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Research Article

Biopesticides and their impact on brinjal Jassid (*Amrasca biguttula biguttula* Ishida)

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Abstract
Brinjal (*Solanum melongena*) is a precious and nourishing vegetable grown worldwide in tropical and subtropical climates. Jassid (*Amrasca biguttula biguttula*I.) (Hemiptera: Cicadellidae),of which nymphs and adults suck the cell sap from the underside of the brinjal leaves resulting in curling and affecting the photosynthesis process. The present study aimed to study the effectiveness of biopesticides and their impact on jassid and its natural enemy in different seasons. The field experiment arranged in randomized block design includes six biorational insecticides such has (T_1)-Spinosad 45 % SC @ 0.4ml/l, (T_2)-Neem Seed Kernel Extract(NSKE) 1% @ 2ml/l, (T_3)-*Beauveria bassiana* 1x 10^8 @ conidia/ml @ 10ml/l, (T_4)-*Metarhizium anisopliae*1x 10^8 conidia/ml @ 10ml/l, (T_5)-*Verticillium lecanii* 1x10^8 conidia/ml @ 10ml/land (T_6)-Untreated plots replicated in four times. It is resulted that all the biorational pesticides performed significantly better than the control. However, among the treatments, application of (T_3)-*Beauveria bassiana* 1x10^8 conidia/ml @ 10 ml/l and (T_2)-Neem Seed Kernel Extract (NSKE) 1% @ 2 ml/l was found to have significantly better results against jassid,during *Rabi*(2021) and *Kharif* season (2022) respectively. For predatory coccinellids,(T_2) - Neem Seed Kernel Extract (NSKE) 1% @ 2 ml/l and(T_1)-Spinosad 45 % SC @ 0.4ml/l were found to be better compared to other treatments in *Rabi* and *Kharif* season. This research will help to understand the importance of biopesticides with eco-friendly approaches to manage jassid.

Keywords: *Amrasca biguttula biguttula,* Biopesticides, Brinjal, Management, Resistant

INTRODUCTION

The "King of vegetables" or brinjal (*Solanum melongena* Linnaeus), commonly known as aubergine, is a vegetable that is produced in tropical, subtropical, and warm temperate regions of the world. It is native to India and is grown year-round under various agro-climatic conditions (Singh *et al.,* 2018). Brinjal is a famous vegetable in Asia and Mediterranean areas (Chapman, 2020). It is the 5^{th} most popular vegetable in the world with a production of 56.6 Mt. China is the leading brinjal-cultivated country with 36.6 Mt, while

India and Egypt are the second and third major producers of brinjal in the world, respectively (Chioti *et al*., 2022). Regarding nutritional value, brinjal has a very low caloric value and is considered among the healthiest vegetables for its high content of vitamins, minerals and bioactive compounds for human health (Plazas *et al*., 2014; Docimo *et al*., 2016).It is a main ingredient in pickle production and a highly effective diabetes treatment. It works well as an anti-inflammatory, laxative, and cardio tonic and aphrodisiac; it improves appetite and lessens inflammation (Sahu, 2018; Shridhara, 2019).

A severe and destructive brinjal pest called *A. biguttulabiguttula*, commonly calledjassid,destroys the crop until harvest. The cell sap from the underside of the leaves is sucked by jassid nymphs and adults, causing the leaves to curl and turn yellow. The toxin found in the leaves can result in necrosis if nymphs and adults consume too much of it (Ramzan*et al*., 2020).Farmers utilized several management techniques at both large and small scale to treat damaged leaves that blister and occasionally fall to the ground (Rahman*et al*., 2009) to lessen jassid attacks and boost brinjal output (Jayakrishnan and Madhuban, 2012; Ramzan *et al*., 2019a). Chemicals are frequently used to manage the pest population. However, overuse of pesticides can result in hazardous bioaccumulation and biomagnification in water or can causeenvironmental pollution that is dangerous to humans and other animals (parasitoids, parasites, and predators) (Jayakrishnan and Madhuban, 2012;Sajid *et al*., 2020). The main drawback of chemical use is insect resistance to several classes of pesticides (Ramzan *et al*., 2019b).

By incorporating biopesticides into integrated pest management (IPM) tactics against agricultural pests, selection pressure on insecticides might be lessened(Kivett *et al*., 2015).The use of *Bacillus thuringiensis* (*Bt*) and Entomopathogenic fungi (EPFs) as insect biological control agents has drawn attention worldwide(Legwaila *et al.,*2015; Jarrahi andSafavi, 2016; Kalvnadi *et al.,* 2018).In IPM techniques, several researchers have explored biopesticides based on EPFs and (*Bt*) as potential substitutes for synthetic pesticides. (Erler andAtes, 2015; Lacey *et al*., 2015; Bayissa *et al*., 2017; Opisa *et al*., 2018).The biopesticides like *Beauveria bassiana, Metarhizium anisopliae*, *Isariafumosorosea*, *Verticillium lecanii*and *Bt*subsp. *Kurstaki* have been used to control agricultural pests (Tefera *et al*., 2016; Abdel-Raheem and Al-Keridis, 2017; Opisa *et al*., 2018; Yasin *et al*., 2019).

Most studies attempting brinjal pest management reported the use of chemical pesticides to efficiently manage brinjal pests. Only a handful of studies documented the effect of biorational pesticides such as eco-friendly newer molecules, microbial and botanical for pest management. Biopesticides are nature's assets that have pavedthe way to eco-friendly pest management, fostering sustainable agriculture. Screening the biopesticides for brinjal pest management is a viable option to reduce problems such as pesticide resistance, pest resurgence, environmental pollution, toxic residues on food, poisoning of non-target organisms etc., associated with the use of synthetic agrochemicals (Pathma*et al*., 2021). Considering these views, the present study was undertaken to evaluate some biorational pesticides against jassid.

MATERIALS AND METHODS

Experimental layout and treatment details

The research trials were conducted at Farm of Lovely Professional University, Department of Entomology, School of Agriculture, Phagwara, Punjab (31.48°N and 75.56°E, 249 m above msl), during *Rabi*(2021) and *Kharif* (2022) season. The brinjal hybrid VNR- 51C was sown in a randomized block design ona plot size of 4.8 X 3.6 m, which included six treatments and four replications with 24 plots with25 plants in each plot and 5 plants selected for data recording. The population of jassids at the initial stage ranged from (15.20 to 22.80 in *Rabi* 2021) and (15.95 to 20.75 in *Kharif* 2022) jassids per plant before the spray and at the final stage was (4.92 to 8.70 in *Rabi* 2021) while (4.13 to 10.81 in *Kharif* 2022) jassids per plant season. The different treatments included (T_1)-Spinosad 45 % SC @0.4ml/l, (T_2)-NSKE1% @2ml/l, (T_3)-*B. bassiana*1x 10^8 conidia/ml @ 10ml/l,(T_4)-*M. anisopliae*1x 10^8 conidia/ml @ 10ml/l, (T_5)-*V. lecanii* 1x10^8conidia/ml @ 10ml/ and (T_6) - untreated plots. The treatments were imposed when the brinjal pest crossed the economic threshold level.So,a single spray was done at once as the jassid population had not crossed its economic threshold level (ETL) on the final day of count and, observations were taken from the prior day before the spray and the data were recorded on 1, 3, 5, 7, 11, and 14days after treatment (DAT). The recommended package of practices for raising a good crop was followed except for the spray of insecticides. Pest natural infestation was allowed to take place and different treatments were applied at the time of pest appearance **(**Plate 1: Trial Plots**)**. The jassid populations and coccinellid beetles were counted before and after the spray of biopesticides. Data were recorded for pests from randomly selected five plants at three different levels of brinjal plants (top, middle, and lower part) at 1, 3, 5, 7, 11 and 14 DAT. (Plate 2: Jassid; Plate 3: Jassid infested leaves; Plate 4: Predatory coccinellids).

Data analysis

Data on population count was transformed into square root transformation (X+ 0.5) as per the method developed by Poisson for statistical analysis (Snedecor and Cochran, 1967). All the data obtained was subjected to an analysis of variance (ANOVA).The means were separated by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984). For all statistical analyses, SPSS version 22.0 was used. Yield data were recorded at harvest of the brinjal crop in two pickings and expressed as kg per hectare.

RESULTS AND DISCUSSION

Effectiveness of eco-friendly insecticides against jassid during *Rabi* and *Kharif* season

As jassidwas a major pest, the efficacy of biorational insecticides was tested against jassid. Jassid nymphs and adults were observed sucking sap from the underside of brinjal leaves, which resulted in the leaves turning yellow, bronze, or even drying up.Testing the bioefficacy of various biopesticides with their recommended doses showed that all the treatments except the control were equally effective on 1 DAT and 14 DAT (Days After Treatments).

The jassid population was significantly (43.44 %)less in the application of the (T_3)-*B. bassiana*1x10^8 conidia/ml @ 10 ml/l in (Table 1) while the application of the (T_2)-NSKE1% @ 2ml/l showed (61.80 %) (Table 3) in compare to other treatments during *Rabi* and *Kharif* season respectively. In six treatments and four replications (6 treatments,4 replications of each = $_{(6,4)}$), all the biorational treatments were found significantly better in performance at 1 DAT ($F_{(6,4)}$; P= 0.000), 3 DAT ($F_{(6,4)}$; P = 0.003), 5 DAT ($F_{(6,4)}$; P = 0.033) however, 7, 11 and 14 DAT observed statistically non-significantwith their effect on jassid population during *Rabi*season (Table 1) while during *Kharif* Season all the treatments performed highly significant impact on jassid (Table 3).The maximumreduction of jassid was recorded in application of (T_3)-*B. bassiana* 1x10^8 conidia/ml @ 10 ml/l of 43.44% during the *Rabi* season (Table 1), while 61.80% reduction was observed at (T_2)-NSKE1% @ 2ml/l during *Kharif* Season (Table 3) (Plate 2: Jassid; Plate 3: Jassid infested leaves).

In *Rabi* 2021, all the treatments significantly increased yield over the control. The maximum fruit yield of (1725.00kg ha^{-1}) was recorded from the fields treated with (T_3)-*B. bassiana*1x10^8 conidia/ml @ 10 ml/l followed by those treated with (T_5)-*V. lecanii* 1x10^8 conidia/ml @ 10 ml/l (1445.83kg ha^{-1}), (T_2)- NSKE 1% @ 2ml/l offering (1425.00 kg ha^{-1}),(T_4)-*M. anisopliae*1x10^8 conidia/ml @ 10 ml/l (1183.33 kg ha^{-1}), (T_1)-Spinosad 45 % SC @ 0.4 ml/l offering(1004.16 kg ha^{-1}) and last was (T_6) - untreated plots with yield of (645.83 kg ha^{-1}) (Table 1).

In *kharif* season 2022, all the treatments significantly increased in yield over the control. The maximum fruit

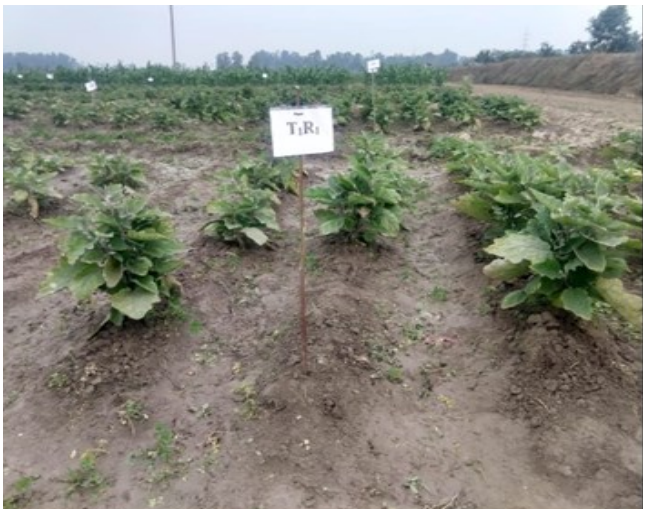

Plate 1. *Trial plots*

Plate 2. *Jassid*

Plate 3. *Jassid infested leaves*

Table 1. Effectiveness of eco-friendly insecticidesagainst jassid in brinjal during (Rabi Season 2021)

Treatments	No. of jassids / per plant*								% Reduction over control	Yield (kg ha^{-1})
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean		
T_1 - Spinosad 45 % SC @ 0.4ml/l	19.25 (4.44)^{ab}	9.25 (3.12)^{bc}	7.25 (2.78)^{a}	7.05 (2.74)^{ab}	6.25 (2.59)^{a}	4.40 (2.21)^{a}	3.70 (2.04)^{a}	6.31	27.47	1004.16^{b}
T_2 - NSKE 1% @ 2ml/l	18.40 (4.34)^{ab}	7.30 (2.79)^{b}	6.00 (2.54)^{a}	5.90 (2.52)^{a}	5.85 (2.51)^{a}	4.85 (2.31)^{a}	3.95 (2.10)^{a}	5.64	35.17	1425.00^{c}
T_3 - Beauveria bassiana 1x10^8 conidia/ml@ 10ml/l	15.20 (3.96)^{a}	3.65 (2.03)^{a}	5.60 (2.46)^{a}	4.70 (2.28)^{a}	6.95 (2.72)^{a}	4.45 (2.22)^{a}	4.20 (2.16)^{a}	4.92	43.44	1725.00^{d}
T_4 - Metarhizium anisopliae 1x10^8 conidia/ml@ 10ml/l	22.80 (4.82)^{b}	8.00 (2.91)^{b}	7.45 (2.81)^{a}	6.45 (2.63)^{a}	6.05 (2.55)^{a}	4.30 (2.19)^{a}	3.25 (1.93)^{a}	5.91	32.06	1183.33^{b}
T_5 - Verticillium lecanii 1x10^8 conidia/ml@ 10ml/l	15.90 (4.04)^{a}	7.40 (2.81)^{b}	6.75 (2.69)^{a}	5.80 (2.50)^{a}	5.55 (2.45)^{a}	4.80 (2.30)^{a}	3.30 (1.94)^{a}	5.60	35.63	1445.83^{c}
T_6 - Control (water)	19.95 (4.52)^{ab}	11.80 (3.50)^{c}	10.75 (3.35)^{b}	9.80 (3.20)^{b}	10.50 (3.31)^{a}	5.65 (2.47)^{a}	3.70 (2.04)^{a}	8.70		645.83^{a}
P value	0.068^{NS}	0.000**	0.003*	0.033*	0.262^{NS}	0.949^{NS}	0.944^{NS}			0.000**
F calculated value	2.619	9.332	6.091	3.308	1.455	0.219	0.229			35.921

*Mean of four replicates (jassids were counted on 5 randomly selected plants per replication and was expressed as no. of leafhoppers per plant) PTC – Pretreatment count; DAT – Days after Treatment. Figures in parentheses are $\sqrt{x+0.5}$ transformed values

Table 2. Effectiveness of eco-friendly insecticideson predatory coccinellids (Rabi Season 2021)

Treatments	No. of coccinellids / per plant*							
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean
T_1 - Spinosad 45 % SC @ 0.4ml/l	1.90 (1.54)^{ab}	1.65 (1.46)^{bc}	1.25 (1.32)^{ab}	1.05 (1.24)^{ab}	0.85 (1.16)^{ab}	0.60 (1.04)^{a}	0.45 (0.97)^{a}	0.97
T_2 - NSKE 1% @ 2ml/l	2.10 (1.61)^{ab}	1.85 (1.53)^{c}	1.55 (1.42)^{b}	1.30 (1.34)^{b}	1.20 (1.30)^{b}	1.05 (1.24)^{b}	0.90 (1.18)^{b}	1.30
T_3 - *Beauveria bassiana* 1x10^8 conidia/ml @ 10ml/l	2.00 (1.58)^{ab}	1.55 (1.42)^{bc}	1.10 (1.26)^{a}	0.95 (1.20)^{ab}	0.75 (1.11)^{a}	0.60 (1.04)^{a}	0.40 (0.94)^{a}	0.89
T_4 - *Metarhizium anisopliae* 1x10^8 conidia/ ml @ 10ml/l	1.80 (1.51)^{a}	1.25 (1.32)^{ab}	1.05 (1.24)^{a}	0.85 (1.16)^{ab}	0.65 (1.07)^{a}	0.50 (1.00)^{a}	0.40 (0.94)^{a}	0.78
T_5 - *Verticillium lecanii* 1x10^8 conidia/ml @ 10ml/l	2.20 (1.64)^{b}	1.05 (1.24)^{a}	0.90 (1.18)^{a}	0.75 (1.11)^{a}	0.60 (1.04)^{a}	0.45 (0.97)^{a}	0.35 (0.92)^{a}	0.68
T_6 - Control (water)	2.20 (1.64)^{b}	2.05 (1.59)^{c}	2.00 (1.58)^{c}	2.20 (1.64)^{c}	1.80 (1.51)^{c}	2.00 (1.58)^{c}	1.85 (1.53)^{c}	1.98
P value	0.135^{NS}	0.004*	0.000**	0.000**	0.000**	0.000**	0.000**	
F calculated value	2.014	5.763	8.820	13.652	13.348	25.878	22.362	

*Mean of four replicates (coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. of coccinellids per plant) PTC – Pretreatment count; DAT – Days after Treatment. Figures in parentheses are $\sqrt{x+0.5}$ transformed values

yield of (1745.83kg ha^{-1}) was recorded from the fields treatedwith(T_2)- NSKE1% @ 2ml/l, followed by those treated with(T_1)-Spinosad 45 % SC @ 0.4 ml/l offering (1654.16 kg ha^{-1}), (T_3)-*B. bassiana*1x10^8 conidia/ml @ 10 ml/l (1366.66 kg ha^{-1}), (T_4)-*M. anisopliae*1x10^8 conidia/ml @ 10 ml/l (1137.50 kg ha^{-1}), (T_5)-*V. lecanii*1x10^8 conidia/ml @ 10 ml/l (945.83kg ha^{-1}),last was (T_6)-untreated plots with yield of (829.16 kg ha^{-1}) (Table 3).

Effectiveness of eco-friendly insecticides against coccinellids during *Rabi* and *Kharif* season

The initial population of predatory coccinellid beetles on precount day ranged from 1.25 to 2.20 coccinellid beetlesplant^{-1} and 0.80 to 1.40 coccinellid beetles per plant

Table 3. Effectiveness of eco-friendly insecticides against jassid in brinjal (Kharif Season 2022)

Treatments	**No. of jassids / per plant***								**% Reduction over control**	**Yield (kg ha^{-1})**
	PTC	**1DAT**	**3DAT**	**5DAT**	**7DAT**	**11DAT**	**14DAT**	**Mean**		
T_1 - Spinosad 45 % SC @ 0.4ml/l	17.05 (4.18)^{a}	11.20 (3.42)^{a}	5.15 (2.37)^{a}	3.95 (2.10)^{a}	3.25 (1.93)^{ab}	1.55 (1.43)^{ab}	1.15 (1.28)^{a}	4.37	59.57	1654.16^{d}
T_2 - NSKE 1% @ 2ml/l	16.60 (4.13)^{a}	11.85 (3.51)^{a}	4.65 (2.26)^{a}	3.75 (2.06)^{a}	2.25 (1.65)^{a}	1.25 (1.32)^{a}	1.05 (1.24)^{a}	4.13	61.80	1745.83^{d}
T_3 - *Beauveria bassiana* 1x10^{8} conidia/ml @ 10ml/l	16.95 (4.17)^{a}	10.25 (3.27)^{a}	8.95 (3.07)^{b}	7.95 (2.90)^{b}	4.95 (2.33)^{b}	3.25 (1.93)^{bc}	2.30 (1.67)^{ab}	6.27	42.00	1366.66^{c}
T_4 - *Metarhizium anisopliae* 1x10^{8} conidia/ml @ 10ml/l	15.95 (4.05)^{a}	11.55 (3.47)^{a}	9.05 (3.09)^{b}	8.45 (2.99)^{b}	5.25 (2.39)^{bc}	3.85 (2.08)^{cd}	2.55 (1.74)^{ab}	6.79	37.18	1137.50^{b}
T_5 - *Verticillium lecanii* 1x10^{8} conidia/ml @ 10ml/l	15.95 (4.05)^{a}	15.05 (3.94)^{ab}	9.55 (3.17)^{b}	8.75 (3.04)^{b}	7.65 (2.85)^{c}	5.55 (2.45)^{de}	3.45 (1.98)^{bc}	8.33	22.94	945.83^{a}
T_6 - Control (water)	15.55 (4.00)^{a}	17.70 (4.26)^{c}	13.35 (3.72)^{c}	12.85 (3.65)^{c}	10.15 (3.26)^{d}	5.95 (2.53)^{e}	4.90 (2.32)^{c}	10.81		829.16^{a}
P value	0.577^{NS}	0.024*	0.000**	0.000**	0.000**	0.000**	0.002*			0.000**
F calculated value	0.783	3.620	9.535	13.127	13.045	9.687	6.683			36.894

*Mean of four replicates (jassids were counted on 5 randomly selected plants per replication and was expressed as no. of leafhoppers per plant) PTC – Pretreatment count; DAT – Days after Treatment. Figures in parentheses are √ x+0.5 transformed values

Plate 4. *Predatory coccinellids*

during *Rabi* and *Kharif* seasons, respectively (Table 2 and 4). However, at the end of 14DAT the population ranged between mean 0.35 to 1.85coccinellid per plant (Table 2) and 0.25 to 0.60 coccinellid beetles plant^{-1} (Table 4)during both seasons. The populations of predatory coccinellid beetles were observed with no significant difference on pretreatment count day during *Rabi* season ($F_{(6,4)}$; P>0.05) (Table 2) and *Kharif* season ($F_{(6,4)}$; P>0.05) (Table 4). Coccinellid populations continuously declined till 14 DAT during *Rabi* and *Kharif* seasons (Tables 2and 4).So, the population of predatory coccinellid was reduced as prey (jassid) population reduced due to the application of spray (Plate 4: Predatory coccinellids).

The entomopathogens like(T_3) -*B. bassiana*,(T_4) -*M. anisopliae* and (T_5) - *V. lecanii* was performed better during *Rabi* than *Kharif* season against jassid. The *Kharif* season was less preferred for entomopathogen development due to rising temperature from May to June, while *Rabi* season was preferred for entomopathogen development because of the moisture present in the environment (Table 1). The population of jassid was directly correlated with various factors like temperature, moisture in the environment, geographic location, leaf structure and biochemical parameters (Ramzan *et al*., 2019c; Naeem-Ullah *et al*., 2020). The population of jassid was reported peak incidence at46th SMW in 2nd week of November (Tupe *et al.,* 2022), 45th SMW in 1st

Table 4. Effectiveness of eco-friendly insecticideson predatory coccinellids (Kharif Season 2022)

Treatments	No. of coccinellids / per plant*							
	PTC	1DAT	3DAT	5DAT	7DAT	11DAT	14DAT	Mean
T_1 - Spinosad 45 % SC @ 0.4ml/l	1.05 $(1.24)^{ab}$	0.95 $(1.20)^{ab}$	0.85 $(1.16)^{ab}$	0.70 $(1.09)^{a}$	0.65 $(1.07)^{ab}$	0.55 $(1.02)^{abc}$	0.40 $(0.94)^{ab}$	0.68
T_2 - NSKE 1% @ 2ml/l	1.40 $(1.37)^{c}$	1.20 $(1.30)^{b}$	1.15 $(1.28)^{ab}$	1.00 $(1.22)^{b}$	0.90 $(1.18)^{bc}$	0.85 $(1.16)^{c}$	0.60 $(1.04)^{b}$	0.95
T_3 - *Beauveria bassiana* $1x10^8$ conidia/ml @10ml/l	0.90 $(1.18)^{ab}$	0.85 $(1.16)^{ab}$	0.75 $(1.11)^{ab}$	0.65 $(1.07)^{a}$	0.60 $(1.04)^{a}$	0.50 $(1.00)^{abc}$	0.40 $(0.94)^{ab}$	0.62
T_4 - *Metarhizium anisopliae* $1x10^8$ conidia/ml @10ml/l	0.80 $(1.14)^{a}$	0.70 $(1.09)^{a}$	0.70 $(1.09)^{ab}$	0.55 $(1.02)^{a}$	0.50 $(1.00)^{a}$	0.40 $(0.94)^{ab}$	0.35 $(0.92)^{ab}$	0.53
T_5 - *Verticillium lecanii* $1x10^8$ conidia/ml @ 10ml/l	0.85 $(1.16)^{a}$	0.75 $(1.11)^{a}$	0.60 $(1.04)^{a}$	0.55 $(1.02)^{a}$	0.45 $(0.97)^{a}$	0.35 $(0.92)^{a}$	0.25 $(0.86)^{a}$	0.49
T_6 - Control (water)	1.30 $(1.34)^{ab}$	1.25 $(1.32)^{b}$	1.20 $(1.30)^{b}$	1.30 $(1.34)^{c}$	0.95 $(1.20)^{c}$	0.80 $(1.14)^{bc}$	0.55 $(1.02)^{ab}$	1.00
P value	0.069^{NS}	0.038*	0.109^{NS}	0.000**	0.003*	0.055^{NS}	0.169^{NS}	
F calculated value	2.607	3.159	2.198	10.219	5.942	2.814	1.822	

*Mean of four replicates (coccinellids were counted on 5 randomly selected plants per replication and was expressed as no. of coccinellids per plant) PTC – Pretreatment count; DAT – Days after Treatment. Figures in parentheses are √ x+0.5 transformed values

week of November (Berani *et al*., 2020) and 1st SMW in January (Lal *et al*., 2019).In the present study, biopesticides were effective against jassid population during both seasons (Table 1 and 3). Half of the recommended doses of popular EPF viz., *B. bassiana, M. anisopliae* and *L. lecanii* with botanicals like neem seed oilhave been found effective against the sucking pest like jassid, whitefly, aphids and others (Halder *et al.,* 2017; Abdel-Raheem and Al-Keridis, 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).

The present study revealed that the application of(T_2) - Neem Seed Kernel Extract and (T_1) - Spinosad resulted in greater mortality than the entomopathogens in *Kharif* than in *Rabi* season (Table 3). However, the Spinosad application exhibited a maximum reduction of jassid population (Yadav and Kumawat, 2014; Bharti and-Shetgar, 2015). Spinosad directly affects the insect nervous system, disrupts neuronal activity by exciting motor neurons and causing involuntary muscle contractions, eventually leading to paralysis and death.Mounting evidence indicates that nAChR α6 serves as a receptor for Spinosad attributed to its binding capacity and involvement in Spinosad resistance (Somers *et al*., 2015). Apart from the azadirachtin compound, nimbin, gedunin, salannin, meliantriol, mahmoodin, nimbolinin secondary plant metabolites present in neem plant are essential in controlling sucking pests like aphid, whitefly and jassid (Alzohairy, 2016, Ali *et al.,* 2017).

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*are relatively safe to natural enemies;where the list includes foliage-dwelling predators as well as sucking insect pests viz., *Coccinellaseptempunctata, Chrysoperlacarnea*, *Episyrphusbalteatus,* ground dwelling predator, *Poeciluscupreus* and parasitoids*Trichrammaatopovirilia, Trathalaflavoorbitalis* larval pupalparasitoid of brinjal fruit and shoot borer (BFSB)(Prithiva *et al.,* 2018; Rajeshwari *et al*., 2019).The impact of botanical pesticides, particularly on natural enemies, was 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).

Conclusion

The entomopathogens like (T_3) -*B. bassiana*,(T_4) -*M. anisopliae* and (T_5) - *V.lecanii* effectively minimized the jassid population directly related to the quality of brinjal. The jassid population was significantly less in the (T_3) - *B. bassiana* in the *Rabi*season and (T_2) - NSKE in *Kharif* season than in other treatments.There wasno residue in the crops or development of resistance to the pest. Therefore, application of entomopathogens and botanicals can be included in the sustainable pest management program.

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Conflict of interest

The authors declare that they have no conflict of interest.

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