yield was noted among all the eight brinjal varieties in which the maximum fruit yield was obtained from varieties NBH-1214 (17228.00 and 17550.15 kg ha⁻¹) followed by MAHY-91 (16263.50 and 17228.00 kg ha⁻¹) compare to all treatments less yield was obtained from was Navkiran having (12727.62 and 13435.57 kg ha⁻¹) and VNR-51C (11377.31 and 12854.93 kg ha⁻¹) during *Rabi* season 2022 and *Kharif* 2023.
 - A correlation of abiotic factors in relation with all the varieties were noted against major pest in which jassid (nymph and adult) and whitefly (adult) had positive relation with temperature in *Rabi* season 2022 while negative relation with minimum temperature was observed in *Kharif* season 2023. Negative relation with relative humidity and rainfall was observed except few varieties had variation in both the seasons. For hadda beetle (grub and adult) all varieties showed a negative relation with temperature and rainfall while humidity had positive relation with all varieties on hadda beetle (grub and adult) population in *Rabi* season 2022. While in *Kharif* season 2023, all the varieties showed positive relation with temperature on hadda beetle population while minimum temperature, relative humidity and rainfall had negative relation with all varieties except few varieties had variation in *Kharif* season 2023. Next, for shoot borer damage in all the varieties showed positive relation with temperature while negative relation with humidity and rainfall on shoot borer damage population in *Rabi* season 2022. In *Kharif* season 2023, all varieties showed positive relation with maximum temperature on shoot borer damage while minimum temperature, relative humidity and rainfall had negative relation with all varieties.
 - Morphometric characterization of brinjal varieties based on vegetative, flower and fruit characters showed a wide variation in all the varieties with significant difference and on that basis varieties were classified as resistance, tolerant, susceptible or highly susceptible in which NBH-1214, Ajay and MAHY-91 are found tolerant and resistance for all four pest next Manjushree and Punjab Bharpur were recorded as moderately tolerant and tolerant for jassid, whitefly and

shoot borer damage for shoot infestation. Manjushree and Punjab Bharpur found susceptible against hadda beetle percent plant infestation but against shoot damage and fruit borer damage these varieties found moderately resistance. Varieties Navkiran, Nishant and VNR-51C found susceptible to highly susceptible against four major pests.

- Observations on the morphological characters of the varieties under study showed that NBH-1214 and Ajay variety had pale green leaves with strong blade thickness, four to six leaf prickles, prickles on fruit calyx in number (7-10 prickles) and pedicle (1-5 prickles), fruit color Green with white strips and Green-purple-white strips with long fruit shapes as compared to other varieties which make them comparatively more resistant to insect pest incidence.
- Morphological characteristics on brinjal showed that leaf trichomes length had negatively correlated with whitefly population in varieties like Manjushree, NBH-1214, Ajay and while in other varieties leaf trichomes length had positively correlated in Punjab Bharpur, Navkiran followed by Nishant and VNR-51C variety with whitefly population incidence. Maximum length of trichome with its diameter was noted in resistance varieties like NBH-1214 (diameter-25.70 μm , length-525.67 μm) followed by MAHY-91 (diameter-48.60 μm , length-500.00 μm) and Ajay (diameter-35.60 μm , length-496.33 μm), while susceptible varieties Navkiran ($r = 0.874^{\text{NS}}$) followed by Nishant ($r = 0.964^{\text{NS}}$) and VNR-51C had shortest trichome length with (diameter-46.60 μm , length-349.67 μm).
- Analysis of biochemical parameters namely phenols, peroxidase, phenylalanine ammonia lyase, proline and proteins of healthy leaves of different varieties showed that all the varieties showed significant difference on all the biochemical parameters content of the plant which may be one of the factors deciding the insect preference and non-preference on the variety. NBH-1214 recorded higher phenol and peroxidase content while Ajay recorded higher proline and phenylalanine ammonia lyase which adds to its nature of resistance to pest damage and lowest was noted in Navkiran and VNR-51C varieties. Protein was found highest in Navkiran and VNR-51C varieties which showed higher susceptibility against pests. Analysis of many other biochemical parameters like total sugars, glucosinolates content, peroxidase

activity and polyphenol oxidase activity at different age of the crop and in healthy and affected leaves which give a better understanding on the role of plant biochemistry on insect preference.

- All the treatments used were effective against jassid and whitefly caused mortality ranged between 48.88 to 87.31 % reduction over control for jassid and 58.28 to 80.11 % reduction over control for whitefly in both the seasons. Foliar application of *B. bassiana* 1×10^8 conidia/ml @ 10ml/l, showed higher mortality ranged from 43.44 to 71.82 % reduction over control for jassid (nymph and adult) management while *V. lecanii* 1×10^8 conidia/ml @ 10ml/l showed higher mortality ranged from 75.53 to 78.39 % reduction over control for whitefly (adult) management in *Rabi* seasons. In *Kharif* season, NSKE 1% @ 2ml/l showed highest percent reduction over control for management of jassid (nymph and adult) ranged from 61.80 to 74.03% and for whitefly (adult) 74.33 to 80.11 % compared to other treatments.
- All the treatments showed high bioefficacy against hadda beetle (grub and adult) populations providing ranged between 53.70 to 84.56 % reduction over control in both seasons. Foliar application of NSKE 1% @ 2ml/l recorded a higher percentage providing ranged from 80.76 to 84.56 % reduction over control in both the seasons followed by Spinosad 45% SC @ 0.4ml/l which provided 76.43 to 82.24 % reduction over control against hadda beetle (grub and adult) in both *Rabi* and *Kharif* season.
- All the treatments showed high bioefficacy against shoot borer damage providing ranged between 66.82 to 84.61 % reduction over control in both the seasons. Foliar application of Spinosad 45% SC @ 0.4ml/l recorded a higher percentage of mortality ranged from 74.53 to 84.61 % reduction over control in both the seasons followed by NSKE 1% @ 2ml/l which provided 69.85 to 79.92 % reduction over control against shoot % fruit borer beetle in both *Rabi* and *Kharif* season.
- Coccinellids were recorded with highest number in untreated plot with an average mean of (1.98) followed by NSKE 1% @ 2ml/l (1.30) and Spinosad 45% SC @ 0.4ml/l (0.97) treated plots in *Rabi* season 2021 and 2022. In *Kharif* 2022 and 2023

highest number of coccinellids were recorded in treated plots *Metarhizium anisopliae* 1×10^8 conidia/ml @ 10ml/l with an average mean (0.96) followed by untreated plots with average mean number of (0.95), so all the treatments are indicating its safety to natural enemies with nearby population of coccinellids found in all treatments in both seasons.

- The average yield of brinjal in all the biorational treatments are ranged from (5606.19 to 16022.85 kg ha⁻¹) in *Rabi* and *Kharif* seasons. Maximum yield was provided by the treatments Spinosad 45% SC @ 0.4ml/l (14973.95 to 16022.85 kg ha⁻¹) followed by NSKE 1% @ 2ml/l (12369.79 to 15118.63kg ha⁻¹) in both *Rabi* and *Kharif* seasons compare to other biorational treatments.
- In host plant resistance trail all the treatments used were effective against jassid (nymph and adult) and whitefly (adult) caused mortality for jassid ranged between 20.74 to 77.84 % reduction over control and 21.43 to 86.08 % reduction over control for whitefly in both the seasons. Foliar application of Jasmonic Acid @ 100 mg/l showed higher mortality ranged from 58.98 to 77.84 % reduction over control for jassid (nymph and adult) management. While Salicylic Acid @ 50 mg/l showed higher mortality ranged from 37.25 to 86.08 % reduction over control for whitefly(adult) management in both *Rabi* and *Kharif* seasons compare to other elicitors treatments.
- In host plant resistance trail all the treatments showed high bioefficacy against hadda beetle (grub and adult) populations providing ranged between 62.12 to 89.78 % reduction over control in both the seasons. Foliar application of Jasmonic Acid @ 100 mg/l recorded a higher percentage providing ranged from 81.51 to 84.04 % reduction over control in *Rabi* season 2021 and 2022. In *Kharif* 2022 and 2023, Panchagavya @ 5% solution which provided 82.43 to 89.78 % reduction over control against hadda beetle (grub and adult) in first spray. During second spray Jasmonic Acid @ 100 mg/l recorded a higher percentage providing 85.96 % reduction over control in *Kharif* 2023.
- All the treatments showed high efficacy against shoot borer damage providing ranged between 60.43 to 87.05 % reduction over control. Foliar application of Panchagavya @ 5% solution recorded a higher percentage of mortality ranged

- from 80.18 to 87.05 % reduction over control in both *Rabi* and *Kharif* seasons followed by Jasmonic Acid @ 100 mg/l which provided 73.38 to 83.53 % reduction over control against shoot borer damage in both *Rabi* and *Kharif* seasons.
- In host plant resistance trail coccinellids were recorded with highest number in treated plot of Acetic Acid @ 0.6 ml/l (0.22 and 0.88) and Vermicompost @ 5 tonnes/ hectare (0.22 to 0.62) with an average mean of followed by Panchagavya @ 5% solution (0.20 to 0.55) in both *Rabi* and *Kharif* seasons compare to other elicitors treatments and so all the treatments are indicating its safety to natural enemies with nearby population of coccinellids noted in all treatments in both seasons.
 - The average yield of all the brinjal elicited treatments was ranged from (5750.86 to 16493.05 kg ha⁻¹) in both *Rabi* and *Kharif* season. The maximum yield was observed in treatments Panchagavya 5 % solution which provided a yield of (16095.19 and 15661.16 kg ha⁻¹) in *Rabi* 2021 and *Kharif* season 2022 and Jasmonic acid @ 395 mg/l having yield of (16493.05 and 16239.87 kg ha⁻¹) in *Rabi* 2022 and *Kharif* season 2023 compare to other treatments.
 - In host plant resistance trail analysis of biochemical parameters namely phenols, peroxidase, phenylalanine ammonia lyase, proline and proteins of healthy leaves of different varieties showed a significant difference on all the biochemical parameters content of the plant which may be one of the factor deciding the insect preference and non-preference on the treatments Panchagavya @ 5% solution recorded higher phenol (105.56 ± 0.32 mg/100g) and proline content (4.89 ± 0.11 μ moles/g) while Jasmonic Acid @ 100 mg/l recorded higher peroxidase (1.31 ± 0.03 μ M/min/g protein) and phenylalanine ammonia lyase (38.79 ± 0.03 μ M cinnamic acid/min/g) which adds to its nature of resistance to pest damage. Protein was found highest in Vermicompost @ 5 tonnes/ hectare (118.25 ± 0.17 mg/100g) followed by Acetic Acid @ 0.6 ml/l (114.27 ± 0.41 mg/100g) varieties which showed higher susceptibility against pests.

Thus, from the current investigation it could be concluded that integrated utilization of host plant resistance genotypes or varieties, use of biorational

insecticides and elicitors could act as an effective, eco-friendly and economic option for pest management. This will enable us to avoid the problems such as pesticide resistance, pest resurgence, environmental pollution etc., and ensuring safety to non-target organisms. This will help us reduce use of chemical insecticides thereby reducing the pesticide residues in food and associated medical complications leading to sustainable agriculture, ensuring good food and healthy living conditions to life on earth.

BIBLIOGRAPHY

1. Abang, A. F., Srinivasan, R., Kekeunou, S., Yeboah, M., Hanna, R., Lin, M. Y., ... & Bilong, C. F. (2016). Relationship of phenotypic structures and allelochemical compounds of okra (*Abelmoschus* spp.) to resistance against *Aphis gossypii* Glover. *International Journal of Pest Management*, 62(1), 55-63.
2. Abbaszadeh, G., Srivastava, C., & Walia, S. (2014). Insecticidal and antifeedant activities of clerodane diterpenoids isolated from the Indian bhant tree, *Clerodendron infortunatum*, against the cotton bollworm, *Helicoverpa armigera*. *Journal of insect science*, 14(1), 29.
3. Abdel -Raheem, M. A., & Al-Keridis, L. A. (2017). Virulence of three entomopathogenic fungi against whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in tomato crop. *Journal of Entomology*, 14(4), 155-159.
4. Abdel -Razek, A. S., Abd El-Ghany, N. M., Djelouah, K., & Moussa, A. (2017). An evaluation of some eco-friendly biopesticides against *Bemisia tabaci* on two greenhouse tomato varieties in Egypt. *Journal of Plant Protection Research*, 57(1), 9-17.
5. Abrol, D. P., & Singh, J. B. (2003). Relative efficacy of some insecticides against brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen., and their impact on fruit yield. *Journal of Asia-Pacific Entomology*, 6(1), 83-90.
6. Adiroubane, D., & Raghuraman, K. (2008). Plant products and microbial formulation in the management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee.). *Journal of biopesticides*, 1(2), 124-129.
7. Afsana, N., Islam, M. M., Hossain, M. E., Nizam, R., Monalesa, N., Hussain, M. A., & Parvin, S. (2017). Response of tomato (*Solanum lycopersicum* L.) to salicylic acid and calcium. *Journal of Applied Life Sciences International*, 15(2), 1-7.
8. Aghamohammadi, Z., Etesami, H., & Alikhani, H. A. (2016). Vermiwash allows reduced application rates of acaricide azocyclotin for the control of two spotted spider mite, *Tetranychus urticae* Koch, on bean plant (*Phaseolus vulgaris* L.). *Ecological Engineering*, 93, 234-241.

9. Agrawal, A. A., Fishbein, M., Jetter, R., Salminen, J. P., Goldstein, J. B., Freitag, A. E., & Sparks, J. P. (2009). Phylogenetic ecology of leaf surface traits in the milkweeds (*Asclepias* Spp.): chemistry, ecophysiology and insect behavior. *New Phytologist*, 183(3), 848-867.
10. Agricultural Statistics at a Glance (2022). desagri.gov.in was first indexed by Google in May 2022.
11. Ajabe, S. S., Jayewar, N. E., & Gosavi, D. U. (2019). Effect of abiotic factors on incidence of major sucking pests on brinjal. *Journal of Entomology and Zoology Studies*, 7(5), 792-796.
12. Akmal, M., Freed, S., Malik, M. N., & Gul, H. T. (2013). Efficacy of *Beauveria bassiana* (Deuteromycotina: Hypomycetes) against different aphid species under laboratory conditions. *Pakistan Journal of Zoology*, 45(1) 71-78.
13. Alam, S. N., Rashid, M. A., Rouf, F. M. A., Jhala, R. C., Patel, J. R., Satpathy, S., ... & Talekar, N. S. (2003). *Development of an integrated pest management strategy for eggplant fruit and shoot borer in South Asia*. AVRDC-WorldVegetableCenter Shanhua, Taiwan. pp. 66-67.
14. Alavo, T. B. (2015). The insect pathogenic fungus *Verticillium lecanii* (Zimm.) Viegas and its use for pests control: a review.
15. Alawlaqi, M. M., & Alharbi, A. A. (2014). Impact of acetic acid on controlling tomato fruit decay. *Life Sci. J*, 11, 114-119.
16. Alborn, H. T., Jones, T. H., Stenhagen, G. S., & Tumlinson, J. H. (2000). Identification and synthesis of volicitin and related components from beet armyworm oral secretions. *Journal of Chemical Ecology*, 26, 203-220.
17. Ali, A., Javed, K., Javed, H., Kassi, A. K., Aslam, M. R., Hussain, K., & Ahmad, T. (2017a). Screening of different brinjal (*Solanum melongena* L.) cultivars against hadda beetle (*Epilachna vigintioctopunctata* F.) in Pothwar region. *Journal of Entomology and Zoology Studies*, 5(1), 786-791.
18. Ali, A., Shah, L., Rahman, S., Riaz, M. W., Yahya, M., Xu, Y. J., ... & Cheng, B. (2018). Plant defense mechanism and current understanding of salicylic acid and NPRs in activating SAR. *Physiological and molecular plant pathology*, 104, 15-22.

19. Ali, M. A., & El-Saeady, A. A. (1986). Phenology and population dynamics of the melon ladybird beetle *Epilachna chrysomelina* (F) in Egypt (Coleoptera: Coccinellidae). *Agricultural Research Review*, 61:79-191.
20. Ali, S. S., Ahmed, S. S., Rizwana, H., Bhatti, F., Khoso, A., Mengal, M. I., ... & Shahwani, S. A. (2017b). Efficacy of different bio-pesticides against major sucking pests on brinjal under field conditions. *Journal of Basic and Applied Science*, 13, 133-138.
21. Ali, S. S., Sher, A., Ahmed, S. S., Rizwana, H., Siddiqui, S., Ali, S. S., ... & Shah, M. A. (2016). Effect of biopesticides against sucking insect pests of brinjal crop under field conditions. *Journal of Basic & Applied Sciences*, 12.
22. Ali, S. S., Sher, A., Ahmed, S. S., Rizwana, H., Siddiqui, S., Ali, S. S., ... & Shah, M. A. (2016). Effect of biopesticides against sucking insect pests of brinjal crop under field conditions. *Journal of Basic & Applied Sciences*, 12.
23. Alzohairy, M. A. (2016). Therapeutics role of *Azadirachta indica* (Neem) and their active constituents in diseases prevention and treatment. *Evidence-Based Complementary and Alternative Medicine*.
24. Amin, M. R., Afrin, R., Alam, M. Z., Hossain, M. M., & Kwon, Y. J. (2017). Effect of leaf trichomes and meteorological parameters on population dynamics of aphid and jassid in cotton. *Bangladesh Journal of Agricultural Research*, 42: 13-25.
25. Amin, M. R., Roy, M. C., Rahman, M. M., Miah, M. G., Kwon, Y. J., & Suh, S. J. (2015). Foraging and growth responses of cotton armyworm *Spodoptera litura* to the biophysical characteristics of five cotton varieties. *Entomological research*, 45(6), 286- 293.
26. Amin, S. M. R., Alam, M. Z., Rahman, M. M., Hossain, M. M., & Mian, I. H. (2014). Study on morphological characteristics of leaves, shoots and fruits of selected brinjal varieties/lines influencing brinjal shoot and fruit borer infestation. *International journal of economic plants*, 1(May, 1), 001-008.
27. Anam, M., Ahmad, M., & Haque, M. A. (2006). Efficacy of neem oil on the biology and food consumption of Epilaichna beetle, *Epilachna dodecastigma* (Wied.). *Journal of Agriculture and Rural Development*, 4(1), 83-88.

28. Ananda, S. M. R., & Murthy, K. N. K. (2017). Response of finger millet under organic nutrient management in groundnut (*Arachis hypogaea* L.) – Finger millet (*Eleusine coracana* L.) cropping system. *International Journal of Pure & Applied Biosciences*, 5(5), 200-206.
29. Anandhi, P. S. V., & Singh, R. K. (2008). Seasonal incidence and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.). *Journal of Entomological Research*, 33(4), 323-329.
30. Ananthakrishnasamy, S., Sarojini, S., Gunasekaran, G., & Manimegala, G. (2009). Flyash-a lignite waste management through vermicomposting by indigenous earthworms *Lampito mauritii*. *Am Eurasian J Agric Environ Sci*, 5(6), 720-724.
31. Anil, M. & Sharma, P. C. (2010). Bioefficacy of insecticides against *Leucinodes orbonalis* on brinjal. *Journal of environmental biology*, 31(4), 399-402.
32. Anjali, M., Singh, N. P., Mahesh M., & Swaroop, S. (2012). Seasonal incidence and effect of abiotic factors on population dynamics of major insect pests on Brinjal crop. *Journal of Environmental Research and Development*, 7(1), 431-435.
33. Ansari, A. A., & Ismail, S. A. (2012). Role of earthworms in vermitechnology. *Journal of Agricultural Technology*, 8(2):405–415.
34. Ansari, A. M., & Singh, Y. V. (2014). Molecular diversity of brinjal (*Solanum melongena* L. and *S. aethiopicum* L.) genotypes revealed by SSR markers. *Electronic Journal of Plant Breeding*, 5(4), 722-728.
35. Arancon, N. Q., Galvis, P. A., & Edwards, C. A. (2005). Suppression of insect pest populations and damage to plants by vermicomposts. *Bioresource technology*, 96(10), 1137-1142.
36. Ashfaq, M., Muhammad Noor-ul-Ane, M. N. U. A., Khuram Zia, K. Z., Abida Nasreen, N., & Mansoor-ul-Hasan, M. U. H. (2010). The correlation of abiotic factors and physio-morphic characteristics of (*Bacillus thuringiensis*) Bt transgenic cotton with whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) and jassid, *Amrasca devastans* (Homoptera: Jassidae) populations. *African Journal of Agricultural Research*, 5, 3102- 3107.
37. Ashraf, H. & Javaid, A. (2012). Evaluation of antifungal activity of Meliaceae family against *Macrophomina phaseolina*. *Mycopath*, 5(2), 81–84.

38. Aslam, M., & Saeed, N. A. (2004). Comparative resistance of different cotton genotypes against sucking insect pest complex of cotton. *Sarhad Journal of Agriculture (Pakistan)*, 20(3), 441–445.
39. Awal, A. (2012). *Efficacy of some prospective insecticides against major insect pest of brinjal and their compatibility with biological control agents* (Doctoral dissertation, Ph.
40. Awang, N. A., Mohd, R. I., Dzolkhifli, O., & Islam, M. R. (2015). Comparative study of the application of jasmonic acid and pesticide in chilli: effects on physiological activities, yield and viruses control. *Bioscience Journal*, 31(3), 672-681.
41. Ayyasamy, R., & Baskaran, P. (2005). Influence of certain leaf characters of brinjal accessions with incidence of *Bemisia tabaci*. *Journal of Food, Agriculture and Environment*, 3, 333–334.
42. Bailey, J., Scott-Dupree, C., Harris, R., Tolman, J., & Harris, B. (2005). Contact and oral toxicity to honey bees (*Apis mellifera*) of agents registered for use for sweet corn insect control in Ontario, Canada. *Apidologie*, 36(4), 623-633.
43. Baker, M. A., Makhdom, A. H., Nasir, M., Imran, A., Ahmad, A. & Tufail, F. (2016). Comparative efficacy of synthetic and botanical insecticides against sucking insect pest and their natural enemies on cotton crop. *Journal of Mountain Area Research*, 1, 1-4. doi: <https://doi.org/10.53874/jmar.v1i0.6>
44. Barak, J. D., Jahn, C. E., Gibson, D. L., & Charkowski, A. O. (2007). The role of cellulose and O-antigen capsule in the colonization of plants by *Salmonella enterica*. *Molecular Plant-Microbe Interactions*, 20(9), 1083-1091.
45. Bardin, M., Fargues, J., & Nicot, P. C. (2008). Compatibility between biopesticides used to control grey mould, powdery mildew and whitefly on tomato. *Biological Control*, 46(3), 476-483.
46. Barik, S., Dash, L., Das, M. P., Panigrahi, T., Naresh, P., Kumari, M., ... & Acharya, G. C. (2020). Screening of brinjal (*Solanum melongena* L.) genotypes for resistance to spotted beetle, *Henosepilachna vigintioctopunctata* (Coccinellidae, Coleoptera). *Journal of Entomology and Zoology Studies*, 8(2), 297-301.

47. Barik, S., Dash, L., Das, M. P., Panigrahi, T., Naresh, P., Kumari, M., Sahu, G. S. & Acharya, G. C. (2020). Screening of brinjal (*Solanum melongena* L.) genotypes for resistance to spotted beetle, *Henosepilachna vigintioctopunctata* (Coccinellidae, Coleoptera). *Journal of Entomology and Zoology Studies*, 8(2), 297-301.
48. Bayram, A., & Tonga, A. (2018). cis-Jasmone treatments affect pests and beneficial insects of wheat (*Triticum aestivum* L.): the influence of doses and plant growth stages. *Crop Protection*, 105, 70-79. doi 10.1016/j.cropro.2017.11.011.
49. Beaulah, A. (2001). *Growth and development of moringa (Moringa oleifera Lam) under organic system of culture* (Doctoral dissertation, Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India).
50. Belina F, David, P.M.M & Pillai, M.A.K (2005). Effect of Cow's urine (Panchagavya) on brinjal pest *Ephilachna vigintipunctate* Fab. and *Leucinodes orovonahis* Guen. *Madras Agricultural Journal*, 92, 358-363.
51. Bera, S., Blundell, R., Liang, D., Crowder, D. W., & Casteel, C. L. (2020). The oxylipin signaling pathway is required for increased aphid attraction and retention on virus- infected plants. *Journal of chemical ecology*, 46, 771-781.
52. Berani, N. K., & Patel, J. J. (2020). Population fluctuation of sucking insect pest of brinjal and its relation with weather parameters. *Journal of Entomology and Zoology Studies*, 8(6), 1613-1617.
53. Bernsdorff, F., Döring, A. C., Gruner, K., Schuck, S., Bräutigam, A., & Zeier, J. (2016). Pipecolic acid orchestrates plant systemic acquired resistance and defense priming via salicylic acid-dependent and-independent pathways. *The Plant Cell*, 28(1), 102-129.
54. Bhagat, K. C., & Munshi, S. K. (2004). Host preference of spotted leaf-eating beetle, *Henosepilachna vigintioct Henosepilachna vigintioctopunctata* (Fabr.) on different brinjal varieties. *Pest Management and Economic Zoology*, 12(1), 77-81.
55. Bhandurge S.S. (2012). Field life tables and mortality factors of *L. orbonalis* Guen. on brinjal cultivars. *M.Sc. (Agri.) Thesis* submitted to VNMKV, Parbhani.
56. Bharadiya, A. M., & Patel, B. R. (2005). Succession of insect pests of brinjal in north Gujarat. *Pest Management and Economic Zoology*, 13(1), 159-161.

57. Bharat. L., Bhadauria, N. S., Singh, P., & Tomar, S. P. S. (2019). Seasonal incidence of sucking insect pests in brinjal and their natural enemies in gird region of Madhya Pradesh, India. *Journal of Pharmacognosy and Phytochemistry*, 8(4), 2077-2079.
58. Bharati, S. M. (2005). Role of organics and indigenous components against *Spodoptera litura* (Fab.) in groundnut and soybean. *M. Sc. (Agri.) Thesis*. University of Agricultural Sciences, Dharwad, 136p.
59. Bhasker, P., Gupta, P. K., & Sharma, H. P. (2020). Role of salicylic acid on growth, yield, quality and disease pest reaction of onion (*Allium cepa* L.) cv. agrifound light red. *SAARC Journal of Agriculture*, 18(1), 39-49.
60. Bhat, M. R., & Limaye, S. R. (2012). Nutrient status and plant growth promoting potential of prepared vermicompost. *International Journal of Environmental Sciences*, 3(1), 312-321.
61. Bhavanam, S., & Stout, M. (2021). Seed treatment with jasmonic acid and methyl jasmonate induces resistance to insects but reduces plant growth and yield in rice, *Oryza sativa*. *Frontiers in Plant Science*, 12, 691768. doi 10.3389/fpls.2021.691768
62. Bhonwong, A., Stout, M. J., Attajarusit, J., & Tantasawat, P. (2009). Defensive role of tomato polyphenol oxidases against cotton bollworm (*Helicoverpa armigera*) and beet armyworm (*Spodoptera exigua*). *Journal of Chemical Ecology*, 35, 28-38.
63. Bideshki, A., & Arvin, M. J. (2010). Effect of salicylic acid (SA) and drought stress on growth, bulb yield and allicin content of garlic (*Allium sativum*) in field. *Plant Ecophysiology*, 2(2), 73-81.
64. Bilal, M., Javed, K., & Javed, H. (2017). Host suitability of brinjal Jassid *Amrasca bigutulla bigutulla* (Cicadellidae: Hemiptera) among different aubergine genotypes in Pothwar region. *Journal of Entomology and Zoology Studies*, 5(2), 174-179.
65. Billard, V., Etienne, P., Jannin, L., Garnica, M., Cruz, F., Garcia-Mina, J. M., ... & Ourry, A. (2014). Two biostimulants derived from algae or humic acid induce similar responses in the mineral content and gene expression of winter oilseed rape (*Brassica napus* L.). *Journal of plant growth regulation*, 33, 305-316. doi: 10.1007/s00344-013-9372-2.

66. Biondi, A., Mommaerts, V., Smaghe, G., Vinuela, E., Zappala, L., & Desneux, N. (2012). The non-target impact of spinosyns on beneficial arthropods. *Pest management science*, 68(12), 1523-1536.
67. Birjhu, K. L., Bhagat, P. K., Painkra, G. P., & Tiwari, J. K. (2020). Efficacy of newer insecticides against hadda beetle (*Epilachna vigintioctopunctata* Fab.) in spine gourd (*Momordica dioica* Roxb.). *Journal of Entomology and Zoology Studies*, 8(5): 1929- 1933.
68. Birjhu, L. S., Yadav, S., & Kashyap, S. (2023). Bio-efficacy of newer insecticides against hadda beetle (*Epilachna vigintioctopunctata* Fab.) (Grub) in spine gourd under laboratory condition. *The Pharma Innovation Journal*, 12(7), 3081-3083.
69. Birkett, M. A., Campbell, C. A., Chamberlain, K., Guerrieri, E., Hick, A. J., Martin, J. L.... & Woodcock, C. M. (2000). New roles for cis-jasmone as an insect semiochemical and in plant defense. *Proceedings of the National Academy of Sciences*, 97(16), 9329-9334.
70. Birla, M. (2011). *Studies on insect pest complex of brinjal, Solanum melongena (Linn.) and their management. MSc (Agri)* (Doctoral dissertation, Thesis submitted to JNKVV Jabalpur (MP), pp.172.
71. Bjorkman, C., & Ahrne, K. (2005). Influence of leaf trichome density on the efficiency of two polyphagous insect predators. *Entomologia experimentalis et applicata*, 115(1), 179- 186.
72. Boomiraj, K., Christopher Louduraj, A., Pannesrselvam, S., Somasundram, E., & Singaram, P. (2004). Insect incidence in bhendi as influenced by application of organic manure, panchagavya and herbal leaf extract spray. In *Proceedings. National seminar. Operational methodology and packages of practice in organic farming. 7th-9th October. Bangalore* (pp. 141-143).
73. Boraiah, B., Devakumar, N., Palanna, K. B., & Shubha, S. (2018). Growth and yield of organic capsicum (*Capsicum annuum* L. var. grossum) as influenced by different sources, levels of organic manures and panchagavya application. *Thunen Report*, 54(1), 451-454.

74. Borkakati, R. N., Venkatesh, M. R., & Saikia, D. K. (2019). Insect pests of Brinjal and their natural enemies. *Journal of Entomology and Zoology Studies*, 7(1), 932-937.
75. Boughton, A. J., Hoover, K., & Felton, G. W. (2005). Methyl jasmonate application induces increased densities of glandular trichomes on tomato, *Lycopersicon esculentum*. *Journal of Chemical Ecology*, 31, 2211-2216.
76. Brueske, C. H. (1980). Phenylalanine ammonia lyase activity in tomato roots infected and resistant to the root-knot nematode, *Meloidogyne incognita*. *Physiological Plant Pathology*, 16(3), 409-414.
77. Bruessow, F., Gouhier-Darimont, C., Buchala, A., Metraux, J. P., & Reymond, P. (2010). Insect eggs suppress plant defence against chewing herbivores. *The Plant Journal*, 62(5), 876-885.
78. Bruinsma, M., Van Dam, N. M., Van Loon, J. J., & Dicke, M. (2007). Jasmonic acid- induced changes in Brassica oleracea affect oviposition preference of two specialist herbivores. *Journal of Chemical Ecology*, 33, 655-668.
79. Carr, J. P., Lewsey, M. G., & Palukaitis, P. (2010). Signaling in induced resistance. *Advances in Virus Research*, 76, 57-121.
80. Chakraborti, S., & Sarkar, P. (2011). Management of *Leucinodes orbonalis* Guenee on eggplants during the rainy season in India. *Journal of Plant Protection Research*, 51(4) 325-328. doi: 10.2478/v10045-011-0053-5
81. Chandrakumar, H. L., Kumar, C. A., Kumar, N. G., Chakravarthy, A. K., & Raju, T. P. (2008). Seasonal occurrence of major insect pests and their natural enemies on brinjal. *Current biotica*, 2(1), 66-69.
82. Chandrashekhar, C. H., Malik, V. S., & Ram Singh, R. S. (2008). Morphological and biochemical factors of resistance in eggplants against *Leucinodes orbonalis* (Lepidoptera: Pyralididae). *Entomologia Generalis*, 31(4), 337-45.
83. Chandrashekharaiyah, M., Satish, S. C., Vasudev, K., Arya, V. V., & Narasimhamurthy, G. M. (2015). Efficacy of plant and aboriginal preparations against diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). *Journal of Entomology and Zoology Studies*, 3(4), 18-23.

84. Chandravanshi, D. K., Tomar, R. K. S., Awasthi, A. K., & Kerketta, A. (2019). Field efficacy of different insecticides and bio-pesticides against okra shoot and fruit borer. *Journal of Pharmacognosy and Phytochemistry*, 8(1), 2623-2625.
85. Channe, J.B., More, N.V., & Kadam, R.S. (2013). Assortment of genetic diversity in brinjal (*Solanum melongena*) genotypes using ISSR markers. *Indian Journal of Applied Research*, 3(6): 44-46.
86. Chatterjee, S., Kundu, S. S., Chettri, D., & Mukhopadhyay, A. K. (2018). Population dynamics of sucking pests in brinjal ecosystem under new gangetic alluvial zone. *Journal of Entomology and Zoology Studies*, 6, 2157-2161.
87. Chauhan, A., & Joshi, P. C. (2010). Composting of some dangerous and toxic weeds using *Eisenia foetida*. *Journal of American Science*, 6(3), 1-6.
88. Chen D, Shao M, Sun S, Liu T, Zhang H, Qin N, Zeng R and Song Y (2019) Enhancement of Jasmonate-Mediated Antiherbivore Defense Responses in Tomato by Acetic Acid, a Potent Inducer for Plant Protection. *Frontiers in plant science*, 10, 764. doi: 10.3389/fpls.2019.00764
89. Cheng, A. X., Xiang, C. Y., Li, J. X., Yang, C. Q., Hu, W. L., Wang, L. J., ... & Chen, X. Y. (2007). The rice (E)- β -caryophyllene synthase (OsTPS3) accounts for the major inducible volatile sesquiterpenes. *Phytochemistry*, 68(12), 1632-1641.
90. Chinard, F. P. (1952). Photometric estimation of proline and ornithine. *Journal of Biological Chemistry*, 199, 91-95.
91. Choudhary B (1976). Vegetables 4th edition, National Book Trust, New Delhi, 50-58.
92. Choudhary, B., & Gaur, K. (2009). *The development and regulation of Bt brinjal in India (Eggplant/Aubergine)*. Ithaca: International Service for the Acquisition of Agri-biotech Applications. 38. Ithaca, NY.
93. Choudhary, G. L., Sharma, S. K., Singh, K. P., Choudhary, S., & Bazaya, B. R. (2017). Effect of Panchagavya on Growth and Yield of Organic black gram [*Vigna mungo* (L.) Hepper]. *International Journal of Current Microbiology and Applied Sciences*, 6(10), 1627-1632.

94. Chowdary, L. R., Bheemanna, M., & Kumar, L. R. (2010). Bioefficacy of rynaxypyr (Coragen) 20 SC against fruit borer *Helicoverpa armigera* (Hubner) in okra. *International Journal of Plant Protection*, 3(2), 379-381.
95. Chu, C. C., Natwick, E. T., Chen, T. Y., & Henneberry, T. J. (2003). Analyses of cotton leaf characteristics effect on *Bemisia tabaci* (Homoptera: Aleyrodidae) biotype B colonization on cotton in Arizona and California. *Southwestern Entomologist*, 28(4), 235- 240.
96. Constabel, C. P., Yip, L., Patton, J. J., & Christopher, M. E. (2000). Polyphenol oxidase from hybrid poplar. Cloning and expression in response to wounding and herbivory. *Plant physiology*, 124(1), 285-296.
97. Cooper, E. L., Kvell, K., Engelmann, P., & Nemeth, P. (2006). Still waiting for the toll?. *Immunology letters*, 104(1-2), 18-28.
98. Cruz, L. R. D. D., Ludwig, F., Steffen, G. P. K., & Maldaner, J. (2018). Development and quality of gladiolus stems with the use of vermicompost and *Trichoderma* sp. in substrate (1). *Ornamental Horticulture*, 24, 70-77.
99. Dahal, B. R., Rijal, S., Poudel, N., Gautam, B., & Neupane, R. B. (2020). Influence of different bio-pesticides and mulching in management of Okra Jassids *Amrasca biguttula biguttula* (Hemiptera: Cicadellidae) in Chitwan district of Nepal. *Cogent Food & Agriculture*, 6(1), 1829271.
100. Dahatonde, J. A., Pandya, H. V., Raut, S. B., & Patel, S. D. (2014). Screening of some genotypes of brinjal for their relative resistance against jassid and whitefly, *Asian Journal of Bio Science*, 9, 137-138.
101. Dar, S. A. (2017b). Biochemicals mode of defense against insect pests. *Book INSECTS. International Research Publication House; B-2/84, Ground Floor, Rohini Sector-16, Delhi-110089, India*, 397-409.
102. Dar, S. A., Wani, A. R., Rather, B. A., Parey, S. H., & Kandoo, A. (2017a). Biochemical basis of resistance in brinjal genotypes against shoot and fruit borer (*Leucinodes Orbonalis*, Guenee). *Chemical Science Review and Letters*, 6(23), 1931-1940.

103. Das, A., Dey, U., Baiswar, P., Pande, R., Ramkrushna, G. I., Layek, J., ... & Prakash, N. (2018). Development of spray schedule involving commercial and indigenous biopesticides for insect pest and disease management in soybean crop. *Innovative Farming*, 3(1), 11-18.
104. Das, S., Hussain, N., Gogoi, B., Buragohain, A. K., & Bhattacharya, S. S. (2017). Vermicompost and farmyard manure improves food quality, antioxidant and antibacterial potential of *Cajanus cajan* (L. Mill sp.) leaves. *Journal of the Science of Food and Agriculture*, 97(3), 956-966.
105. Dash, S. P., Singh, J., & Sharma, D. (2019). Morphological characterization of brinjal (*Solanum melongena* L.) germplasm. *Journal of Pharmacognosy and Phytochemistry*, 8(2), 1574-1578.
106. Datta, S., Singh, J., Singh, S., & Singh, J. (2016). Earthworms, pesticides and sustainable agriculture: a review. *Environmental Science and Pollution Research*, 23(9), 8227-8243.
107. Dela, M. A., Koffivi, K. G., Komina, A., Arnaud, A., Philippe, G., & Adole, G. I. (2014). Evaluation of neem leaves-based preparations as insecticidal agents against the green peach aphid, *Myzus persicae* (Sternorrhyncha: Aphididae). *African Journal of Agricultural Research*, 9(17), 1344-1352.
108. Deole, S. (2015). Population dynamics of major insect pests of brinjal crop in summer season. *Journal of Hill Agriculture*, 6(2), 180-183.
109. Deshmukh, R. M., & Bhamare, V. K. (2006). Field evaluation of some insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. *International Journal of Agricultural Sciences*, 2(1), 247-249.
110. Devi, P. (2013). *Population dynamics and management of major insect pests on brinjal* (Doctoral dissertation, M. Sc. Thesis IGKV, Raipur. pp: 52).
111. Devi, P., Gawde, P. & Koshta, V. K. (2015). Screening of some brinjal cultivars for resistance to shoot and fruit borer (*Leucinodes orbonalis* Guenee). *The Bioscan*, 10(1), 247-251.

112. Devi, P., Sahu, T. K., Ahirwar, R. B. & Kostha, V. K. (2014). Field evaluation of insecticides for management of shoot and fruit borer, *Leucinodes orbonalis* Guenee in Brinjal. *International Quarterly Journal of Environmental Sciences*, 6(1), 463-466.
113. Dharmendar Singh, D. S., Jaglan, R. S., & Ram Singh, R. S. (2002). Leaf morphological characteristics of brinjal in relation to whitefly incidence. *Haryana Journal of Horticultural Sciences*, 31(3/4), 289-291.
114. Docimo, T., Francese, G., Ruggiero, A., Batelli, G., De Palma, M., Bassolino, L., ... & Tucci, M. (2016). Phenylpropanoids accumulation in eggplant fruit: characterization of biosynthetic genes and regulation by a MYB transcription factor. *Frontiers in Plant Science*, 6, 1233. doi: 10.3389/fpls.2015.01233
115. Dorna, H., Qi, Y., & Szopinska, D. (2018). The effect of acetic acid, grapefruit extract and selected essential oils on germination, vigour and health of carrot (*Daucus carota* L.) seeds. *Acta Scientiarum Polonorum. Hortorum Cultus*, 17(2), 27–38.
116. Doshi, K. M. (2004). Influence of biochemical factors on the incidence of shoot and fruit borer infestation in eggplant. *Capsicum & Eggplant News letter*, 23, 145-48.
117. Dripps, J., Olson, B., Sparks, T., & Crouse, G. (2008). Spinetoram: how artificial intelligence combined natural fermentation with synthetic chemistry to produce a new spinosyn insecticide. *Plant Health Progress*, Php-2008-0822-01-Ps.
118. Driver, F., Milner, R. J., & Trueman, J. W. (2000). A taxonomic revision of *Metarhizium* based on a phylogenetic analysis of rDNA sequence data. *Mycological research*, 104(2), 134-150.
119. Durak, A., Altuntaş, O., Kutsal, I. K., Işık, R., & Karaat, F. E. (2017). The effects of vermicompost on yield and some growth parameters of lettuce. *Turkish Journal of Agriculture-Food Science and Technology*, 5(12), 1566-1570.
120. Durrant, W. E., & Dong, X. (2004). Systemic acquired resistance. *Annual Review of Phytopathology*, 42, 185-209.

121. Dutt, U. (2007). Mealy bug infestation in Punjab: Bt. cotton falls flat. *Mealy Bug Infestation in Punjab: Bt. Cotton Falls Flat*. Kheti Virasat Mission. Jaitu, Faridkot district based environmental NGO in Punjab, 2007.
122. Dutta, N. K., Alam, S. N., Mahmudunnabi, M., Amin, M. R. & Kwon, Y. J. (2017). Effect of insecticides on population reduction of sucking insects and lady bird beetle in eggplant field. *Bangladesh Journal of Agricultural Research*, 42(1), 35-42.
123. Ebrahimi, M., Souri, M. K., Mousavi, A., & Sahebani, N. (2021). Biochar and vermicompost improve growth and physiological traits of eggplant (*Solanum melongena* L.) under deficit irrigation. *Chemical and Biological Technologies in Agriculture*, 8, 1- 14.
124. Elanchezhyan, K., Baskaran, R. K., & Rajavel, D. S. (2008). Field screening of brinjal varieties on major pests and their natural enemies. *Journal of Biopesticides*, 1(2), 113- 120.
125. Elanchezhyan, K., Baskaran, R. K., & Rajavel, D. S. (2009). Bio-chemical basis of resistance in brinjal genotypes to shoot and fruit borer, *Leucinodes orbonalis* Guen. *Journal of Entomological Research*, 33(2), 101-104.
126. El-Saidy, A. E., & El-Hai, K. M. A. (2016). Effect of some evaporation matters on storability of sunflower (*Helianthus annuus* L.) seed. *Pakistan Journal of Biological Sciences: PJBS*, 19(6), 239-249.
127. Elteraifi, I. E., & Hassanali, A. (2011). Oil and Azadirachtin contents of neem (*Azadirachta indica* A. Juss) seed kernels collected from trees growing in different habitats in Sudan. *International Journal of Biological and Chemical Sciences*, 5(3), 1063–1072.
128. El-Wakeil, N. E., & Volkmar, C. (2012). Effect of jasmonic application on economically insect pests and yeald in spring wheat. *Gesunde Pflanzen*, 64(3), 107–116 doi 10.1007/s10343-012-0278-x.
129. El-Wakeil, N. E., Volkmar, C., & Sallam, A. A. (2010). Jasmonic acid induces resistance to economically important insect pests in winter wheat. *Pest Management Science: Formerly Pesticide Science*, 66(5), 549-554.

130. Erb, M., & Reymond, P. (2019). Molecular interactions between plants and insect herbivores. *Review of Plant Biology*, 70, 527-557. doi: 10.1146/annurev-arplant-050718-095910.
131. Esakkiammal, B., Lakshmibai, L., & Sornalatha, S. (2015). Studies on the combined effect of vermicompost and vermiwash prepared from organic wastes by earthworms on the growth and yield parameters of *Dolichous lab lab*. *Asian Journal of Pharmaceutical Science and Technology*, 5(4), 246-252.
132. Faize, L., & Faize, M. (2018). Functional analogues of salicylic acid and their use in crop protection. *Agronomy*, 8(1), 5.
133. Fan, J., Zhang, X. Y., Sun, X. Z., & Xu, B. Y. (2020). Effect of methyl jasmonate on aphid resistance of chrysanthemum. *Ying Yong Sheng tai xue bao= The Journal of Applied Ecology*, 31(12), 4197-4205.
134. Gautam S., Tomar S. P. S., Singh P. D., Suryawanshi D. K. & Singh U. C. (2019a) Screening of brinjal (*Solanum melongena* L.) Varieties against insect pest complex. *International Journal of Agriculture Sciences*, 11(7), 8180-8182.
135. Gautam, M., Kafle, S., Regmi, B., Thapa, G., & Paudel, S. (2019b). Management of brinjal fruit and shoot borer (*Leucinodes orbonalis* Guenee) in Nepal. *Acta Scientific Agriculture*, 3(9), 188-195.
136. Gawade, B., & Sirohi, A. (2011). Induction of Resistance in Eggplant (*Solanum melongena*) by Salicylic Acid against Root-Knot Nematode, *Meloidogyne incognita*. *Indian Journal of Nematology*, 41(2), 201-205.
137. Gayakwad, V. (2012). Studies on Insect Pest Complex of Brinjal, *Solanum melongena* and their management M.Sc. (Ag.) Thesis submitted to JNKVV Jabalpur (M.P.).
138. Ghasem, S., Morteza, A. S. & Maryam, T. (2014). Effect of organic fertilizer on cucumber (*Cucumis sativus*) yield. *International Journal of Agriculture and Crop Sciences*. 7(11): 808-814.
139. Ghosh, S. K., & Chakraborty, G. (2012). Integrated field management of *Henosepilachna vigintioctopunctata* (Fabr.) on potato using botanical and microbial pesticides. *Journal of biopesticides*, 5, 151-154.

140. Ghosh, S. K., & Senapati, S. K. (2001b). Biology and seasonal fluctuation of *Henosepilachna vigintioctopunctata* Fabr. on brinjal under Terai region of West Bengal. *Indian Journal of Agricultural Research*, 35(3), 149-154.
141. Ghosh, S.K (2014). Incidence of white fly (*Bemisia tabaci* Genn.) and their sustainable management by using biopesticides. *Building Organic Bridges*, 2, 623-626.
142. Ghosh, U. J., & Negi, D. S. (2020). Evaluation of botanicals matured in dairy animals pee alone and a long with panchagavya against brinjal shoot and natural product drill. *The American Journal of Agriculture and Biomedical Engineering*, 2(11), 21-23.
143. Gokila, G., Premalatha, K., Chinniah, C., Shanthi, M., Nalini, R., & Vellaikumar, S. (2021). Field assessment of elicitors on rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) (Pyralidae: Lepidoptera) and coccinellid population in rice ecosystem. *Journal of Entomology and Zoology Studies*, 9(1), 1104.
144. Gokulapriya, G., Chandrasekaran, M., Devi, A. N., & Indhumathi, K. (2021). Study on biochemical basis of resistance in brinjal accessions against shoot and fruit borer, *Leucinodes orbonalis* Guenee. *The Pharma Innovation Journal*, 10(12), 1862-1866.
145. Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John Wiley & Sons.
146. Gopalan, C., Rama Sastri, B. V., & Balasubramanian, S. (2007). Nutritive Value of Indian foods, published by National institute of Nutrition (NIN). *ICMR (Indian Council of Medical Research)*.
147. Gore, N. S., & Sreenivasa, M. N. (2011). Influence of liquid organic manures on growth, nutrient content and yield of tomato (*Lycopersicon esculentum* Mill.) in the sterilized soil. *Karnataka Journal of Agricultural Sciences*, 24(2), 153-157.
148. Gowrish, K. R., Ramesha, B., & Ushakumari, R. (2015). Biorational management of major pests of brinjal. *Indian Journal of Entomology*, 77(1), 51-55.
149. Gudeta, K., Julka, J. M., Kumar, A., Bhagat, A., & Kumari, A. (2021). Vermiwash: An agent of disease and pest control in soil, a review. *Heliyon*, 7, e06434.

150. Gullo, M., Verzelloni, E., & Canonico, M. (2014). Aerobic submerged fermentation by acetic acid bacteria for vinegar production: Process and biotechnological aspects. *Process Biochemistry*, 49(10), 1571-1579.
151. Gupta, P. K., Singh, A. K., Benjamin, J. C., Masih, H., Singla, A., Ojha, S. K., & Ramteke, P. W. (2018). Study of Vermicompost and Vermiwash Produced from Cow Manure and Rice Bran Waste on the Physiological Growth of *Abelmoschus esculentus* L. *International Journal of Current Microbiology and Applied Sciences*, 7(8), 1447-1464.
152. Gupta, S., & Yadav, S. (2016). Immuno-defense strategy in earthworms: a review article. *International Journal of Current Microbiology and Applied Sciences*, 5, 1022-1035.
153. Gupta, Y. C., & Kauntey, R. P. S. (2008). Studies on fruit characters in relation to infestation of shoot and fruit borer, *Leucinodes orbonalis* Guen. in brinjal, *Solanum melongena* Linn. *Journal of Entomological Research*, 32(2), 119-123.
154. Gurve S. W. (2016). Mechanism of resistance and management of okra shoot and fruit borer, *Earias vittella* (Fabricius). Ph.D. Thesis submitted to MPKV, Rahuri (Maharashtra), India, 1-186.
155. Habibi, G. (2012). Exogenous salicylic acid alleviates oxidative damage of barley plants under drought stress. *Acta Biologica Szegediensis*, 56(1), 57-63.
156. Halder, J., Kushwaha, D., Rai, A. B., Singh, A. & Singh. B. (2017). Potential of entomopathogens and neem oil against two emerging insect pests of vegetables. Indian. *Journal of Agricultural Sciences*, 87(2), 220-224.
157. Halder, J., Majumder, S., & Pandey, K. K. (2023). Whether the addition of neem oil increases the bioefficacy of entomopathogenic fungi against sucking pests? A case study from eggplant ecosystem. *Munis Entomology & Zoology*, 18(1), 409-417.
158. Hammerschmidt, R., Nuckles, E. M., & Kuc, J. (1982). Association of enhanced peroxidase activity with induced systemic resistance of cucumber to *Colletotrichum lagenarium*. *Physiological Plant Pathology*, 20(1), 73-82.

159. Hanif, M. U., Raza, A. B. M., Majeed, M. Z., Arshad, M., & Ullah, M. I. (2021). Laboratory evaluation of selected differential chemistry and botanical insecticides against hadda beetle *Epilachna vigintioctopunctata* Fabricius (Coleoptera: Coccinellidae). *Punjab University Journal of Zoology*, 36(2), 185-191.
160. Harish, D. K., Agasimani, A. D., Imamsaheb, S. J., & Patil, S. S. (2011). Growth and yield parameters in brinjal as influenced by organic nutrient management and plant protection conditions. *Research Journal of Agricultural Sciences*, 2(2), 221-225.
161. Hartmann, M., & Zeier, J. (2019). N-hydroxyphenylacetic acid and salicylic acid: a metabolic duo for systemic acquired resistance. *Current opinion in plant biology*, 50, 44- 57.
162. Haruta, M., Pedersen, J. A., & Constabel, C. P. (2001). Polyphenol oxidase and herbivore defense in trembling aspen (*Populus tremuloides*): cDNA cloning, expression, and potential substrates. *Physiologia plantarum*, 112(4), 552-558.
163. Haseeb, M., Qamar, M., & Sharma, D. K. (2009). Seasonal incidence of brinjal hadda beetle, *Henosepilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae) in Aligarh, Uttar Pradesh. *Trends in Biosciences*, 2(1), 31-32.
164. Hayat, Q., Hayat, S., Irfan, M., & Ahmad, A. (2010). Effect of exogenous salicylic acid under changing environment: a review. *Environmental and experimental botany*, 68(1), 14-25.
165. Heng-Moss, T., Sarath, G., Baxendale, F., Novak, D., Bose, S., Ni, X., & Quisenberry, S. (2004). Characterization of oxidative enzyme changes in buffalograsses challenged by *Blissus occiduus*. *Journal of Economic Entomology*, 97(3), 1086-1095.
166. Hossain, M. M., Shahjahan, M., Prodhan, A. K. M. A., Islam, M. S., & Begum, M. A. (2002). Study of anatomical characters in relation to resistance against brinjal shoot and fruit borer. *Pakistan Journal of Biological Sciences*, 5:672-78.
167. Hossain, M. M., Shahjahan, M., Salam, M. A., & Begum, M. A. (2002b). Screening of some brinjal varieties and lines against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. *Pakistan Journal of Biological Sciences (Pakistan)*, 5(10), 1032-1040.

168. Hosseinzadeh, S. R., Amiri, H., & Ismaili, A. (2016). Effect of vermicompost fertilizer on photosynthetic characteristics of chickpea (*Cicer arietinum* L.) under drought stress. *Photosynthetica*, 54, 87-92.
169. Howe, G. A., Major, I. T., & Koo, A. J. (2018). Modularity in jasmonate signaling for multistress resilience. *Annual Review of Plant Biology*, 69, 387-415.
170. Humane, A. N., Zanzwar, P. R., & Sonkamble, M. M. (2021). Influence of weather parameters on incidence of major pests of brinjal. *International Journal of Ecology and Environmental Sciences*, 3(1), 179-184.
171. Hussain, B., War, A. R., & Sharma, H. C. (2014). Jasmonic and salicylic acid-induced resistance in sorghum against the stem borer *Chilo partellus*. *Phytoparasitica*, 42, 99-108.
172. Hussain, N. (2016). *Gainful utilization of toxic and allelopathic weeds for the generation of biofertilizer through vermicomposting: an assessment of the fertilizer value of the resultant vermicompost* (Doctoral dissertation).
173. Hussain, N., Abbasi, T., & Abbasi, S. A. (2016). Vermicomposting transforms allelopathic parthenium into a benign organic fertilizer. *Journal of Environmental Management*, 180, 180-189.
174. Hussain, N., Abbasi, T., & Abbasi, S. A. (2017). Toxic and allelopathic ipomoea yield plant-friendly organic fertilizer. *Journal of Cleaner Production*, 148, 826-835.
175. Hussain, N., Abbasi, T., & Abbasi, S. A. (2018). Generation of highly potent organic fertilizer from pernicious aquatic weed *Salvinia molesta*. *Environmental Science and Pollution Research*, 25, 4989-5002.
176. Ibrahim, M., Yasmeen, S., Zaman, G., Bin, L., Al-Qurainy, F., Athar, H. U. R., ... & Ashraf, M. (2016). Protein profiling analysis of *Gossypium hirsutum* (Malvales: Malvaceae) leaves infested by cotton whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae). *Applied entomology and zoology*, 51, 599-607.
177. Indhumathi, J., Muthukrishnan, N., Durairaj, C., Thavaprakash, N., & Soundararajan, R. P. (2019). Effect of methyl salicylate on rice leaf folder *Cnaphalocrocis medinalis* (Guenee), parasitoid *Xanthopimpla flavolineata* (Cameron) and predator *Micraspis* sp. *Madras Agricultural Journal*, 106(1-3):74-79.

178. Indirakumar, K., Devi, M., & Loganathan, R. (2016). Seasonal incidence and effect of abiotic factors on population dynamics of major insect pests on brinjal crop. *International Journal of Plant Protection*, 9(1), 142-145.
179. Indrayani, I. G. A. A., & Sulistyowati, E. (2005). Pengaruh kerapatan bulu daun pada tanaman kapas terhadap kolonisasi *Bemisia tabaci* Gennadius. *Industrial Crops Research Journal*, 11(3), 101-106.
180. Innes, R. (2018). The positives and negatives of NPR: a unifying model for salicylic acid signaling in plants. *Cell*, 173(6), 1314-1315.
181. Ishiwari, H., Suzuki, T., & Maeda, T. (2007). Essential compounds in herbivore-induced plant volatiles that attract the predatory mite *Neoseiulus womersleyi*. *Journal of Chemical Ecology*, 33(9), 1670-1681.
182. Islam, M. A. (2013). *Evaluation of Plant extracts for the management of brinjal shoot and fruit borer* (M.Sc. thesis, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207).
183. Islam, M. T., Chhanda, R. A., Pervin, N., Hossain, M. A., & Chowdhury, R. U. (2018). Characterization and genetic diversity of brinjal germplasm. *Bangladesh journal of agricultural research*, 43(3): 499-512.
184. Isshiki, S., Okubo, H., & Fujieda, K. (1994). Genetic control of isozymes in eggplant and its wild relatives. *Euphytica*, 80(1), 145-150.
185. Jackson, G. (2016). Potato ladybird beetle. Pacific pests and pathogens fact sheet. PestNet, Queensland, Australia.
186. Jafir, M., Shehzad, M., Abbas, Q., Nazeer, J., Ahmad, A. A., Ali, Y., ... & Javed, M. W. (2018). Germplasm screening of brinjal (*Solanum melongena* L.) cultivars for resistance to sucking insect pests. *Journal of Entomology and Zoology Studies*, 6(1), 1134-1137.
187. Jagginavar, S. B., Sunitha, N. D., & Biradar, A. P. (2009). Bioefficacy of flubendiamide 480 SC against brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. *Karnataka Journal of Agricultural Sciences*, 22(3), 712-713.

188. Jain, P., Sharma, R. C., Bhattacharyya, P., & Banik, P. (2014). Effect of new organic supplement (Panchgavya) on seed germination and soil quality. *Environmental monitoring and assessment*, 186, 1999-2011. doi 10.1007/s10661-013-3513-8
189. James, D. G. (2003). Field evaluation of herbivore-induced plant volatiles as attractants for beneficial insects: methyl salicylate and the green lacewing, *Chrysopa nigricornis*. *Journal of Chemical Ecology*, 29, 1601-1609.
190. James, D. G., & Grasswitz, T. R. (2005). Synthetic herbivore-induced plant volatiles increase field captures of parasitic wasps. *BioControl*, 50(6), 871-880.
191. Janda, T., Gondor, O. K., Yordanova, R., Szalai, G., & Pal, M. (2014). Salicylic acid and photosynthesis: signalling and effects. *Acta physiologiae plantarum*, 36, 2537-2546.
192. Jat, K. L., & Pareek, B. L. (2003). Biophysical and bio-chemical factors of resistance in brinjal against *Leucinodes orbonalis*. *Indian Journal of Entomology*, 65 (2), 252-258.
193. Javed, H., Hussain, S. S., Javed, K., Mukhtar, T., & Abbasi, N. A. (2017). Comparative infestation of brinjal stem borer (*Euzophera perticella*) on six aubergine cultivars and correlation with some morphological characters. *Pakistan Journal of Agricultural Sciences*, 54(4).
194. Javed, H., Mohsin, A., Aslam, M., Naeem, M., Amjad, M., & Mahmood, T. (2011). Relationship between morphological characters of different aubergine cultivars and fruit infestation by *Leucinodes orbonalis* Guenee. *Pakistan Journal of Botany*, 43(4), 2023- 2028.
195. Javed, M. W., Malik, M. K. & Jafir, M. (2018). Management dynamics of potential bio- pesticides against polyphagous sucking pests on eggplant (*Solanum melongena* L.). *Journal of Entomology and Zoology Studies*, 6(2), 576-579.
196. Jayasimha, G. T., Rachana, R. R., & Nalini, K. R. R. (2017). Field evaluation of synthetic elicitors as attractants to predators of rice brown planthopper, *Nilaparvata lugens* (Stal.)(Delphacidae: Homoptera). *Journal of Entomology and Zoology Studies*, 5(4), 840- 844.

197. Joshi, R., Singh, J., & Vig, A. P. (2015). Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. *Reviews in Environmental Science and Bio/Technology*, 14, 137-159.
198. Jugno, T. Q., ul Hassan, W., Bashir, N. H., Sufian, M., Nazir, T., Anwar, T., & Hanan, A. (2018). Potential assessment of *Metarhizium anisopliae* and *Bacillus thuringiensis* against Brinjal insect pests *Amrasca bigutulla* (Jassid) and *Aphis gossypii* (Aphid). *Journal of Entomology and Zoology Studies*, 6(2), 32-36.
199. Kadam, J. R., Bhosale, U. D., & Chavan, A. P. (2006). Influence of insecticidal treatment sequences on population of *Leucinodes orbonalis* Gn and its predators. *Journal of Maharashtra agriculture University*, 31 (3), 379-382.
200. Kadgonkar, T. S., Bagde, A. S., Deshmukh, V. J., & Mali, A. S. (2018). Seasonal incidence of major pests of brinjal. *International Journal of Current Microbiology and Applied Sciences*, 7(9), 2727-2731.
201. Kadu, R. V. (2018). *Resistance mechanism in okra genotypes against leafhopper, Amrasca biguttula biguttula* (Ishida) and whitefly (*Bemisia tabaci* Gennadius) and their management (Doctoral dissertation, PhD Thesis, MPKV, Rahuri (Maharashtra), India) 1- 171.
202. Kalaiyarasi, L., Livingstone, A. R., & Madhanagopal, R. (2017). Effect of weather parameters on the incidence of different life stages of a serious pest *H. vigintioctopunctata* (Fab.) on Brinjal in Chennai locality, India. *Journal of Entomology and Zoology Studies*, 5, 1520-1525.
203. Kalawate, A. K., & Dethe, M. D. (2012). Bioefficacy study of biorational insecticide on brinjal. *Journal of Biopesticides*, 5(1): 75-80.
204. Kameshwaran, C., & Kumar, K. (2015). Efficacy of newer insecticides against the brinjal, *Solanum melongena* (L.) shoot and fruit borer, *Leucinodes orbonalis* (Guen.) in Karaikal district, UT of Puducherry. *Asian Journal of Bio Science*, 10(2):119-128.
205. Kapil, D. S. A., Yadav, S. S., & Bhall, R. (2022). Seasonal abundance and impact of abiotic factors on major sucking pests of brinjal. *Journal of Entomology and Zoology Studies*, 10(4), 165-168.

206. Karimi, H., Mokhtari, M., Salehi, F., Sojoudi, S., & Ebrahimi, A. (2017). Changes in microbial pathogen dynamics during vermicomposting mixture of cow manure–organic solid waste and cow manure–sewage sludge. *International Journal of Recycling of Organic Waste in Agriculture*, 6, 57-61. <https://doi.org/10.1007/s40093-016-0152-4>
207. Kariyanna, B., Prabhuraj, A., Mohan, M., Bheemanna, M., Basavaraj Kalmath, P. Y., & Diwan, J. R. (2020). Insecticide usage pattern and evolution of resistance in eggplant shoot and fruit borer, *Leucinodes orbonalis* guenée (lepidoptera: crambidae) in India. *Plant Archives*, 20(2), 1255-1261.
208. Karkar, D. B., Korat, D. M., & Dabhi, M. R. (2014a). Evaluation of botanicals for their bioefficacy against insect pests of brinjal, *Karnataka Journal of Agricultural Sciences*, 27(2), 145-147.
209. Karkar, D. B., Korat, D. M., & Dabhi, M. R. (2014b). Bio efficacy of microbial insecticides against insect pests of brinjal, *Karnataka Journal of Agricultural Sciences*, 27(2), 236-238.
210. Karmakar, S. K., Samanta, S., Sen, K., Manger, A., Padhi, G. K., Das, U., & Samanta, A. (2018). Bio-pesticidal management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.). *Journal of Entomology and Zoology Studies*, 6(4), 1142-1145.
211. Kassi, A. K., Javed, H., & Mukhtar, T. (2019). Screening of different aubergine cultivars against infestation of brinjal fruit and shoot borer (*Leucinodes orbonalis* Guenee). *Pakistan Journal of Zoology*, 51(2). vol. 51(2), pp 603-609, 2019.
212. Kaur R, & Mavi, G. S. (2005). Biology of *Epilachna vigintioctopunctata* (Fabricius) (Coleoptera: Coccinellidae) on brinjal in Ludhiana, Punjab. *Crop Research*. 29(1), 141- 144.
213. Kaur S, & Singh S. (2013). Comparison of different pest management strategies in brinjal. Indian Society of Vegetable Science, National Symposium on Abiotic and Biotic Stress Management in Vegetable Crops, 4(4):321.

214. Kaur, P., Yadav, G. S., Wargantiwar, R. K., & Burange, P. S. (2014). Population dynamics of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Crambidae) under agroclimatic conditions of Hisar, Haryana, India. *The Ecoscan*, 8(1&2), 1-5.
215. Kavishetti, V., & Lekha Rani, C. (2018). Screening of brinjal hybrids for resistance to brinjal shoot and fruit borer, *Leucinodes orbonalis* (G.). *International Journal of Current Microbiology and Applied Sciences*, 7(02), 2458-2462.
216. Khan, I. A., Habib, K., Rasheed Akbar, A. K., Saeed, M., Farid, A., Ali, I., & Alam, M. (2015). Proximate chemical composition of brinjal, *Solanum melongena* L. (Solanales: Solanaceae), genotypes and its correlation with the natural enemies in Peshawar. *Journal of Entomology and Zoology Studies*, 3, 07-11.
217. Khan, M. A., Waseem Akram, W. A., Khan, H. A. A., Javed Asghar, J. A., & Khan, T. M. (2010). Impact of Bt-cotton on whitefly, *Bemisia tabaci* (Genn.) population. *Pakistan Journal of Agricultural Sciences*, 47(4), 327-332.
218. Khan, M. M., Ali, A., Nadeem, I., Khan, M. Y., & Muhammad, F. A. R. (2017). Morphological and biochemical Bt cotton plant trait induced resistance against cotton jassid *Amrasca biguttula biguttula* (Ishida) and cotton whitefly *Bemisia tabaci* (Genn.). *Journal of Innovative BioResearch*, 1, 36-45.
219. Khan, M. M., Khan, M. Y., Muhammad, R., Ullah, K., Yasir, M., Khalid, A., & Ahsan, M. (2018). Morphological and biochemical characters of eggplant (*Solanum melongena*) conferring resistance against whitefly (*Bemisia tabaci*). *Journal of Entomology and Zoology Studies*, 6 (5), 915-920.
220. Khan, M. M., Khan, M. Y., Muhammad, R., Ullah, K., Yasir, M., Khalid, A., & Ahsan, M. (2018). Morphological and biochemical characters of eggplant (*Solanum melongena*) conferring resistance against whitefly (*Bemisia tabaci*). *Journal of Entomology and Zoology Studies*, 6 (5), 915-920.
221. Khan, R., & Singh, Y. V. (2014). Screening for shoot and fruit borer (*Leucinodes orbonalis* Guenee.) resistance in brinjal (*Solanum melongena* L.) genotypes. *The Ecoscan*, 6, 41-45.

222. Khan, W., Prithiviraj, B., & Smith, D. L. (2003). Photosynthetic responses of corn and soybean to foliar application of salicylates. *Journal of plant physiology*, 160(5), 485-492.
223. Khare, V. K. & Sneha, (2021). Spinosad for control of brinjal shoot and fruit borer: Efficacy and economics. *Journal of Entomology and Zoology Studies*, 9(1), 1843-1845.
224. Khattak, M.K., Rashid M., Hussain S.A.S., & Islam T. (2006). Comparative effect of Neem (*Azadirachta indica*) oil, Neem seed water extract and Baythroid against whitefly, Jassids and Thrips on cotton. *Pakistan Entomologist*, 28(1), 31-37.
225. Khorsheduzzaman, A. K. M., Alam, M. Z., Rahman, M. M., Mian, M. K., & Mian, M. I. H. (2010). Biochemical basis of resistance in eggplant (*Solanum melongena* L.) to *Leucinodes orbonalis* Guenee and their correlation with shoot and fruit infestation. *Bangladesh Journal of Agriculture Research*, 35, 149-55.
226. Khoshfarman-Borji, H., Yali, M. P., & Bozorg-Amirkalaei, M. (2020). Induction of resistance against *Brevicoryne brassicae* by *Pseudomonas putida* and salicylic acid in canola. *Bulletin of Entomological Research*, 110(5), 597-610.
227. Khursheed, S., & Desh, R. (2014). Population Dynamics of Hadda Beetle, *Henosepilachna Vigintioctopunctata* on Bittergourd in Mid-hill Himalayas. *Indian journal of plant protection*, 42(1), 59-63.
228. Kim, J. M., To, T. K., Matsui, A., Tanoi, K., Kobayashi, N. I., Matsuda, F., ... & Seki, M. (2017). Acetate-mediated novel survival strategy against drought in plants. *Nature Plants*, 3(7), 1-7.
229. Kim, S. I., Chae, S. H., Youn, H. S., Yeon, S. H., & Ahn, Y. J. (2011). Contact and fumigant toxicity of plant essential oils and efficacy of spray formulations containing the oils against B-and Q-biotypes of *Bemisia tabaci*. *Pest Management Science*, 67(9), 1093- 1099.
230. Kirst, H. A. (2010). The spinosyn family of insecticides: realizing the potential of natural products research. *The Journal of Antibiotics*, 63(3), 101-111.
231. Klessig, D. F., Choi, H. W., & Dempsey, D. M. A. (2018). Systemic acquired resistance and salicylic acid: past, present, and future. *Molecular Plant-Microbe Interactions*, 31(9), 871-888.

232. Kodandaram, M. H., Halder, J., & Rai, A. B. (2014). New insecticide molecules and entomopathogens against Hadda beetle, *Henosepilachna vigintioctopunctata* infesting vegetable cowpea. *Indian Journal of Plant Protection*, 42(4), 333-7.
233. Kodandaram, M. H., Rai, A. B., Sharma, S. K., & Singh, B. (2017). Shift in the level of susceptibility and relative resistance of brinjal shoot and fruit borer *Leucinodes orbonalis* (Guen) to diamide insecticides. *Phytoparasitica*, 45(2), 151-154.
234. Kodandaram, M. H., Rai, A. B., Sireesha, K., & Halder, J. (2015). Efficacy of cyantraniliprole a new anthranilic diamide insecticide against *Leucinodes orbonalis* (Lepidoptera: Crambidae) of brinjal. *Journal of Environmental Biology*, 36(6), 1415.
235. Koike, M., Higashio, T., Komori, A., Akiyama, K., Kishimoto, N., Masuda, E., ... & Nagao, H. (2004). *Verticillium lecanii* (Lecanicillium spp.) as epiphyte and its application to biological control of arthropod pests and diseases. *IOBC/wprs Bulletin*, 27(8), 41-44.
236. Koul, O. (2007). Neem: a global perspective. *Neem: Today and in the New Millennium*, 1.
237. Kraus, E. C., & Stout, M. J. (2019). Seed treatment using methyl jasmonate induces resistance to rice water weevil but reduces plant growth in rice. *PloS One*, 14(9), e0222800.
238. Krishna Kumari, G. N., Balachandran, J., Aravind, S., & Ganesh, M. R. (2003). Antifeedant and growth inhibitory effects of some neo-clerodane diterpenoids isolated from Clerodendron species (Verbenaceae) on *Earias vitella* and *Spodoptera litura*. *Journal of agricultural and food chemistry*, 51(6), 1555-1559.
239. Kroschel, J., Mujica, N., Okonya, J., & Alyokhin, A. (2020). Insect pests affecting potatoes in tropical, subtropical, and temperate regions. *The Potato Crop: Its Agricultural, Nutritional and Social Contribution to Humankind*, 251-306.
240. Kucera, B., Cohn, M. A., & Leubner-Metzger, G. (2005). Plant hormone interactions during seed dormancy release and germination. *Seed Science Research*, 15(4), 281-307.

241. Kumar, A., Chandra, U., Veer, R., Gautam, C. P. N., & Yadav, S. (2021). Incidence of insect pests associated with brinjal (*Solanum melongena* L.) crop at Ayodhya region. *The Pharma Innovation Journal*, 10(7), 1933-1936.
242. Kumar, D., Haq, I., Chapagai, D., Tripathi, D., Donald, D., Hossain, M., & Devaiah, S. (2015). Hormone signaling: current perspectives on the roles of salicylic acid and its derivatives in plants. *The Formation, Structure and Activity of Phytochemicals*, 115-136.
243. Kumar, G., Meena, B. L., Kar, R., Tiwari, S. K., Gangopadhyay, K. K., Bisht, I. S., & Mahajan, R. K. (2008). Morphological diversity in brinjal (*Solanum melongena* L.) germplasm accessions. *Plant Genetic Resources*, 6(3), 232-236.
244. Kumar, H. S. R., Gowda, J. V., Sridhar, D., & Poornima, D. S. (2011a). Effect of integrated organic sources of nutrients on quality and economics of groundnut (*Arachis hypogaea* L.). *Advance Research Journal of Crop Improvement*, 2(1), 81-85.
245. Kumar, K. R., Singh N. N., Raju, S. V. S. & Mishra V. K. (2017b). Influence of abiotic factors on seasonal incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. in Varanasi Region. *International Journal of Current Microbiology and Applied Sciences*, 6(4), 1513-1518.
246. Kumar, N. (2021). *PUNTA NDYA* (Doctoral dissertation, Lovely Professional University Punjab).
247. Kumar, R. S., Ganesh, P., Tharmaraj, K., & Saranraj, P. (2011b). Growth and development of blackgram (*Vigna mungo*) under foliar application of Panchagavya as organic source of nutrient. *Current Botany*, 2(3), 09-11.
248. Kumar, S., Sachan, S. K., Kumar, V., & Gautam, M. P. (2019). Abundance of insect pests associated with brinjal (*Solanum melongena* L.) crop. *Journal of Entomology and Zoology Studies*, 7(3), 1014-1017.
249. Kumar, S., Singh, S. K., & Malik, Y. P. (2018a). Population dynamics of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. on brinjal at Kanpur agroclimatic region. *Journal of Entomology and Zoology Studies*, 6(6), 91-93.

250. Kumari, A., Chawla, N., & Dhatt, A. S. (2014). Comparison of eggplant genotypes for phenolic compounds and other biochemical parameters. *International Journal of Advanced Research*, 2(9), 615-622.
251. Kumawat, R. N., Mahajan, S. S., & Mertia, R. S. (2009). Response of cumin (*Cuminum cyminum* L.) to panchagavya and plant leaf extracts in arid western Rajasthan. *Journal of Spices and Aromatic Crops*, 18(2), 92-99.
252. Kumawat, R.N., Mertia, R.S. & Mahajan, S.S. (2010). Comparative performance of groundnut-cumin and cluster bean-cumin cropping systems under foliar application of panchgavya in western Rajasthan. *Annals of Arid Zone*. 49(1), 31-38.
253. Kunbhar, S., Rajput, L. B., Gilal, A. A., Channa, G. A., & Sahito, J. G. M. (2018). Impact of botanical pesticides against sucking insect pests and their insect predators in brinjal crop. *Journal of Entomology and Zoology Studies*, 6(2), 83-87.
254. Laichattiwari, M. A., Meena, R. S., & Singh, P. S. (2018). Physio-Morphic characters of different varieties/genotypes against population fluctuation of sucking pests of brinjal *Solanum melongena* (L.). *International Journal of Agriculture, Environment and Biotechnology*, 11(2), 409-414.
255. Lakehal, A., & Bellini, C. (2019). Control of adventitious root formation: insights into synergistic and antagonistic hormonal interactions. *Physiologia Plantarum*, 165(1), 90- 100.
256. Lal, B., Bhadauria, N. S., Singh, P., & Tomar, S. P. S. (2019). Seasonal incidence of sucking insect pests in brinjal and their natural enemies in gird region of Madhya Pradesh, India. *Journal of Pharmacognosy and Phytochemistry*, 8(4), 2077-2079.
257. Latif, M. A., Rahman, M. M., & Alam, M. Z. (2010). Efficacy of nine insecticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) in eggplant. *Journal of Pest Science*, 83(4), 391-397.
258. Latif, M. A., Rahman, M. M., Islam, M. R., & Nuruddin, M. M. (2009). Survey of arthropod biodiversity in the brinjal field. *Journal of Entomology*, 6(1), 28-34.
259. Lazcano, C., & Domínguez, J. (2011). The use of vermicompost in sustainable agriculture: impact on plant growth and soil fertility. *Soil nutrients*, 10(1-23), 187.

260. Le Gall, M., & Behmer, S. T. (2014). Effects of protein and carbohydrate on an insect herbivore: the vista from a fitness landscape. *Integrated and Comparative Biology*, 54, 1- 13.
261. Le Gall, M., & Behmer, S. T. (2014). Effects of protein and carbohydrate on an insect herbivore: the vista from a fitness landscape. *Integrated and Comparative Biology*, 54, 1- 13.
262. Legocki, J., Polec, I., & Zelechowski, K. (2010). Contemporary trends in development of active substances possessing the pesticidal properties: spinosyn insecticides. *Pestycydy*, (1-4), 59-71.
263. Leo Daniel Amalraj, E., Praveen Kumar, G., Mir Hassan Ahmed, S. K., Abdul, R., & Kishore, N. (2013). Microbiological analysis of panchagavya, vermicompost, and FYM and their effect on plant growth promotion of pigeon pea (*Cajanus cajan* L.) in India. *Organic Agriculture*, 3(1), 23-29.
264. Li, Q., Xie, Q. G., Smith-Becker, J., Navarre, D. A., & Kaloshian, I. (2006). Mi-1-mediated aphid resistance involves salicylic acid and mitogen-activated protein kinase signaling cascades. *Molecular Plant-Microbe Interactions*, 19(6), 655-664.
265. Li, R., Weldegergis, B. T., Li, J., Jung, C., Qu, J., Sun, Y., ... & Ye, J. (2014). Virulence factors of gemini virus interact with MYC2 to subvert plant resistance and promote vector performance. *The Plant Cell*, 26(12), 4991-5008. doi: 10.1105/tpc.114.133181
266. Lim, S. L., Wu, T. Y., Lim, P. N., & Shak, K. P. Y. (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. *Journal of the Science of Food and Agriculture*, 95(6), 1143-1156.
267. Lima, G. P. P., Da Rocha, S. A., Takaki, M., Ramos, P. R. R., & Ono, E. O. (2008). Comparison of polyamine, phenol and flavonoid contents in plants grown under conventional and organic methods. *International Journal of Food Science & Technology*, 43(10), 1838-1843.
268. Lit, M. C., 2009. Combined resistance of eggplant, *Solanum melongena* L., to leafhopper, *Amrasca bigutulla bigutella* (Ishida) and eggplant borer, *Leucinodes orbonalis* Guenee. Terminal Report, Inst. Plant Breeding, Philippines Univ. Laos Banos, College Laguna. pp. 191.

269. Liu, M., Wang, C., Wang, F., & Xie, Y. (2019). Maize (*Zea mays*) growth and nutrient uptake following integrated improvement of vermicompost and humic acid fertilizer on coastal saline soil. *Applied Soil Ecology*, 142, 147-154.
270. Lodhi, R.C. (2005). Seasonal incidence and management of major insect pests of brinjal M.Sc. (Ag.) Thesis submitted to JNKVV, Jabalpur (M.P.).
271. Lokanadhan, S., Muthukrishnan, P., & Jeyaraman, S. (2012). Neem products and their agricultural applications. *Journal of Biopesticides*, 5, 72.
272. Lortzing, T., & Steppuhn, A. (2016). Jasmonate signaling in plants shapes plant–insect interaction ecology. *Current opinion in Insect Science*, 14, 32-39.
273. Lortzing, V., Oberlander, J., Lortzing, T., Tohge, T., Steppuhn, A., Kunze, R., & Hilker, M. (2019). Insect egg deposition renders plant defence against hatching larvae more effective in a salicylic acid-dependent manner. *Plant, Cell & Environment*, 42(3), 1019- 1032.
274. Lowry, O. H., Rosebrough, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with the Folin phenol reagent. *Journal of Biological Chemistry*, 193(1), 265-275.
275. Lu, J., Li, J., Ju, H., Liu, X., Erb, M., Wang, X., & Lou, Y. (2014). Contrasting effects of ethylene biosynthesis on induced plant resistance against a chewing and a piercing- sucking herbivore in rice. *Molecular plant*, 7(11), 1670-1682.
276. Ma, F., Yang, X., Shi, Z., & Miao, X. (2020). Novel crosstalk between ethylene- and jasmonic acid-pathway responses to a piercing–sucking insect in rice. *New Phytologist*, 225(1), 474-487.
277. Mahajan, S. S., Kumawat, R. N., & Mertia, R. S. (2012). Organic seed production of cumin (*Cuminum cyminum* L.) with foliar application of Panchgavya and plant leaf extracts in arid western rajasthan. *International Journal of Seed Spices*, 2(2), 19-26.
278. Mahesh, P., & Men, U. B. (2007). Seasonal incidence of *Leucinodes orbonalis* on Brinjal. *Annals of Plant Protection Science*, 15(2), 469-539.
279. Mahmood, T., Hussain, S. I., Khokhar, K. M., Jeelani, H., & Jeelani, G. (2002). Varietal resistance in eggplant to cotton Jassid (*Amrasca Biguttula Biguttula*). *Asian Journal of Plant Sciences*, 1(2), 107-108.

280. Mahmoud, M.F., & Mahfouz, H.M. (2015). Effects of salicylic acid elicitor against aphids on wheat and detection of infestation using infrared thermal imaging technique in Ismailia, Egypt. *Pesticides and Phytomedicine/Pesticidi i fitomedicina*, 30(2), 91-97.
281. Mahmud, M., Abdullah, R., & Yaacob, J. S. (2018). Effect of vermicompost amendment on nutritional status of sandy loam soil, growth performance, and yield of pineapple (*Ananas comosus* var. MD2) under field conditions. *Agronomy*, 8(9), 183.
282. Mainali, R. P., Peneru, R. B., Pokhrel, P., & Giri, Y. P. (2015). Field bio-efficacy of newer insecticides against eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee. *International Journal of Applied Sciences and Biotechnology*, 3(4), 727-730.
283. Malik, Y. P., & Pal Rishi, P. R. (2013). Seasonal incidence of brinjal fruit and shoot borer (*Leucinodes orbonalis* Guen.) on different germplasm of brinjal in central UP. *Trends in Biosciences*, 6(4), 389-394.
284. Malini, C. D., Prasanna, K. P., & Gopalakrishnan, T. R. (2013). Screening brinjal genotypes for resistance to jassid (*Amrasca biguttula biguttula* [Ishida]). *Journal of Tropical Agriculture*, 51(1), 42-50.
285. Mallick, J. R., Dash, S., & Patnaik, H. P. (2019). Bio-rational and cost-effective control of shoot and fruit borer incidence on brinjal. *Journal of Entomology and Zoology Studies*, 7(1), 1026-1029.
286. Mamum, M. A. A., Islam, K. S., Jahan, M., & Das, G. (2014). Comparative potency of three insecticides against the infestation of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. *Scholars Academic Journal of Biosciences*, 2(6), 364-369.
287. Mandal, D., Baral, K., Chattterjee, H., & Mandal, P. (2005). Integrated pest management of eggplant shoot and fruit borer, *L. orbonalis* Gune. In: *National Symposium on Recent Advances in Integrated Management of Brinjal Shoot and Fruit Borer*. pp. 58-62.

288. Mandal, S., Padamshali, S., Rana, N., & Kolhekar, S. (2018). itk based pest management module for sucking peston brinjal (*Solanum melongena* L.) under terai agro-ecological system of west bengal. *Journal of Pharmacognosy and Phytochemistry*, 7(1S), 2065-2070.
289. Mandal, S., Singh, N. J., & Konar, A. (2010). Efficacy of synthetic and botanical insecticide against whitefly (*Bemisia tabaci*) and shoot and fruit borer (*Leucinodes orbonalis*) on brinjal (*Solanum melongena* L.). *Journal of Crop and Weed*, 6(1), 49-51.
290. Mandavgane, S. A., & Kulkarni, B. D. (2020). Valorization of cow urine and dung: a model biorefinery. *Waste and biomass valorization*, 11(3), 1191-1204.
291. Mane, P. D., & Kulkarni, S. N. (2010). Bio-efficacy of neem products against *Epilachna vigintioctopunctata* Fab. on brinjal, *Green Farming*, 1(3), 330.
292. Mane, P. D., & Kulkarni, S. N. (2011). Population dynamics of white flies, *Bemisia tabaci* Genn. on brinjal. *International Journal of Plant Protection*, 4(1), 140- 142.
293. Manikandan, P., Saravanaraman, M., Selvanarayanan, V., & Suguna, K. (2019). Incidence and host preference of brinjal hadda beetle *Epilachna vigintioctopunctata* (fabricius) (coccinellidae: coleoptera) on different solanaceous weed hosts. *International Journal of Advances in Agricultural Science and Technology*, 6(7), 1-13.
294. Manivannan, A., Sridhar, R. P., Kamalakannan, A., Ganapathy, N. & Karthikeyan, S. (2018). In vitro efficacy of bio control agents against cotton leafhopper, *Amrasca biguttula biguttula* (Ishida) (homoptera: cicadellidae). *International Journal of Current Microbiology and Applied Sciences*, 7(9), 2026-2031.
295. Manzoni, C. G., Grützmacher, A. D., Giolo, F. P., Härter, W. D. R., & Müller, C. (2006). Side effects of pesticides used in integrated production of apple in adults of *Trichogramma pretiosum*. *Pesquisa Agropecuaria Brasileira*, 41(10), 1461-1467.
296. Marquis, V., Smirnova, E., Poirier, L., Zumsteg, J., Schweizer, F., Reymond, P., & Heitz, T. (2020). Stress-and pathway-specific impacts of impaired jasmonoyl-isoleucine (JA-Ile) catabolism on defense signalling and biotic stress resistance. *Plant cell & environment*, 43(6), 1558-1570.

297. Masood N. (2011). *Spatio-temporal trends and integrated management of sugarcane whitefly, Aleurolobus barodensis (mask.), (Aleyrodidae: Homoptera)*, (Doctoral dissertation University of Agriculture, Faisalabad Pakistan).
298. Matthes, M. C., Bruce, T. J., Ton, J., Verrier, P. J., Pickett, J. A., & Napier, J. A. (2010). The transcriptome of cis-jasmone-induced resistance in *Arabidopsis thaliana* and its role in indirect defence. *Planta*, 232, 1163-1180.
299. Meena, K. R., Khinchi, S.K., Kumawat, K.C., Jat, B.L. (2017). Seasonal abundance of major sucking insect pests of Brinjal, *Solanum melongena* L. and their natural enemies. *Indian Journal Applied Entomology*, 31(2), 70-73.
300. Miles, M. (2003). The effects of spinosad, a naturally derived insect control agent to the honeybee. *Bulletin of Insectology*, 56, 119-124.
301. Mishra, P. N., Singh Y. V., Nautiyal M. C. (1988). Screening of brinjal varieties for resistance to shoot and fruit borer (*Leucinodes orbonalis* Guen.) (Pyralidae: Lepidoptera). *South Indian Hort.*;36(4), 188-192.
302. Miura, K., & Tada, Y. (2014). Regulation of water, salinity, and cold stress responses by salicylic acid. *Frontiers in Plant Science*, 5(4), 1-12.
303. Mohanchander, P., Reegan, A. D., Rahman, M. A., & Raveen, R. S. (2013). Effect of Hadda beetle, *Epilachna vigintioctopunctata* Fab. (Coleoptera: Coccinellidae) infestation on eggplant leaf (*Solanum melongena* L.) and bio-control potential of essential oil formulations. *Pakistan Journal of Biological Sciences: PJBS*, 16(19), 991-997.
304. Mohase, L., & van der Westhuizen, A. J. (2002). Salicylic acid is involved in resistance responses in the Russian wheat aphid-wheat interaction. *Journal of Plant Physiology*, 159(6), 585-590.
305. Moran, P. J., & Thompson, G. A. (2001). Molecular responses to aphid feeding in *Arabidopsis* in relation to plant defense pathways. *Plant Physiology*, 125(2), 1074-1085.
306. Morgan, E. D. (2009). Azadirachtin, a scientific gold mine. *Bioorganic & Medicinal Chemistry*, 17(12), 4096-4105.

307. Muhammad, A., & Kashere, M. A. (2020). Neem, *Azadirachta indica* L. (A. Juss): an eco- friendly botanical insecticide for managing farmersa insects pest problems- a review. *FUDMA Journal of Sciences*, 4(4), 484-491.
308. Mukhopadhyay, A., & Mandal, A. (1994). Screening of brinjal (*Solanum melongena*) for resistance to major insect pests. *The Indian Journal of Agricultural Sciences*, 64(11), 798-803.
309. Munde, A. D., Latpate, C. B., Shinde, S. T., & Badgujar, A. G. (2011). Integrated management of aphids and jassids infesting brinjal. *Journal of Entomological Research*, 35(1), 43-49.
310. Murtaza, G., Ramzan, M., Razzaq, A., Numan, M., Beanish, R., Zafar, A., ... & Adnan, M. (2020). Screening of Brinjal (*Solanum melongena*) varieties against Jassid, *Amrasca bigutulla bigutulla*. *Journal of Innovative Sciences*, 7(1), 1-5.
311. Murugesan, N., & Muruges, T. (2008). Efficacy of some plant products against spotted leaf beetle (Hadda beetle), *Henosepilachna vigintioctopunctata* (F.) in Brinjal. *Journal of Biopesticides*, 1(1), 67-69.
312. Muthukumar, M. & Kalyanasundaram. (2003). Influence of biotic factors on the incidence of major insect pests in brinjal (*Solanum melongena* L.). *South Indian Horticulture*, 51(1/6), 214-218.
313. Nadana, G. R. V., Rajesh, C., Kavitha, A., Sivakumar, P., Sridevi, G., & Palanichelvam, K. (2020). Induction of growth and defense mechanism in rice plants towards fungal pathogen by eco-friendly coelomic fluid of earthworm. *Environmental Technology & Innovation*, 19, 101011.
314. Nadi, M., Golchin, A., Mozafari, V., Saeidi, T. & Sedaghati, E. (2011). The effects of different vermicomposts on the growth and chemical composition of the pistachio seedlings. *Journal of Research in Agriculture Science*. 7, 59-69.
315. Naeem-Ullah, U., Ramzan, M., Bokhari, S. H. M., Saleem, A., Qayyum, M. A., Iqbal, N. & Saeed, S. (2020). Insect pests of cotton crop and management under climate change scenarios. *Environment, Climate, Plant and Vegetation Growth*, 367-396. [https:// doi.org/10.1007/978-3-030-49732-3_15](https://doi.org/10.1007/978-3-030-49732-3_15)

316. Nagappan, N., Irene Vethamoni, P., & Natarajan, N. (2017). Association of biochemical characters on shoot and fruit borer (*Leucinodes orbonalis* Gn.) resistance in green fruited brinjal. *International Journal of Chemical Studies*, 5(6), 212-214.
317. Naik, S. K., Barman, D., Devadas, R., & Ushabharathi, T. (2013). Evaluation of Panchgavya as source of nutrient for Cymbidium orchids. *African Journal of Agricultural Research*, 8(46), 5728-5732.
318. Naik, V. C. B., Rao, P. A., Krishnayya, P. V. & Rao, V. S. (2008). Seasonal incidence and management of spotted leaf beetle, *Henosepilachna virginotioctopunctata* (F.) in brinjal. *Journal of Applied Zoological Research*, 19(1), 1-4.
319. Naik, V. C. B., Rao, P. A., Krishnayya, P. V., & Chalam, M. S. V. (2009). Seasonal incidence and management of *Bemisia tabaci* Gennadius and *A. biguttula biguttula* Ishida of brinjal. *Annals of Plant Protection Science*, 17(1), 971-3573.
320. Najar, I. A., Khan, A. B., & Hai, A. (2015). Effect of macrophyte vermicompost on growth and productivity of brinjal (*Solanum melongena*) under field conditions. *International Journal of Recycling of Organic Waste in Agriculture*, 4, 73-83.
321. Nakamura, K., & Ohgushi, T. (1981). Studies on the population dynamics of a thistle- feeding lady beetle, *Henosepilachna pustulosa* (Kono) in a cool temperate climax forest. II. Life tables, key-factor analysis, and detection of regulatory mechanisms. *Research on Population Ecology*, 23, 210-231.
322. Naqvi, A. R., Pareek, B. L., Nanda, U. S., & Mitharwal, B. S. (2008). Leaf morphology and biochemical studies on different varieties of brinjal in relation to major sucking insect pests. *Plant Protection Science*, 36(2), 245-248.
323. Nasrin, R., Ali, E., Jahanfar, D., & Soodabeh, J. (2017). Salicylic acid induced changes on antioxidant capacity, pigments and grain yield of soybean genotypes in water deficit condition. *Journal of Plant Interactions*, 12(1), 457-464.
324. Natarajan, K., & Manual, A. (2002). Other Indian Press. *Mapusa, Goa, India*, 333.
325. Nayak, U. S. (2014). Influence of environmental factors on population dynamics and infestation pattern of *Leucinodes orbonalis* in winter brinjal of Odisha. *International Journal of Plant Research*, 27(3), 244-250.

326. Nayak, U. S., Baral, K., Rath, L. K., & Mandal, P. (2011). Relative efficacy of certain new generation insecticides against of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. *Journal of Plant Protection and Environment*, 8 (2), 108-109.
327. Nayak, U. S., Baral, K., Rath, L. K., & Mondal, P. (2012). Seasonal incidence of *Leucinodes orbonalis* Guenee in brinjal and the effect of abiotic factors on its population dynamics. *Journal of Plant Protection and Environment*, 9(2), 24-27.
328. Nazar, R., Umar, S., Khan, N. A., & Sareer, O. (2015). Salicylic acid supplementation improves photosynthesis and growth in mustard through changes in proline accumulation and ethylene formation under drought stress. *South African Journal of Botany*, 98, 84-94.
329. Nelson, S. J., Sithanantham, S., Natarajan, N., & Praneetha, S. (2020). Population dynamics of brinjal shoot and fruit borer *Leucinodes orbonalis* guenee. *Indian Journal of Entomology*, 82(2), 251-253.
330. Netam, M., Lakra, R., Koshta, V. K., Sharma, D., & Deole, S. (2018). Screening of Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee.), for resistance in Brinjal (*Solanum melongena* L.) Germplasm Lines. *International Journal of Current Microbiology and Applied Sciences*, 7(02), 3700-3706.
331. Neupane, S., Subedi, S., Thapa, R. B., G. C, Y. D., Pokhrel, S., Regmi, P. P., & Shrestha, J. (2016). Efficacy of biorational compounds against whitefly (*Bemisia tabaci* genn.) on blackgram (*Vigna mungo* L.). *Journal of AgriSearch*, 3(1), 34-39.
332. Nikooei, M., Fathipour, Y., Jalali Javaran, M., & Soufbaf, M. (2015). How different genetically manipulated Brassica genotypes affect life table parameters of *Plutella xylostella* (Lepidoptera: Plutellidae). *Journal of Economic Entomology*, 108(2), 515-524.
333. Niranjana, R. F., Devi, M., & Philip Sridhar, R. (2017). Field efficacy of insecticides for the management of BSFB. *Journal of Agricultural Sciences*, 37-44.
334. Nithish, A. (2020). Study on management of damage caused by *Henosepilachna vigintioctopunctata* in brinjal. *Journal of Pharmacognosy and Phytochemistry*, 9(5), 2874-2881.

335. Nonita, M., Bijaya, P., & Singh, T. K. (2007). Effect of abiotic and biotic factors on the abundance of *Aphis gossypii* Glover infesting brinjal. *Indian Journal of Entomology*, 69 (2), 149-153.
336. Nouri-Ganbalani, G., Borzoui, E., Shahnavaizi, M., & Nouri, A. (2018). Induction of resistance against *Plutella xylostella* (L.) (Lep.: Plutellidae) by jasmonic acid and mealy cabbage aphid feeding in *Brassica napus* L. *Frontiers in physiology*, 9, 859.
337. Ohgushi, T., & Sawada, H. (1985). Population equilibrium with respect to available food resource and its behavioural basis in an herbivorous lady beetle, *Henosepilachna niponica*. *The Journal of Animal Ecology*, 54(3), 781-796.
338. Ozawa, R., Shimoda, T., Kawaguchi, M., Arimura, G. I., Horiuchi, J. I., Nishioka, T., & Takabayashi, J. (2000). Lotus japonicus infested with herbivorous mites emits volatile compounds that attract predatory mites. *Journal of Plant Research*, 113(4), 427-433.
339. Paczka, G., Mazur-Paczka, A., Garczynska, M., Hajduk, E., Kostecka, J., Bartkowska, I., & Butt, K. R. (2021). Use of vermicompost from sugar beet pulp in cultivation of peas (*Pisum sativum* L.). *Agriculture*, 11(10), 919.
340. Pagar, R. D., Patel, M. M., & Munde, S. D. (2015). Influenced of panchagavya on growth and yield of wheat (*Triticum aestivum* L.). *Agriculture for Sustainable Development*, 3(1), 57-59.
341. Pagar, R. D., Patel, M. M., & Munde, S. D. (2015). Influenced of panchagavya on growth and yield of wheat (*Triticum aestivum* L.). *Agriculture for Sustainable Development*, 3(1), 57-59.
342. Pandey, K. K., & Gupta, R. C. (2012). Management of Fusarium wilt of tomato by application of bioagents and salicylic acid. *Indian Phytopathology*, 65(1), 94-96.
343. Pao, S., Kalantari, A., & Khalid, M. F. (2008). Eliminating *Salmonella enterica* in alfalfa and mung bean sprouts by organic acid and hot water immersions. *Journal of food processing and preservation*, 32(2), 335-342.
344. Papen, H., Geßler, A., Zumbusch, E., & Rennenberg, H. (2002). Chemolithoautotrophic nitrifiers in the phyllosphere of a spruce ecosystem receiving high atmospheric nitrogen input. *Current Microbiology*, 44, 56-60.

345. Parida, H. R., Mandal, J., & Mohanta, S. (2020). A note on morphological characterization of brinjal (*Solanum melongena* L.) genotypes. *Journal of Crop and Weed*, 16(1), 250-255.
346. Patel, C. C., Singh, D., Sridhar, V., Choudhary, A., Dindod, A., & Padaliya, S. R. (2019). Bioefficacy of cow urine and different types of bio-pesticide against major sucking insect pests of Bt cotton. *Journal of Entomology and Zoology Studies*, 7(3), 1181-1184.
347. Patel, L. C., Konar, A., & Sarkar, A. (2015). *Aphis Gossypii* Glover in alluvial zone of west bengal research article brinjal germplasm against whitefly (*Bemisia Tabaci*). *International Journal of Current Research*, 7(9), 20403-20406.
348. Pathma, J., & Sakthivel, N. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. *SpringerPlus*, 1(1), 1-19. <https://doi.org/10.1186/2193-1801-1-26>
349. Pathma, J., & Sakthivel, N. (2013). Molecular and functional characterization of bacteria isolated from straw and goat manure based vermicompost. *Applied Soil Ecology*, 70, 33- 47.
350. Pathma, J., Raman, G., & Sakthivel, N. (2019). Microbiome of rhizospheric soil and vermicompost and their applications in soil fertility, pest and pathogen management for sustainable agriculture. In *Soil Fertility Management for Sustainable Development* (pp. 189-210). Springer, Singapore.
351. Patial, A., & Mehta, P. K. (2008). Pest complex of brinjal and their succession under mid hills of Himachal Pradesh. *Journal of Insect Science Ludhiana*, 21(1), 67-71.
352. Patil, S. V., Halikatti, S. I., Hiremath, S. M., Babalad, H. B., Sreenivasa, M. N., Hebsur, N. S., & Somanagouda, G. (2012). Effect of organics on growth and yield of chickpea (*Cicer arietinum* L.) in vertisols. *Karnataka Journal of Agricultural Sciences*, 25(3), 326- 331.
353. Patil, S., & Hole, U. (2021). Biochemical basis of resistance in brinjal to *Leucinodes orbonalis* Guenee and their correlation with shoot and fruit damage. *The Pharma Innovation Journal*, 10(7), 566-573.

354. Pattyn, J., Vaughan-Hirsch, J., & Van de Poel, B. (2021). The regulation of ethylene biosynthesis: a complex multilevel control circuitry. *New Phytologist*, 229(2), 770-782.
355. Pazhanisamy, M., & Archunan, K. (2019). Efficacy of botanicals extracts mixture with panchagavya against shoot and fruit borer, *Earias vittella* (Fab.) on bhendi under in vitro condition. *Journal of Biopesticides*, 12(1), 36-39.
356. Pierre-Louis, R. C., Kader, M. A., Desai, N. M., & John, E. H. (2021). Potentiality of vermicomposting in the South Pacific Island countries: A review. *Agriculture*, 11(9), 876.
357. Podder, S., Uddin, M. M., & Adnan, S. M. (2013). Assessment of the effectiveness of different botanicals and chemical insecticide in managing Epilachna beetle, *Epilachna dodecastigma* (Wied.). *International Research Journal of Agricultural Science and Soil Science*, 1(4), 52-59.
358. Prabhu, M., Natarajan, S., Veeraragavathatham, D., & Pugalendhi, L. (2009). The biochemical basis of shoot and fruit borer resistance in interspecific progenies of brinjal (*Solanum melongena*). *EurAsian Journal of BioSciences*, 3(1), 50-57.
359. Prasad, T. V., Bhardwaj, R., Gangopadhyay, K. K., Arivalagan, M., Bag, M. K., Meena, B. L., & Dutta, M. (2014). Biophysical and biochemical basis of resistance to fruit and shoot borer (*Leucinodes orbonalis* Guenee) in eggplant. *Indian Journal of Horticulture*, 71(1), 67-71.
360. Praveen, P. K., Saha, T., Prakash, R., & Kumar, A. (2020). Screening of brinjal genotypes resistance against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee). *International Journal of Communication Systems*, 8(1), 1907-1909.
361. Praveen, S. L., Emmanuel, N., Viji, C. P., Umajyothi, K., & Salomi, D. R. (2018). Screening of diverse brinjal genotypes against major pests of brinjal. *Journal of Entomology and Zoology Studies*, 6(5), 1052-1059.
362. Prithiva, J. N., Ganapathy, N., Jeyarani, S., & Ramaraju, K. (2018). Relative safety of Beauveria bassiana (Bb 112) oil formulation to *Cryptolaemus montrouzieri* Mulsant. *Journal of Biological Control*, 32(3), 212-214. doi: 10.18311/jbc/2018/17684

363. Prodhan, M. Z. H., Hasan, M. T., Chowdhury, M. M. I., Alam, M. S., Rahman, M. L., Azad, A. K., ... & Shelton, A. M. (2018). Bt eggplant (*Solanum melongena* L.) in Bangladesh: Fruit production and control of eggplant fruit and shoot borer (*Leucinodes orbonalis* Guenee), effects on non-target arthropods and economic returns. *PLoS One*, 13(11), e0205713.
364. Puentes, A., Zhao, T., Lundborg, L., Bjorklund, N., & Borg-Karlson, A. K. (2021). Variation in methyl jasmonate-induced defense among Norway spruce clones and trade-offs in resistance against a fungal and an insect pest. *Frontiers in plant science*, 12, 962.
365. Putta Raju B. (2008). Seasonal occurrence of major insect pests and their natural enemies on brinjal. *Current Biotica*, 2(1), 63-73.
366. Qamar, M., & Haseeb, M. (2019). Population dynamics of *Henosepilachna* spp. in relation to various host plants. *Journal of Entomology and Zoology Studies*, 7(3), 291- 298.
367. Qamar, M., Haseeb, M., & Sharma, D. K. (2009). Biology and morphometrics of *Henosepilachna vigintioctopunctata* (Fab.) on brinjal. *Annals of Plant Protection Sciences*, 17(2), 303-306.
368. Rahman, M. M., Mostofa, M. G., Rahman, M. A., Islam, M. R., Keya, S. S., Das, A. K. & Tran, L. S. P. (2019). Acetic acid: A cost-effective agent for mitigation of seawater- induced salt toxicity in mung bean. *Scientific reports*, 9(1), 15186. doi: 10.1038/s41598- 019- 51178-w
369. Raina, J., & Yadav, G. S. (2018). Brinjal shoot and fruit borer: Bio-ecology and management. *Journal of pharmacognosy and phytochemistry*, 7(4), 444-449.
370. Rajendran, B. (2002). Preliminary studies on the effect of green muscardine fungus, *Metarhizium anisopliae* (Metsch.) Sorokin on eggplant spotted beetle, *Henosepilachna vigintioctopunctata* Fab. [Coleoptera: Coccinellidae]. *Pest Management in Horticultural Ecosystems*, 8, 127-130.
371. Rajesh, M., & Jayakumar, K. (2013). Changes in morphological, biochemical and yield parameters of *Abelmoschus esculents* (L.) Moench due to panchagavya spray. *International Journal of Modern Plant & Animal Sciences*, 1(2), 82-95.

372. Rajeshwari, G., Reddy, N. A., Chakravarthy, A. K., Sridhar, V., & Murthy, B. N. S. (2019). Bio-efficacy of biorational insecticides against thrips and aphids on pomegranate and their safety to natural enemies. *Journal of Entomology and Zoology Studies*, 7(3), 1141-1144.
373. Rakesh, S., Poonguzhali, S., Saranya, B., Suguna, S., & Jothibas, K. (2017). Effect of Panchagavya on growth and yield of *Abelmoschus esculentus* cv. Arka Anamika. *International Journal of Current Microbiology and Applied Sciences*, 6(9), 3090-3097.
374. Rameshkumar, D., Swarna Priya R., Muthukrishnan, N., Ravikesavan, R. & Savitha, B. K (2019). Biochemical and biophysical characteristics of brinjal for resistance to shoot and fruit borer (*Leucinodes Orbonalis* Guenee). *International Journal of Advanced Biotechnology Research*, 9(4), 270-274.
375. Ramzan, M., Naeem-Ullah, U., Ishtiaq, M., Murtazam, G., Qayyum, M. A., & Manzoor, F. (2019). Population dynamics of natural enemies and their correlation with weather parameters in cotton. *Journal of Innovative Sciences*, 5(1), 40-45.
376. Rangasamy, M., Rathinasabapathi, B., McAuslane, H. J., Cherry, R. H., & Nagata, R. T. (2009). Oxidative responses of St. Augustinegrasses to feeding of southern chinch bug, *Blissus insularis* Barber. *Journal of Chemical Ecology*, 35, 796-805.
377. Rani, N., Akhtar, S., Kumari, P., & Verma, R. K. (2018). Screening of local and exotic eggplant genotypes for tolerance to shoot and fruit borer. *International Journal of Current Microbiology and Applied Sciences*, 7, 4553-4559.
378. Ranmalbhai, J. A. (2014). *Morphological, biochemical and molecular characterization of okra cultivars [Abelmoschus esculentus (L.) Moench]* (M. Sc. Thesis submitted to Anand Agricultural University, Anand (Gujarat), India 2014, 1-114).
379. Rashid, M.A., Nazimuddin, M., Hussain, M. M, Rehman, M. A., Nahar, M. S., & Alam, S. N, (2002). Seventh annual report of international pest management collaborative research support program (ipmcersp), 1999-2000. Office of international research education and development, Virginia tech., Blacksburg, VA., 370-372.

380. Razmi, N., Ebadi, A., Daneshian, J., & Jahanbakhsh, S. (2017). Salicylic acid induced changes on antioxidant capacity, pigments and grain yield of soybean genotypes in water deficit condition. *Journal of Plant Interactions*, 12(1), 457-464.
381. Reddy, E. E. P., & Patel, A. I. (2014). Heterosis studies for yield and yield attributing characters in brinjal (*Solanum melongena* L.). *Journal of Recent Advances in Agriculture*, 2(2), 175-180.
382. Reddy, G. V., Antwi, F. B., Shrestha, G., & Kuriwada, T. (2016). Evaluation of toxicity of biorational insecticides against larvae of the alfalfa weevil. *Toxicology Reports*, 3, 473-480. <https://doi.org/10.1016/j.toxrep.2016.05.003>
383. Reddy, S. G. E., & Srinivasa, N. (2001). Preliminary screening of brinjal varieties against insects infesting leaves, *Insect Environment*, 7(2), 67-69.
384. Reshma, M., & Behera, P. K. (2018). Efficacy of some new insecticides against Brinjal Shoot and Fruit Borer *Leucinodes orbonalis*. *International Journal of Current Microbiology and Applied Sciences*, 7(5), 1170-1176.
385. Rioux, S., Pouleur, S., Randall, P., Vanasse, A., Turkington, T. K., Dion, Y., & Belkacemi, K. (2016). Efficacy of acetic acid vapours and dry heat to control *Fusarium graminearum* and *Bipolaris sorokiniana* in barley and wheat seeds. *Phytoprotection*, 96(1), 1-11.
386. Rishi, P., Vikrant, S. D., Sanjeev, S., & Sanjeev, K. (2018). Screening of some brinjal germplasm line against brinjal shoot and fruit borer *Leucinodes orbonalis* guenee in central (UP). *Journal of Entomology and Zoology Studies*, 6(2), 160-166.
387. Rodriguez-Alvarez, C. I., Lopez-Climent, M. F., Gomez-Cadenas, A., Kaloshian, I., & Nombela, G. (2015). Salicylic acid is required for Mi-1-mediated resistance of tomato to whitefly *Bemisia tabaci*, but not for basal defense to this insect pest. *Bulletin of Entomological Research*, 105(5), 574-582. doi: 10.1017/S0007485315000449
388. Rohwer, C. L., & Erwin, J. E. (2008). Horticultural applications of jasmonates. *Journal of Horticultural Science & Biotechnology*, 83(3), 20-22.
389. Saha, T., Chandran, N., Kumar, R., & Ray, S. N. (2014). Field efficacy of newer insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) in Bihar. *Pesticide Research Journal*, 26(1), 63-67.

390. Sahu, A. (2008). Studies on insect pest complex of egg-plant and its management through chemicals. *M. Sc. (Ag.) Thesis submitted to JNKVV, Jabalpur (MP) pp*, 1-87.
391. Sajjan, N. I. (2006). Role of Biorationals in the management of diamond back moth, *Plutella xylostella* L. in cabbage ecosystem. *M.Sc. (Agri) Thesis*. University of Agricultural Sciences, Dharwad. 165 P.
392. Sakhubai, H. T., Laxminarayana, H., & Chaya, P. P. (2014). Effect of bio-inoculants and bio-formulations on growth, yield and quality of Buckwheat. *International Journal of Agricultural Sciences and Veterinary Medicine*, 2(4), 2320-3730.
393. Salako, E. A., Anjorin, S. T., Garba, C. D., & Omolohunnu, E. B. (2008). A review of neem biopesticide utilization and challenges in Central Northern Nigeria. *African Journal of Biotechnology*, 7(25), 265-269.
394. Saljoqi, A. U. R., & Khan, S. (2007). Relative abundance of the red pumpkin beetle, *Aulacophora foveicophora* Lucas, on different cucurbitaceous vegetables. *Sarhad Journal of Agriculture*, 23(1), 109-114.
395. Salles, I. I., Blount, J. W., Dixon, R. A., & Schubert, K. (2002). Phytoalexin induction and β -1, 3-glucanase activities in *Colletotrichum trifolii* infected leaves of alfalfa (*Medicago sativa* L.). *Physiological and Molecular Plant Pathology*, 61(2), 89-101.
396. Salve, R. S., Sonkamble, M. M., & Patil, S. K. (2020). Screening of brinjal varieties for resistance to major insect pests. *Journal of Entomology and Zoology Studies*, 8(1), 1484- 1489.
397. Saniewski, M., Dziurka, M., Dziurka, K., Goraj-Koniarska, J., Ueda, J., & Miyamoto, K. (2020). Methyl jasmonate induces leaf senescence of *Ginkgo biloba* L.: Relevance to endogenous levels of plant hormones. *Plant Growth Regulation*, 91, 383-396.
398. Sanjutha, S., Subramanian, S., Rani, C. I., & Maheswari, J. (2008). Integrated nutrient management in *Andrographis paniculata*. *Research Journal of Agriculture and Biological Science*, 4(2), 141-145.

399. Sarfraz, M., Dosdall, L. M., & Keddie, B. A. (2005). Spinosad: a promising tool for integrated pest management. *Outlooks on Pest Management*, 16(2), 78-84.
400. Sasan, R. K., & Bidochka, M. J. (2012). The insect-pathogenic fungus *Metarhizium robertsii* (Clavicipitaceae) is also an endophyte that stimulates plant root development. *American journal of botany*, 99(1), 101-107.
401. Sathya, S., Pazhanisamy, M., & Archunan, K. (2019). Evaluation of aqueous botanical extracts with panchagavya combination against tobacco caterpillar, *Spodoptera litura* Fab. *Journal of Biopesticides*, 12(2), 149-152.
402. Savy, D., Brostaux, Y., Cozzolino, V., Delaplace, P., Du Jardin, P., & Piccolo, A. (2020). Quantitative structure-activity relationship of humic-like biostimulants derived from agro-industrial byproducts and energy crops. *Frontiers in Plant Science*, 11, 581.
403. Scott-Dupree, C. D., Conroy, L., & Harris, C. R. (2009). Impact of currently used or potentially useful insecticides for canola agroecosystems on *Bombus impatiens* (Hymenoptera: Apidae), *Megachile rotundata* (Hymenoptera: Megachilidae), and *Osmia lignaria* (Hymenoptera: Megachilidae). *Journal of Economic Entomology*, 102(1), 177- 182.
404. Selvaraj, P. (2004). Panchakavya an organic insect repellent. *Num vazhi velanmai*.
405. Senthilkumar, M., Bharath M., Nisha, L. L. J. L., & Basavaraju H. (2015). Field efficacy of panchagavya on insect pests recorded during the study in *Tectona Grandis*. *International Journal of Research in Agriculture and Forestry*, 2, 1-8.
406. Shah, J., Chaturvedi, R., Chowdhury, Z., Venables, B., & Petros, R. A. (2014). Signaling by small metabolites in systemic acquired resistance. *The Plant Journal*, 79(4), 645-658.
407. Shaik, S. (2012). Studies on seasonal incidence of major insect pests and efficacy of new insecticide molecules against shoot and fruit borer (*Leucinodes orbonalis* Guenee) on brinjal (*Solanum melongena* L.). M.Sc. thesis, IGKV, Raipur. pp: 78.
408. Shaikh, A. A., Patel, D. R., & Patel, J. J. (2013). Screening of different genotypes/cultivars against sucking pests infesting brinjal. *AGRES—An International e- Journal*, 2(1), 51-57.

409. Shama, M.A., Moussa, S.A.M., Abo, El. & Fade, N.I. (2016). Salicylic acid efficacy on resistance of garlic plants (*Allium sativum*, L.) to water salinity stress on growth, yield and its quality. *Alexandria Science Exchange Journal*, 37(2), 165-174.
410. Shannag, H. K., Al-Haj, M. S., & Capinera, J. L. (2018). Responses of the Whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae) to Biologically Based Insecticides. *American Journal of Entomology*, 2(3), 28-35.
411. Sharma, J. H., & Tayde, A. R. (2017). Population dynamics of brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. and hadda beetle, *Epilachna vigintioctopunctata* Fab. on brinjal at Allahabad agroclimatic region. *International Journal of Current Microbiology and Applied Sciences*, 6(6), 2055-2060.
412. Sharma, N., Sharma, S., Chudasama, J. A., & Bhadauria, N. S. (2015). Varietal screening against shoot and fruit borer (*Leucinodes orbonalis* G.) of brinjal. *Research in Environment and Life Sciences*, 8, 779-782.
413. Sharma, R., & Sharma, P. (2021). Fungal entomopathogens: a systematic review. *Egyptian Journal of Biological Pest Control*, 31, 1-13.
414. Sharma, S. S., & Kaushik, H. D. (2010). Effect of Spinosad (a bioinsecticide) and other insecticides against pest complex and natural enemies on eggplant (*Solanum melongena* L.). *Journal of Entomological Research*, 34(1), 39-44.
415. Shekar, K. C., Ashok, P., & Sasikala, K. (2013). Characterization, character association, and path coefficient analyses in eggplant. *International Journal of Vegetable Science*, 19(1), 45-57.
416. Shi, X., Pan, H., Xie, W., Wang, S., Wu, Q., Chen, G., ... & Zhang, Y. (2017). Different effects of exogenous jasmonic acid on preference and performance of viruliferous *Bemisia tabaci* B and Q. *Entomologia Experimentalis et Applicata*, 165(2-3), 148-158. doi: 10.1111/eea.12635
417. Shinde, K. G., Bhalekar, M. N., & Patil, B. T. (2012). Characterization of brinjal (*Solanum melongena* L.) germplasm. *Vegetable Science*, 39(2), 186-188.
418. Shipa, A. S., Amin, M. R., Swapon, M. A. H., & Akanda, A. M. (2021). Incidence of sucking insect pests on cotton plants based on the weather conditions. *Journal of Bangladesh Agricultural University*, 19(1), 8-13.

419. Shirale, D., Patil, M., & Parimi, S. (2017). Insecticide resistance in field populations of *Leucinodes orbonalis* (Lepidoptera: Crambidae) in India. *The Canadian Entomologist*, 149(3), 399-407.
420. Shrestha, G., Mettupalli, S., Gadi, R., Miller, D. A., & Reddy, G. V. (2020). Spinosad and mixtures of an entomopathogenic fungus and pyrethrins for control of *Sitona lineatus* (Coleoptera: Curculionidae) in field peas. *Journal of Economic Entomology*, 113(2), 669- 678.
421. Shrinivas, M., Shekharappa, S., & Balikai, R. A. (2009). Evaluation of plant products in combination with cow urine and panchagavya against sorghum shoot fly, *Atherigona soccata* Rondani. *Karnataka Journal of Agricultural Sciences*, 22(3), 618-620.
422. Shukla, A., & Khatri, S. N. (2010). Incidence and abundance of brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee. *Bioscan*, 5(2), 305-308.
423. Singh, B. K., Pandey, R., Singh, A. K., & Dwivedi, S. V. (2021). Efficacy of certain insecticides against brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee. *Indian Journal of Entomology*, 83(3), 464-467.
424. Singh, J. P., Gupta, P. K., Chandra, U., Singh, V. K., & Singh, A. K. (2016). Field screening of brinjal germplasm against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee.) at different stages of plant. *International Journal of Plant Protection*, 9(1), 84-90.
425. Singh, R. R., Singh, T. K., & Shah, M. S. (2011). Population incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen (Lepidoptera: Pyralidae) in Manipur. *Journal of Experimental Zoology*, 4(1), 229-232.
426. Singh, Y. P., & Singh, P. P. (2002). Nature and extent of damage and avoidable yield losses due to shoot and fruit borer (*Leucinodes orbonalis*) to brinjal (*Solanum melongena*) at medium high-altitude hills of Meghalaya. *Indian Journal of Entomology*, 64(1), 12- 16.
427. Singh, Y., Jha, A., Verma, S., Mishra, V. K., & Singh, S. S. (2013). Population dynamics of sucking insect pests and its natural enemies on okra agro-ecosystem in Chitrakoot region. *African Journal of Agricultural Research*, 8(28), 3814-3819.

428. Sinha, S. R., Paul, A. V. N., & Singh, R. (2009). Bio-efficacy of insecticides against two major insect pests of brinjal. *Annals of Plant Protection Sciences*, 17(1), 226-228.
429. Sireesha, O. (2013). Effect of plant products, Panchagavya and bio-control agents on rice blast disease of paddy and yield parameters. *International Journal of Research in Biological Sciences*, 3(1), 48-50.
430. Smith, J. L., De Moraes, C. M., & Mescher, M. C. (2009). Jasmonate-and salicylate- mediated plant defense responses to insect herbivores, pathogens and parasitic plants. *Pest Management Science: Formerly Pesticide Science*, 65(5), 497-503.
431. Sobhy, I. S., Erb, M., & Turlings, T. C. (2014). Plant strengtheners enhance parasitoid attraction to herbivore-damaged cotton via qualitative and quantitative changes in induced volatiles. *Pest Management Science*, 71(5), 686-693.
432. Sobhy, I. S., Erb, M., Sarhan, A. A., El-Husseini, M. M., Mandour, N. S., & Turlings, T. C. (2012). Less is more: treatment with BTH and laminarin reduces herbivore-induced volatile emissions in maize but increases parasitoid attraction. *Journal of Chemical Ecology*, 38, 348-360.
433. Solaiman, A. H. M., Nishizawa, T., Khatun, M., & Ahmad, S. (2014). Morphological characterization and genetic diversity studies of promising brinjal genotypes for hybridization program in Bangladesh. *J. Adv. Agric*, 3(3), 218-28.
434. Somasundaram, E., & Amanullah, M. M. (2007). Panchagavya on growth and productivity of crops: A review. *Green Farming*, 1, 22-26.
435. Somasundaram, E., Sankaran, N., & Thyagarajan, T. M. (2004). Modified panchagavya for better yield. *The Hindu, Thursday 12th February*.
436. Sonali, D. (2008). Screening of brinjal cultivars against jassid, *Amrasca biguttula biguttula* based on the leaf texture of the plant. *Journal of Applied Zoological Researches*, 19(2), 139-140.
437. Sood, S., Sharma, P. C., & Negi, N. (2023). Efficacy of Insecticides and Some Organic Products Against Brinjal Shoot and Fruit Borer *Leucinodes Orbonalis* (Guenee). *Indian Journal of Entomology*, 1-3. doi. No.: 10.55446/IJE.2023.630

438. Soualakhe, A. B., Bantewad, S. D., & Jayewar, N. E. (2021). Biorational management of brinjal shoot and fruit borer *Leucinodes Orbonalis*. *The Pharma Innovation Journal*, 10(8), 617-623.
439. Soundarajan, R., & Baskaran, P. (2001). Mechanisms of resistance in brinjal (*Solanum melongena* L.) to whietfly *Bemisia tabaci* (Gennadius). *Madras Agricultural Journal*, 88(10-12), 657-659.
440. Sowmiya, K., Pazhanisamy, M., Archunan, K., & Ezhilkumar, S. (2020). Bio-efficacy of aqueous botanical extracts with panchagavya combination against shoot and fruit borer, *Leucinodes orbonalis* (guene) in Brinjal. *Plant Archives*, 20(2), 3794-3796.
441. Sowmya, E., & Pradeep, S. (2020). Screening of traditional brinjal (*Solanum melongena* L.) varieties against cotton leaf hopper, *Amrasca bigutulla bigutulla* (Ishida). *International Journal of Current Microbiology and Applied Science*, 9(8), 3513- 3524.
442. Sparks, T. C., Crouse, G. D., Dripps, J. E., Anzeveno, P., Martynow, J., DeAmicis, C. V., & Gifford, J. (2008). Neural network-based QSAR and insecticide discovery: spinetoram. *Journal of Computer-Aided Molecular Design*, 22, 393-401.
443. Srinivasan, R. (2008). Integrated pest management for BSFB in south and Sotheast Asia: past, present and future. *Journal of Biopesticides*, 105-112.
444. Strapasson, P., Pinto-Zevallos, D. M., Paudel, S., Rajotte, E. G., Felton, G. W., & Zarbin, P. H. (2014). Enhancing plant resistance at the seed stage: low concentrations of methyl jasmonate reduce the performance of the leaf miner *Tuta absoluta* but do not alter the behavior of its predator *Chrysoperla externa*. *Journal of Chemical Ecology*, 40, 1090- 1098.
445. Subbaratnam, G. V., & Butani, D. K. (1981). Screening of eggplant varieties for resistance to insect pest complex. *Vegetable Science*, 8(2), 149-153.
446. Subbaratnam, G. V., & Butani, D. K. (1982). Chemical control of insect pest complex of brinjal. *Entomon*, 7(1), 97-100.
447. Subramaniam, A. (2005). Effect of Panchagavya on Escherichia coli in procured milk. *Indian Veterinary journal*, 82, 799-800.

448. Sudisha, J., Sharathchandra, R. G., Amruthesh, K. N., Kumar, A., & Shetty, H. S. (2012). Pathogenesis related proteins in plant defense response. *Plant defence: biological control*, 379-403.
449. Sujatha, S., & Bhat, R. (2016). Impact of organic and inorganic nutrition on soil–plant nutrient balance in arecanut (*Areca catechu* L.) on a laterite soil. *Journal of Plant Nutrition*, 39(5), 714-726.
450. Sultana, M. N., Uddin, M. M., Ahmad, M., & Adnan, S. M. (2017). Varietal preference of okra jassid, *Amrasca devastans* (Dist.) under field condition of Bangladesh. *Journal of the Bangladesh Agricultural University*, 15(2), 227-233.
451. Sun, Y. C., Pan, L. L., Ying, F. Z., Li, P., Wang, X. W., & Liu, S. S. (2017). Jasmonic acid-related resistance in tomato mediates interactions between whitefly and whitefly- transmitted virus. *Scientific Reports*, 7(1), 566. doi: 10.1038/s41598-017-00692-w
452. Sundararasu, K., & Jeyasankar, A. (2014). Effect of vermiwash on growth and yield of brinjal, *Solanum melongena* (eggplant or aubergine). *Asian Journal of Science and Technology*, 5(3), 171-173.
453. Supriya, H. D. and Mamocha K. S. (2019). Screening of brinjal varieties resistant to brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) *Indian Journal of Hill Farming*, 68-71.
454. Swaminathan, C., Swaminathan, V. & Vijayalakshmi. K. (2007). Panchagavya- Boon to organic farming. International Book Distributing Company. Lucknow. pp. 55-57.
455. Swaminathan, R., Manjoo, S., & Hussain, T. (2010). Anti-feedant activity of some biopesticides on *Henosepilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae). *Journal of Biopesticides*, 3(Special Issue), 77.
456. Swarnam, T. P., Velmurugan, A., & Roy, N. (2016). Effect of foliar application of panchagavya on yield and quality characteristics of eggplant (*Solanum melongena* l). *Advances in Life Sciences*, 5(7), 2636-2639.
457. Szopinska, D. (2013). The effects of organic acids treatment on germination, vigour and health of zinnia (*Zinnia elegans* Jacq.) seeds. *Acta Scientiarum Polonorum, Hortorum Cultus*, 12, 17–29.

458. Taggar, G. K., & Gill, R. S. (2012). Preference of whitefly, *Bemisia tabaci*, towards black gram genotypes: Role of morphological leaf characteristics. *Phytoparasitica*, 40, 461- 474.
459. Tescari, E., Chloridis, A., Bacci, L., Bradascio, R., & Giberti, A. (2014). Spinetoram (Delegate®, Radiant®), Nuovo insetticida ad ampio spettro d'azione. *Atti Giorn. Fitopatol*, 1, 11-20.
460. Thaler, J. S. (1999). Jasmonate-inducible plant defences cause increased parasitism of herbivores. *Nature*, 399(6737), 686-688.
461. Thamburaj, S., & Singh, N. (2001). Vegetables, tubercrops, and spices. Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, New Delhi, pp: 30-32.
462. Thapa, R. B., Achham, B., Tiwari, S., & Dhakal, S. C. (2009). Field screening of selected brinjal genotypes against shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Pyralidae: Lepidoptera) in Eastern Terai of Nepal. *Journal of the Institute of Agriculture and Animal Sciences*, 30, 173-177.
463. Tharmaraj, K., Ganesh, P., Kumar, R. S., Anandan, A., & Kolanjinathan, K. (2011). A critical review on Panchagavya-a boon plant growth. A Boon Plant Growth. *International Journal of Pharmaceutical and Biological Archive*, 2(6), 1611-1614.
464. Thokchom, S., Akoijam, R., Ningombam, A., Bharteey, P. K., & Erla, S. (2022). Succession of insect pests and natural enemies in brinjal in Manipur, North East India with bio-pesticide application. *Agricultural Mechanization in Asia*, 53(7), 9049-9059.
465. Thompson, G. D., Dutton, R., & Sparks, T. C. (2000). Spinosad—a case study: an example from a natural products discovery programme. *Pest Management Science: formerly Pesticide Science*, 56(8), 696-702.
466. Thurkathipana, N., & Mikunthan, G. (2008). Eco-friendly management of hadda beetle using *Beauveria bassiana* in Brinjal. *Communications in Agricultural and Applied Biological Sciences*, 73(3), 597-602.

467. Tiwari, G., Prasad, C. S., Kumar, A., & Nath, L. (2012). Influence of weather factors on population fluctuation of pest complex on brinjal. *Annals of Plant Protection Sciences*, 20(1), 68-71.
468. Tombion, L., Puerta, A. V., Barbaro, L. A., Karlanian, M. A., Sangiacomo, M. A., & Garbi, M. (2016). Substrate characteristics and lettuce (*Lactuca sativa* L.) seedling quality depending on the vermicompost dose. *Chilean Journal of Agricultural & Animal Sciences*, 32(1), 46-52.
469. Tome, H. V. V., Barbosa, W. F., Martins, G. F., & Guedes, R. N. C. (2015). Spinosad in the native stingless bee *Melipona quadrifasciata*: regrettable non-target toxicity of a bioinsecticide. *Chemosphere*, 124, 103-109.
470. Traw, B. M., & Dawson, T. E. (2002). Differential induction of trichomes by three herbivores of black mustard. *Oecologia*, 131, 526-532.
471. Traw, M. B., & Bergelson, J. (2003). Interactive effects of jasmonic acid, salicylic acid, and gibberellin on induction of trichomes in Arabidopsis. *Plant Physiology*, 133(3), 1367-1375.
472. Tripathi, D., Raikhy, G., & Kumar, D. (2019). Chemical elicitors of systemic acquired resistance—Salicylic acid and its functional analogs. *Current Plant Biology*, 17, 48-59.
473. Tripura, A., Chatterjee, M. L., Pande, R., & Patra, S. (2017). Biorational management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) in mid hills of Meghalaya. *Journal of Entomology and Zoology Studies*, 5(4), 41-45.
474. Tupe, A. P., Lad, A. G., & Pawar, A. A. (2022). Seasonal incidence of major insect pests of Brinjal in relation to weather parameters. *The Pharma Innovation Journal*, 11(12), 2606-2609.
475. Tushar, M. G., Uikey, B. L., Barma, P., Jha, S. (2014). Incidence studies on some important insect pests of cucumber (*Cucumis sativus* L.). *The Ecosan*. 8, 177-180.
476. Ulland, S., Ian, E., Mozuraitis, R., Borg-Karlson, A. K., Meadow, R., & Mustaparta, H. (2008). Methyl salicylate, identified as primary odorant of a specific receptor neuron type, inhibits oviposition by the moth *Mamestra brassicae* L. (Lepidoptera, Noctuidae). *Chemical Senses*, 33(1), 35-46.

477. Umamageswari, P., Rajavel, D. S., & Govindan, K. (2008). Biological activity of certain botanicals on bhendi shoot and fruit borer, *Earias vitella* (Fabricius). *Journal of Plant Protection and Environment*, 5(1), 69-73.
478. Upadhyay, V., Rai, D., Rana, M., Mehra, P., & Pandey, A. K. (2014). *Verticillium lecani* (Zimm.): A potential entomopathogenic fungus. *International Journal of Agriculture, Environment and Biotechnology*, 7(4), 719-727.
479. Utsumi, Y., Utsumi, C., Tanaka, M., Ha, C. V., Matsui, A., Matsunaga, S., & Seki, M. (2019). Acetic acid treatment enhances drought avoidance in cassava (*Manihot esculenta* Crantz). *Frontiers in Plant Science*, 10, 439960. doi: 10.3389/fpls.2019.00521
480. Valle, G. E., Lourenção, A. L., & Pinheiro, J. B. (2012). Adult attractiveness and oviposition preference of *Bemisia tabaci* biotype B in soybean genotypes with different trichome density. *Journal of Pest Science*, 85, 431-442.
481. Vallimayil, J., & Sekar, R. (2012). Investigation on the effect of panchagavya on southern sunnhemp mosaic virus (SSMV) infected plant systems. *Global Journal of Environmental Research*, 6(2), 75-79.
482. Vanlaldiki, H., Singh, M. P., & Sarkar, P. K. (2013). Efficacy of ecofriendly insecticides on the management of diamondback moth (*Plutella xylostella* Linn.) on cabbage. *The Bioscan*, 8(4), 1225-1230.
483. Varghese, S. M., & Prabha, M. L. (2014). Biochemical characterization of vermiwash and its effect on growth of *Capsicum frutescens*. *Malaya Journal of Biosciences*, 1(2), 86-91.
484. Varma, S., & Anandhi, P. (2008). Assessment of mortality factors, biology and morphometrics of hadda beetle, *Henosepilachna vigintioctopunctata* (F.) on brinjal. *Annals of Plant Protection Sciences*, 16(1), 119-123.
485. Varma, S., Anandhi, P., Srivastava, D. S., & Singh, Y. (2011). Population dynamics and evaluation of certain bio-products against brinjal leafhopper, *Amrasca bigutulla bigutulla* in Allahabad condition. *Journal of Entomological Research*, 35(3), 215-220.

486. Vasumathi, R. (2001). Influence of organic manures, biofertilizers and plant density on growth, yield and alkaloid content of Bhumyamalaki (*Phyllanthus amarus* Schum. And Thonn.). *M. Sc. (Agric.) Thesis*.
487. Venkatesha, M. G. (2006). Seasonal occurrence of *Henosepilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae) and its parasitoid on Ashwagandha in India. *Journal of Asia-Pacific Entomology*, 9(3), 265-268.
488. Venu, R. C., Sheshu Madhav, M., Sreerekha, M. V., Nobuta, K., Zhang, Y., Carswell, P. & Wang, G. L. (2010). Deep and comparative transcriptome analysis of rice plants infested by the beet armyworm (*Spodoptera exigua*) and water weevil (*Lissorhoptrus oryzophilus*). *Rice*, 3, 22-35.
489. Verma, S., Singh, A., Pradhan, S. S., Singh JP, & Verma S. K. (2018). Effects of organic formulations and synthetic fertilizer on the performance of pigeonpea in eastern region of Uttar Pradesh. *Bangladesh Journal of Botany*, 47(3), 467-471.
490. Vethamoni, P. I., & Praneetha, S. (2016). Growth and yield attributes with shoot and fruit borer resistance in parents and F1 hybrids of brinjal. *Madras Agricultural Journal*, 103(1/3), 83-86.
491. Vicentini, S., Faria, M., & de Oliveira, M. R. (2001). Screening of *Beauveria bassiana* (Deuteromycotina: Hyphomycetes) isolates against nymphs of *Bemisia tabaci* (Genn.) biotype B (Hemiptera: Aleyrodidae) with description of a new bioassay method. *Neotropical Entomology*, 30, 97-103.
492. Vieira, S. S., Bueno, A. F., Boff, M. I. C., Bueno, R. C. O. F., & Hoffman-Campo, C. B. (2011). Resistance of soybean genotypes to *Bemisia tabaci* (Genn.) biotype B (Hemiptera: Aleyrodidae). *Neotropical Entomology*, 40, 117-122.
493. Vijayakumari, B., Yadav, R. H., Gowri, P., & Kandari, L. S. (2012). Effect of panchagavya, humic acid and micro herbal fertilizer on the yield and post harvest soil of soyabean (*Glycine max* L.). *Asian Journal of Plant Sciences*, 11(2), 83-86.
494. Vimalendran, L., & Wahab, K. (2013). Effect of foliar spray of Panchagavya on yield attributes, yield and economics of baby corn. *Journal of Agronomy*, 12(2), 109-112.

495. Vishwakarma, R., Prasad, P. H., Ghatak, S. S., & Mondal, S. (2011). Bio-efficacy of plant extracts and entomopathogenic fungi against *Epilachna* beetle, *Henosepilachna vigintioctopunctata* (Fabricius) infesting bottle gourd. *Journal of Insect Science*, 24, 65- 70.
496. Wagh, S. S., Pawar, D. B., Chandele, A. G., & Ukey, N. S. (2012). Biophysical mechanisms of resistance to brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee in brinjal. *Pest management in horticultural ecosystems*, 18(1), 54-59.
497. Waghmode, B. R., Sonawane, S. V., & Tajane, D. S. (2015). Differential responses of yield and quality to organic manures in sweet corn [*Zea mays* (L.) *saccharata*]. *International Journal of Agricultural Science*, 11(2), 229-237.
498. Wahengbam, J., Bhushan, L. S., Patil, J. B., & Pathma, J. (2021). Insecticides Derived from Natural Products: Diversity and Potential Applications. In *Current Trends in Microbial Biotechnology for Sustainable Agriculture* (pp. 403-437). Springer, Singapore.
499. Wang, K. L., Li, H., & Ecker, J. R. (2002). Ethylene biosynthesis and signaling networks. *Plant Cell*, 4, 131–151.
500. War, A. R., Paulraj, M. G., War, M. Y., & Ignacimuthu, S. (2011). Jasmonic acid-mediated-induced resistance in groundnut (*Arachis hypogaea* L.) against *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). *Journal of Plant Growth Regulation*, 30(4), 512-523.
501. War, A. R., Paulraj, M. G., War, M. Y., & Ignacimuthu, S. (2012). Herbivore-induced resistance in different groundnut germplasm lines to asian armyworm, *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Acta Physiologiae Plantarum*, 34, 343-352.
502. Wargantiwar, R. K., Ashwani Kumar, A. K., & Saima Kumar, S. K. (2010). Bioefficacy of some botanicals and in combination with insecticide against *Leucinodes orbonalis* (Guenee) in brinjal under Allahabad agro-climatic condition. *International Journal of Plant Protection*, 3(2), 245-247.
503. Wu, J., & Baldwin, I. T. (2009). Herbivory-induced signalling in plants: perception and action. *Plant, Cell & Environment*, 32(9), 1161-1174.

504. Xiao, Z., Liu, M., Jiang, L., Chen, X., Griffiths, B. S., Li, H., & Hu, F. (2016). Vermicompost increases defense against root-knot nematode (*Meloidogyne incognita*) in tomato plants. *Applied Soil Ecology*, 105, 177-186.
505. Xin, Z., Yu, Z., Erb, M., Turlings, T. C., Wang, B., Qi, J.... & Lou, Y. (2012). The broad-leaf herbicide 2, 4-dichlorophenoxyacetic acid turns rice into a living trap for a major insect pest and a parasitic wasp. *New Phytologist*, 194(2), 498-510.
506. Xu, H. L. (2001). Effects of a microbial inoculant and organic fertilizers on the growth, photosynthesis and yield of sweet corn. *Journal of crop production*, 3(1), 183-214.
507. Yadav, A., Raghuraman, M., & Choudhary, S. (2016). Periodic occurrence and association of whitefly and jassid on brinjal (*Solanum melongena* L.) with weather parameters. *Journal of Experimental Zoology India*, 19(1), 447-450.
508. Yadav, R., & Chang, N. T. (2014). Effects of temperature on the development and population growth of the melon thrips, *Thrips palmi*, on eggplant, *Solanum melongena*. *Journal of Insect Science*, 14(1), 78.
509. Yang, S., Song, F., & Xie, J. (2013). Resistance of jasmonic acid-mediated cotton seedlings against the relative growth rate of *Helicoverpa armigera*. *Journal of Northwest A & F University-Natural Science Edition*, 41(5), 66-74.
510. Yang, X., Chen, L., Yang, Y., Guo, X., Chen, G., Xiong, X., ... & Li, G. (2020). Transcriptome analysis reveals that exogenous ethylene activates immune and defense responses in a high late blight resistant potato genotype. *Scientific Reports*, 10(1), 21294.
511. Yousafi, Q., Afzal, M., Aslam, M., Razaq, M., & Shahid, M. (2013). Screening of brinjal (*Solanum melongena* L.) varieties sown in autumn for resistance to cotton jassid, *Amrasca bigutulla bigutulla* (Ishida). *Pakistan Journal of Zoology*, 45(4).
512. Yu, H., Zhang, Y., Wu, K., Gao, X. W., & Guo, Y. Y. (2008). Field-testing of synthetic herbivore-induced plant volatiles as attractants for beneficial insects. *Environmental Entomology*, 37(6), 1410-1415.

513. Zambrano-Moreno, E. L., Chavez-Jauregui, R. N., Plaza, M. D. L., & Wessel-Beaver, L. (2015). Phenolic content and antioxidant capacity in organically and conventionally grown eggplant (*Solanum melongena*) fruits following thermal processing. *Food Science and Technology*, 35(3), 414-420.
514. Zander, M. (2021). Many ways to repress! JAZ's agony of choices. *Molecular Plant*, 14(5), 714-716.
515. Zarate, S. I., Kempema, L. A., & Walling, L. L. (2007). Silverleaf whitefly induces salicylic acid defenses and suppresses effectual jasmonic acid defenses. *Plant Physiology*, 143(2), 866-875.
516. Zhang, B., Ma, R., Guo, L., Song, Z., & Yu, M. (2017). Effects of exogenous salicylic acid on physiological traits and CBF gene expression in peach floral organs under freezing stress. *Archives of Biological Sciences*, 69(4), 585-592.
517. Zhang, S. Z., Hua, B. Z., & Zhang, F. (2008). Induction of the activities of antioxidative enzymes and the levels of malondialdehyde in cucumber seedlings as a consequence of *Bemisia tabaci* (Hemiptera: Aleyrodidae) infestation. *Arthropod-Plant Interactions*, 2, 209-213.
518. Zhao, L. Y., Chen, J. L., Cheng, D. F., Sun, J. R., Liu, Y., & Tian, Z. (2009). Biochemical and molecular characterizations of *Sitobion avenae*-induced wheat defense responses. *Crop Protection*, 28(5), 435-442.
519. Zhu, Z., & Lee, B. (2015). Friends or foes: new insights in jasmonate and ethylene co- actions. *Plant and Cell Physiology*, 56(3), 414-420.
520. Zieslin, N., & Ben-Zaken, R. (1993). Peroxidase activity and presence of phenolic substances in peduncles of rose flowers. *Plant physiology and biochemistry (Paris)*, 31(3), 333-339.

Annexure 1: Detailed data of weather forecasting *Rabi* season 2022

<i>Rabi</i> season 2022						
SMW	Date	Max Temp (°C)	Min Temp. (°C)	RH (M) (%)	RH (E) (%)	Rainfall (mm)
51	17 Dec to 23 Dec	24.57	9.86	90.43	77.57	0.00
52	24 Dec to 31 Dec	21.63	8.63	94.25	78.75	0.25
1	01 Jan to 07 Jan	14.40	5.50	94.14	81.86	0.00
2	08 Jan to 14 Jan	13.50	8.43	95.57	82.71	0.30
3	15 Jan to 21 Jan	14.40	5.94	91.43	76.57	0.00
4	22 Jan to 28 Jan	18.70	7.56	84.14	63.57	4.94
5	29 Jan to 4 Feb	20.13	8.69	94.57	76.00	1.77
6	05 Feb to 11 Feb	23.71	11.79	80.29	58.14	0.00
7	12 Feb to 18 Feb	25.97	10.80	63.00	41.43	0.00
8	19 Feb to 25 Feb	28.09	14.30	92.29	56.29	0.00

SMW = Standard Metrological Week; Max. Temp. = Average Maximum Temperature (°C); Min.Temp. = Average Minimum Temperature (°C); RH (M) = Morning Realtive Humidity (%); RH (E) = Evening Realtive Humidity (%); R = Rainfall (mm per week)

Annexure 2: Detailed data of weather forecasting *Kharif* season 2023

<i>Kharif</i> season 2023						
SMW	Date	Max. Temp (°C)	Min Temp. (°C)	RH. (M) (%)	RH. (E) (%)	Rainfall (mm)
23	04 June to 10 June	37.57	22.14	79.43	34.57	3.37
24	11 June to 17 June	36.29	23.71	84.43	45.86	5.89
25	18 June to 24 June	37.86	27.57	80.86	51.57	2.57
26	25 June to 01 July	35.71	27.00	82.71	56.14	0.34
27	02 July to 08 July	33.57	25.29	86.71	65.57	21.89
28	09 July to 15 July	33.57	25.86	88.43	66.14	1.63
29	16 July to 22 July	34.57	27.43	86.43	70	7.17
30	23 July to 29 July	33.57	27.00	90.86	72.71	8.57
31	30 July to 05 Aug	35.43	27.59	90.86	68.71	8.66
32	06 Aug to 12 Aug	34.29	26.86	90.29	73.00	0.83

SMW = Standard Metrological Week; Max. Temp. = Average Maximum

Temperature (°C); Min.Temp. = Average Minimum Temperature (°C); RH

(M)

= Morning Realtive Humidity (%); RH (E) = Evening Realtive Humidity (%); R

= Rainfall (mm per week)

LISTS OF PUBLICATIONS

Sr. No.	Name of the Research Paper	Journal	Impact Factor	Status
1.	Biopesticides and their impact on brinjal Jassid (<i>Amrasca biguttula biguttula</i> Ishida)	Journal of Applied and Natural Science	Research (0.47) Scopus	Published