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Efficacy of botanicals and bio-pesticides against shoot and fruit borer in Brinjal

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ABSTRACT

The present investigation was undertaken to find the efficacy of botanicals and biopesticides against brinjal shoot and fruit borer during kharif 2019-2020 at the Research farm, JNKVV, College of Agriculture, Tikamgarh (M.P.). The experiment consists nine treatments viz., Neem oil 1% (T_1), Karanj oil 1% (T_2), Beauveria bassiana 1× 10^{12} spores/ml (T_3), Metarrhizium anisopliae 1× 10^{12} spores/ml (T_4), Neem oil- Bb-Neem oil (T_5), Neem oil – Ma –Neem oil (T_6), Karanj oil –Bb –Karanj oil (T_7), Karanj oil –Ma-Karanj oil (T_8) and Untreated control (T_9). The results revealed that Neem oil 1% proved to be most effective in controlling the population of brinjal shoot and fruit borer by recording minimum shoot and fruit infestation of 5.80 and 6.65% respectively followed by Neem oil-Ma-Neem oil. However, Karanj oil 1% proved to be least effective. The highest net profit and cost benefit ratio was observed from the plot treated with Neem oil 1% (Rs 46860/ha and 1:26.0) followed by Neem oil- Ma -eem oil (Rs 42770/ha and 1:25.3). The maximum fruit yield of 237.33 q/ha was recorded with the application of Neem oil 1% which was 25.79% higher than the control. Other treatments gave yield ranging from 217 – 233.33 q/ha.

Keywords: Brinjal, fruit & shoot borer, botanicals bio-pesticide

INTRODUCTION

Brinjal, *Solanum melongena* (L.) is also known as eggplant, belongs to family *Solanaceae*. The eggplant is a delicate, tropical perennial plant often cultivated as a tender or half hardy annual in temperate climates. In India, during 2018, brinjal is cultivated in about 730.4 thousand hectares with production and productivity of 12800.8 thousand MT and 17.5 MT ha^{-1}, respectively. In Madhya Pradesh, brinjal is cultivated in about 51.35 thousand hectare with production and productivity of 1073.63 thousand MT and 20.91 MT ha^{-1}, respectively (Anonymous, 2019). The major constraint of low productivity of brinjal is due to damage of number of insect pests. Among the insect pests shoot and fruit borer *Leucinodes orbonalis* (Guenee), epilachna beetle *Epilachna vigintioctopunctata* (Fabricius), jassids *Amrasca biguttula biguttula* (Ishida) and whitefly *Bemisia tabaci* (Gennadius) are considered to have economic importance. However, brinjal shoot and fruit borer is considered as the major insect pest of brinjal in Asia as it causes serious damage especially during the fruiting stage. The shoot and fruit borer has a specific nature of feeding. After hatching, the tiny larvae bore in the growing tips of young shoots during vegetative stage of the crop. Yellowing and wilting of the affected shoots are the common symptom of attack (Hedge *et al.,* 2009). During flowering and fruiting stage, the larva prefers flower buds and young fruits. It bores into the young fruits by making a very small hole around the calyx. Thereafter, it completes its larval stage within the developing fruits and the mature larvae come out from the fruit for pupation. It inflicts yield loss as high as 85–90% (Misra 2008; Jagginavar *et al.*, 2009; Chakraborti and Sarkar 2011). A number of chemical insecticides have been reported to be effective against these pests (Singh and Nath, 2007; Gautam *et al.*, 2008 and Tiwari *et al.*, 2011), but they are ecologically unacceptable. Brinjal crop is harvested at regular intervals and the use of toxic pesticides is not advisable. Repeated use of broad spectrum synthetic chemicals also results in environmental contamination, bioaccumulation and bio-magnification of toxic residues and disturbance in ecological balance (Dadmal *et al.,* 2004). Sole dependence on several broad spectrum insecticides for the control of these pests has led to insecticidal resistance, resurgence of minor pests and destruction of natural enemies. Use of bio-control agents and plant products like *Beauveria bassiana, Metarrhizium anisopliae,* neem and karanj are safe and non-hazardous tactic for the management of insect pests. Use of bio-pesticides, botanicals, vermin-compost and indigenous products etc., may provide alternative solutions to chemical application for management

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of brinjal pest thereby increasing the income of farmers and saving the environment for future generation of man and his animals. The present studies were undertaken with the objectives to evaluate the efficacy and economics of botanicals and bio-pesticides in the management of brinjal shoot and fruit borer.

MATERAILS AND METHODS

The field experiment was conducted at Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, Tikamgarh (M.P.) with brinjal (cv. Kashi Sandesh) during *Kharif* 2019-20. The experiment was laid out in a randomized block design (RBD) with nine different treatments including one untreated check *viz.* Neem oil 1% (T_1), Karanj oil 1% (T_2), *Beauveria bassiana* 1× 10^{12} spores/ml (T_3), *Metarrhizium anisopliae* 1× 10^{12} spores/ml (T_4), Neem oil- *Bb*- Neem oil (T_5), Neem oil – *Ma* – Neem oil (T_6), Karanj oil –*Bb* –Karanj oil (T_7), Karanj oil –*Ma*-Karanj oil (T_8) and Untreated control (T_9). Each treatment was replicated thrice. For nursery, seeds of brinjal were sown with row to row distance of 10 cm on July 15, 2019. The experimental field was ploughed twice with the help of tractor mounted disc harrow. The field was ensured with the fine tilth. Twenty five days old seedlings of brinjal were planted on August 09, 2019. Light irrigation was provided after transplanting for better establishment of seedlings. All the agronomical practices, except the package recommended for insect pests management were adopted to raise a good crop. The recommended dose of fertilizers such as N, P_2O_5 and K_2O (180:80:80) were applied for crop production. The half dose of nitrogen and full dose of phosphorus and potash were applied as basal at the time of last ploughing while remaining dose of nitrogen was top dressed 30 days after transplanting. All the treatments were sprayed at an interval of 15 days between each spray by using high volume knapsack sprayer @ 500 liters of spray solution per ha to determine the efficacy against major insect pests of brinjal. The shoot infestation was noticed during first week of October, 2019 and it reached the ETL during third week of October 2019. The first spray was done at ETL level. The treatments were sprayed thrice. Observations on the efficacy of treatments were recorded one day before the treatment and after 3, 7 and 10 days of first, second spray and third spray respectively. Pre treatment observation on incidence of insect pests of brinjal was recorded one day before treatment. Post treatment observations were recorded at 3, 7 and 10 days after spraying. Observations on shoot and fruit borer population were recorded on five randomly selected plants in each plot at each picking. The number of healthy and damaged fruits were counted and weighted separately. The data obtained were analyzed statistically after using appropriate transformation. The percentage data were processed under Arcsine transformation before statistical analysis.

Percentage of fruit damage and yield (q/ha) were calculated on the basis of following formula

$$\text{Per cent fruit damage} = \frac{\text{Weight of aged fruits}}{\text{Total weight of fruits (healthy + damaged)}}$$

With a view to ascertain the effect of different botanical and biopesticides on the yield, the harvested fruits of brinjal were weighed separately from net plot area in each treatment. The total yield of the marketable fruitsobtained from different treatments was calculated andconverted by considering the additional cost (cost of botanicals and biopesticides and operational charges) and benefit (compared tountreated control) in the respective treatments.

RESULTS AND DISCUSSION

Effects of different treatments on percent shoot infestation at three sprays:

First spray

The data obtained from the first spray against the population of shoot and fruit borer at 1 day before and 3rd, 7th and 10th day after treatment were analyzed (Table 2). The shoot infestation varied from 9.67 – 16.67% in different treatments including untreated control denoting that the shoot and fruit borer population was more or less uniformly distributed in the field. Data recorded on the third day after spray, showed significantly reduced shoot infestation as compared to control (17.67%) . The lowest (5.83%) infestation was observed in Neem oil 1% , followed by Neem oil 1% – *Ma* –Neem oil **S.**

1% (7.00%), *Metarrhizium anisopliae* (8.83%), Neem oil 1% – *Bb* –Neem oil 1% (8.90%),*Beauveria bassiana* (10.60%), Karanj oil 1% -*Bb* - Karanj oil 1% (11.00%), Karanj oil 1% (11.67%) and Karanj oil 1% –*Ma* –Karanj oil 1% (12.0%). The treatments Neem oil 1%, Neem oil 1% – *Ma* –Neem oil 1% , Neem oil 1% – *Bb* – Neem oil 1% and *Metarrhizium anisopliae* were at par and significantly superior over other treatments. Data recorded on the seventh day after spray revealed the lowest (7.00%) infestation in Neem oil 1%, followed by Neem oil – *Ma* –Neem oil 1% (7.50%), Neem oil – *Bb* – Neem oil 1% (9.17%), *Metarrhizium anisopliae* (9.60%), *Beauveria bassiana* (11.17%), Karanj oil 1%–*Bb* –Karanj oil 1% (11.67%), Karanj oil 1% (12.00%) and Karanj oil 1%–*Ma* –Karanj oil 1% (12.33%). The treatments Neem oil 1% and Neem oil 1% – *Ma* –Neem oil 1% were at par and significantly superior over other treatments. Data observed on the tenth day after spray showed the lowest (7.33%) infestation in Neem oil 1%, followed by Neem oil 1%– *Ma* –Neem oil 1% (7.73%), Neem oil 1%– *Bb* –Neem oil 1% (9.50%), *Metarrhizium anisopliae* (10.17%), *Beauveria bassiana* (11.67%), Karanj oil 1%–*Bb* –Karanj oil 1% (12.00%), Karanj oil 1% (12.33%) and Karanj oil 1%–*Ma* –Karanj oil 1% (12.87%). The treatments Neem oil 1% and Neem oil 1%– *Ma* –Neem oil 1%) were at par and significantly superior over other treatments.

Table 1: Efficacy of botanicals and bio-pesticides in the management of shoot and fruit borer, *Leucinodes orbonalis* during 1st spray

Treatments	Dose/ha (ml)	Shoot infestation(%) during 1st spray				
		1 DBS	3 DAS	7 DAS	10 DAS	Mean
T_1-Neem oil 1%	3000	9.67 (18.11)	5.83 (13.96)	7.00 (15.32)	7.33 (15.71)	6.72 (15.00)
T_2-Karanj oil 1%	3000	14.00 (21.96)	11.67 (19.66)	12.00 (20.27)	12.33 (20.56)	12.00 (20.16)
T_3-*Beauveria bassiana* 1× 10^{12} spores/ml	1000	13.33 (16.40)	10.60 (18.99)	11.17 (19.51)	11.67 (19.97)	11.14 (19.49)
T_4-*Metarrhizium anisopliae* 1× 10^{12} spores/ml	1000	12.00 (16.13)	8.83 (17.29)	9.60 (18.01)	10.17 (18.54)	9.53 (17.95)
T_5-Neem oil – *Bb* – Neem oil	3000-1000-3000	13.00 (20.33)	8.90 (17.33)	9.17 (17.62)	9.50 (17.95)	9.19 (17.63)
T_6-Neem oil – *Ma* –Neem oil	3000-1000-3000	10.67 (19.05)	7.00 (15.34)	7.50 (15.89)	7.73 (16.17)	7.41 (15.79)
T_7-Karanj oil –*Bb* –Karanj oil	3000-1000-3000	14.33 (22.24)	11.00 (19.29)	11.67 (19.95)	12.00 (20.23)	11.56 (19.82)
T_8-Karanj oil –*Ma* –Karanj oil	3000-1000-3000	14.67 (22.30)	12.00 (20.17)	12.33 (20.56)	12.87 (21.09)	12.40 (20.58)
T_9-Untreated control	---	16.67 (19.93)	17.67 (24.82)	18.33 (25.34)	19.00 (25.83)	18.33 (25.33)
S.E.m ±		6.15	1.16	0.55	0.56	0.76
C.D at 5%		N.S	3.49	1.65	1.69	2.28

Figures in parentheses are angular transformed values; DBS- Days before spraying; DAS- Days after spraying

On the basis of mean of overall observations all the biopesticidal treatments significantly reduced the shoot infestation as compared to control (18.33%). Among the treatments Neem oil 1% was found to be the most effective (6.72%) which was significantly better than Neem oil 1%– *Bb* –Neem oil 1% (9.19%), *Metarrhizium anisopliae* (9.53%), *Beauveria bassiana* (11.14%), Karanj oil 1%–*Bb* –Karanj oil 1% (11.56%), Karanj oil 1% (12.00%) and Karanj oil 1%–*Ma* –Karanj oil 1% (12.40%) but at par with Neem oil 1%– *Ma* –Neem oil 1% (7.41%).

Table 2: Efficacy of botanicals and bio-pesticides in the management of shoot and fruit borer, *Leucinodes orbonalis* during 2nd spray

Treatments	Dose/ha (ml)	Shoot infestation(%) during 1st spray				
		1 DBS	3 DAS	7 DAS	10 DAS	Mean
T_1-Neem oil 1%	3000	8.67 (17.02)	5.00 (12.88)	6.67 (14.96)	7.30 (15.67)	6.32 (14.50)
T_2-Karanj oil 1%	3000	13.00 (21.13)	11.33 (19.67)	11.73 (20.03)	12.50 (20.70)	11.86 (20.13)
T_3-*Beauveria bassiana* 1× 10^{12} spores/ml	1000	12.67 (20.66)	10.17 (18.59)	11.53 (19.85)	11.70 (19.55)	11.13 (19.33)
T_4-*Metarrhizium anisopliae* 1× 10^{12} spores/ml	1000	10.33 (18.75)	8.00 (16.41)	8.83 (17.26)	9.67 (18.11)	8.83 (17.26)
T_5-Neem oil – *Bb* – Neem oil	3000-1000-3000	11.33 (19.66)	8.27 (16.71)	9.20 (17.65)	10.03 (18.47)	9.17 (17.61)
T_6-Neem oil – *Ma* –Neem oil	3000-1000-3000	9.67 (18.01)	6.67 (14.95)	7.43 (15.82)	7.97 (16.39)	7.36 (15.72)
T_7-Karanj oil –*Bb* –Karanj oil	3000-1000-3000	13.37 (20.49)	10.00 (18.42)	10.73 (19.05)	11.43 (19.69)	10.72 (19.05)
T_8-Karanj oil –*Ma* –Karanj oil	3000-1000-3000	13.17 (21.28)	8.40 (16.84)	9.20 (17.66)	10.00 (18.43)	9.20 (17.64)
T_9-Untreated control	---	19.67 (25.82)	20.00 (26.57)	20.67 (27.04)	21.00 (27.27)	20.56 (26.96)
S.E.m ±		2.38	0.41	0.55	1.24	0.73
C.D at 5%		N.S	1.22	1.64	3.72	2.19

Figures in parentheses are angular transformed values; DBS- Days before spraying; DAS- Days after spraying

Second spray

The data obtained from the second spray against the population of shoot and fruit borer at 1 day before and 3rd, 7th and 10th day after treatment were analyzed (Table 3). The shoot infestation varied from 8.67 – 19.67% in different treatments and all the treatment proved better than the control. Data recorded on the third day after spray showed the lowest (5.00%) infestation in Neem oil 1% followed by Neem oil 1% – *Ma* –Neem oil (6.67%), *Metarrhizium anisopliae* (8.00%), Neem oil 1% – *Bb* – Neem oil (8.27%), Karanj oil 1% –*Ma* –Karanj oil 1% (8.40%), Karanj oil 1% –*Bb* –Karanj oil1% (10.00%), *Beauveria bassiana* (10.17%), and Karanj oil 1% (11.33%). The treatments Neem oil 1% was significantly superior over other treatments.Data observed on the seventh day after spray revealed the lowest (6.67%) infestation in Neem oil 1%, followed by Neem oil 1%– *Ma* –Neem oil1% (7.43%), *Metarrhizium anisopliae* (8.83%), Karanj oil 1%–*Ma* –Karanj oil1% (9.20%), Neem oil 1%– *Bb* – Neem oil1% (9.20%), Karanj oil 1%–*Bb* –Karanj oil1% (10.73%), *Beauveria bassiana* (11.53%), and Karanj oil 1% (11.73%). The treatments Neem oil 1% and Neem oil 1%– *Ma* –Neem oil1% were at par and significantly superior over other treatments.Data observed on the tenth day after spray showed the lowest (7.30%) infestation in Neem oil 1%, followed by Neem oil 1% – *Ma* – Neem oil1% (7.97%), *Metarrhizium anisopliae* (9.67%), Karanj oil 1% –*Ma* –Karanj oil1% (10.00%), Neem oil 1% – *Bb* – Neem oil1% (10.03%), Karanj oil 1%–*Bb* –Karanj oil1% (11.43%), *Beauveria bassiana* (11.70%), and Karanj oil 1% (12.50%). The treatments Neem oil 1%, Neem oil 1%– *Ma* –Neem oil 1%, Neem oil 1%– *Bb* – Neem oil 1%, *Metarrhizium anisopliae* and Karanj oil 1% –*Ma* –Karanj oil 1% were at par and significantly superior over other treatments.

On the basis of mean of overall observations all the biopesticidal treatments significantly reduced the shoot infestation as compared to control (20.56%). Among the treatments Neem oil 1% was found to be the most effective (6.32%) which was significantly better than *Metarrhizium anisopliae* (8.83%), Neem oil 1%– *Bb* – Neem oil 1% (9.17%), Karanj oil 1%–*Ma* –Karanj oil 1% (9.20%), Karanj oil 1%–*Bb* –Karanj oil 1% (10.72%), *Beauveria bassiana* (11.13%), and Karanj oil 1% (11.86%) but at par with Neem oil 1%– *Ma* –Neem oil 1% (7.36%).

Table 3: Efficacy of botanicals and bio-pesticides in the management of shoot and fruit borer, *Leucinodes orbonalis* during 3rd spray

Treatments	Dose/ha (ml)	Shoot infestation(%) during 1st spray				
		1 DBS	3 DAS	7 DAS	10 DAS	Mean
T_1-Neem oil 1%	3000	6.17 (14.38)	2.83 (9.68)	3.37 (10.57)	4.20 (11.82)	3.47 (10.69)
T_2-Karanj oil 1%	3000	11.67 (19.97)	10.43 (18.84)	11.23 (19.58)	11.67 (19.97)	11.11 (19.46)
T_3-*Beauveria bassiana* 1× 10^{12} spores/ml	1000	10.40 (18.81)	8.47 (16.91)	9.33 (17.75)	10.00 (18.20)	9.27 (17.62)
T_4-*Metarrhizium anisopliae* 1× 10^{12} spores/ml	1000	8.00 (16.37)	5.40 (13.43)	6.00 (14.17)	7.33 (15.70)	6.24 (14.43)
T_5-Neem oil – *Bb* – Neem oil	3000-1000-3000	7.00 (15.32)	4.20 (11.82)	5.50 (13.56)	6.77 (15.06)	5.49 (13.48)
T_6-Neem oil – *Ma* –Neem oil	3000-1000-3000	6.50 (14.76)	3.40 (10.62)	4.47 (12.19)	5.13 (13.10)	4.33 (11.97)
T_7-Karanj oil –*Bb* –Karanj oil	3000-1000-3000	9.00 (17.44)	7.50 (15.89)	8.40 (16.84)	9.10 (17.56)	8.33 (16.76)
T_8-Karanj oil –*Ma* –Karanj oil	3000-1000-3000	9.90 (18.33)	7.83 (11.24)	9.43 (17.88)	10.17 (18.59)	9.14 (17.57)
T_9-Untreated control	---	16.33 (23.03)	18.33 (25.33)	20.67 (27.03)	21.33 (27.50)	20.11 (26.62)
S.E.m ±		1.77	0.38	0.45	0.79	0.54
C.D at 5%		N.S	1.15	1.35	2.38	1.63

Figures in parentheses are angular transformed values; DBS- Days before spraying; DAS- Days after spraying

Third spray

The data obtained from the third spray against the population of shoot and fruit borer at 1 day before and 3rd, 7th and 10th day after treatment were analyzed (Table 4). The shoot infestation varied from 6.17 – 16.33% in different treatments and all the treatment proved better than the control. Data recorded on the third day after spray showed the lowest (2.83%) infestation in Neem oil 1%, followed by Neem oil1% – *Ma* –Neem oil 1% (3.40%), Neem oil1% – *Bb* –Neem oil 1% (4.20%), *Metarrhizium anisopliae* (5.40%), Karanj oil 1% –*Bb* –Karanj oil 1% (7.50%), Karanj oil1% –*Ma* –Karanj oil 1% (7.83%), *Beauveria bassiana* (8.47%), and Karanj oil 1% (10.43%). The treatments Neem oil 1% and Neem oil 1%– *Ma* –Neem oil 1% were at par and significantly superior over other treatments.Data observed on the seventh day after spray revealed the lowest (3.37%) infestation in Neem oil 1%, followed by Neem oil 1%– *Ma* –Neem oil 1% (4.47%), Neem oil 1%– *Bb* –Neem oil 1% (5.50%), *Metarrhizium anisopliae* (6.00%), Karanj oil1% –*Bb* –Karanj oil 1% (8.40%), *Beauveria bassiana* (9.33%), Karanj oil 1%–*Ma* –Karanj oil 1% (9.43%) and Karanj oil 1% (11.23%). The treatments Neem oil 1% and Neem oil 1% – *Ma* –Neem oil 1% were at par and significantly superior over other treatments. Data observed on the tenth day after spray showed the lowest (4.20%) infestation was in Neem oil 1%, followed by Neem oil 1%– *Ma* –Neem oil 1% (5.13%), Neem oil 1%– *Bb* –Neem oil 1% (6.77%), *Metarrhizium anisopliae* (7.33%), Karanj oil 1%–*Bb* –Karanj oil 1% (9.10%), *Beauveria bassiana* (10.00%), Karanj oil 1%–*Ma* –Karanj oil 1% (10.17%) and Karanj oil 1% (11.67%). The treatments Neem oil 1% and Neem oil 1%– *Ma* –Neem oil 1% were at par and significantly superior over other treatments.

On the basis of mean of overall observations all the biopesticidal treatments significantly reduced the shoot infestation as compared to control (20.11%). Among the treatments Neem oil 1% was found to be the most effective (3.47%) which was significantly better than Neem oil 1%– *Bb* –Neem oil 1% (5.49%), *Metarrhizium anisopliae* (6.24%), Karanj oil 1%–*Bb* –Karanj oil 1% (8.33%), Karanj oil 1%–*Ma* –Karanj oil 1% (9.14%), *Beauveria bassiana* (9.27%) and Karanj oil 1% (11.11%) but at par with Neem oil 1%– *Ma* –Neem oil 1%

(4.33%). Bhagwan and Kumar (2017) recorded minimum shoot infestation 9.83% using neem oil and Goud *et al.* (2019) reported that neem oil was effective in controlling shoot and fruit borer which were in close conformity with present studies.

Table 4: Effect of bio-pesticidal treatments on fruit infestation percentage at different pickings against *L.orbonalis*

Treatments	Dose/ha (ml)	Fruit infestation (%)				
		1st picking	2nd picking	3rd picking	4th picking	Mean
T_1-Neem oil 1%	3000	8.17 (16.60)	7.10 (15.43)	5.90 (14.02)	6.00 (14.18)	6.10 (14.30)
T_2-Karanj oil 1%	3000	14.33 (22.24)	13.67 (21.69)	11.97 (20.23)	12.00 (20.26)	12.27 (20.50)
T_3-*Beauveria bassiana* 1× 10^{12} spores/ml	1000	11.67 (19.95)	10.83 (19.20)	9.50 (17.95)	10.33 (18.75)	10.67 (19.06)
T_4-*Metarrhizium anisopliae* 1× 10^{12} spores/ml	1000	11.33 (19.67)	10.50 (18.90)	9.17 (17.61)	9.67 (18.11)	10.17 (18.59)
T_5-Neem oil – *Bb* – Neem oil	3000-1000-3000	10.67 (19.06)	9.67 (18.11)	8.33 (16.74)	8.63 (17.09)	9.17 (17.62)
T_6-Neem oil – *Ma* –Neem oil	3000-1000-3000	10.33 (18.75)	9.33 (17.75)	8.00 (16.35)	8.23 (16.67)	8.77 (17.21)
T_7-Karanj oil –*Bb* –Karanj oil	3000-1000-3000	14.00 (21.96)	13.00 (21.13)	11.67 (19.97)	12.00 (20.14)	12.33 (20.52)
T_8-Karanj oil –*Ma* –Karanj oil	3000-1000-3000	12.00 (20.23)	10.67 (19.06)	9.93 (18.37)	10.17 (18.54)	10.77 (19.14)
T_9-Untreated control	---	23.33 (28.88)	27.67 (31.73)	26.33 (30.87)	25.67 (30.44)	24.00 (29.33)
S.E.m ±		0.57	0.54	0.68	0.77	0.41
C.D at 5%		1.72	1.62	2.04	2.31	1.31

Figures in parentheses are angular transformed values

Effect of different bio- pesticidal treatments on percent fruit infestation at different pickings

Results of different bio-pesticidal treatments on percent fruit infestation in brinjal are presented in Table 5

First picking

During the first picking among these nine treatments *viz.,* Neem oil 1% (8.17%) recorded the most significant reduction in fruit infestation caused by *Leucinodes orbonalis* and was followed by Neem oil – *Ma* –Neem oil (10.33%), Neem oil 1%– *Bb* –Neem oil 1% (10.67%), *Metarrhizium anisopliae* (11.33%), *Beauveria bassiana* (11.67%), Karanj oil 1% –*Ma* –Karanj oil 1% (12%), Karanj oil1% –*Bb* –Karanj oil 1% (14%) and Karanj oil 1% (14.33%). In the untreated plot, the infestation was the highest (23.33%).

Second picking

During second picking among the nine treatments Neem oil 1% recorded the most significant reduction in fruit infestation caused by *Leucinodes orbonalis*, with lowest fruit infestation (7.10%) followed by Neem oil 1%– *Ma* –Neem oil 1% (9.33%), Neem oil 1%– *Bb* –Neem oil 1% (9.67%) and *Metarrhizium anisopliae* (10.50%), Karanj oil 1%–*Ma* –Karanj oil 1% (10.67%), *Beauveria bassiana* (10.83 %), Karanj oil 1%–*Bb* –Karanj oil 1% (13.00%) and Karanj oil 1% (13.67%). In the untreated plot, the infestation was the highest (27.67%).

Third picking

During the observation recorded on third picking, Neem oil 1% (5.90%) recorded the most significant reduction in fruit infestation followed by Neem oil 1%– *Ma* –Neem oil 1% (8.00%), Neem oil 1%– *Bb* –Neem oil 1% (8.33%) and *Metarrhizium anisopliae* (9.17%), *Beauveria*

bassiana (9.50 %), Karanj oil 1%–*Ma* –Karanj oil 1% (9.93%), Karanj oil 1%–*Bb* –Karanj oil 1% (11.67%) and Karanj oil 1% (11.97%). In the untreated plot, the infestation was the highest (26.33%). At fourth picking, all the treatments showed reduction over control and Neem oil 1% showing highest reduction on fruit infestation with lowest infestation of 6.00%. At fifth picking, all the treatments showed reduction over control and Neem oil 1% recorded highest reduction on fruit infestation with lowest infestation of 6.10%. Overall observation on fruit infestation showed that Neem oil 1% (T_1) (6.65%) has the highest reduction of fruit infestation when compared to all other treatments and was significantly superior over all other treatments. It was followed by Neem oil 1%– *Ma* –Neem oil 1%(T_6) (8.93%), Neem oil 1%– *Bb* –Neem oil 1%(T_5) (9.29%), *Metarrhizium anisopliae* (T_4) (10.17%), *Beauveria bassiana* (T_3) (10.60%), Karanj oil 1%–*Ma* –Karanj oil 1%(T_8) (10.71%), Karanj oil 1%–*Bb* –Karanj oil 1%(T_7) (12.60%), Karanj oil 1% (T_2) (12.85%) and control (25.40%).The present findings are in agreement with other previous studies including Tripura *et al.* (2017) whose study reported the highest reduction in fruit infestations (53.56%) by using neem oil; Mane and Kulkarni (2010) recorded lowest infestation (17.65%) in the treatment of nimbicidin (neem oil) against shoot and fruit borer. Likewise Murugesan and Murugesh (2009) findings also showed thatneem oil 2% was the best treatment both in *kharif* and *rabi* with 60.20% and 59.91% reduction in fruit damage. Rakibuzzaman *et al.* (2019) recorded that the foliar application of neem oil had reduced the infestation significantly. Karkar *et al.* (2014) recorded that neem oil had effectiveness for reducing shoot and fruit infestation.

Table 5: Economics of brinjal under different biopesticides during *Kharif* 2019-20

Treatments	Treatments	Fruit yield (q/ha)	% Increase in yield over control	Additional profit (Rs/ha) @ Rs 1000 per quintal	Cost of treatments (Rs/ha)	Net profit (Rs/ha)	Cost benefit ratio
T_1-Neem oil 1%	3000	8.17 (16.60)	7.10 (15.43)	5.90 (14.02)	6.00 (14.18)	6.10 (14.30)	6.65 (14.90)
T_2-Karanj oil 1%	3000	14.33 (22.24)	13.67 (21.69)	11.97 (20.23)	12.00 (20.26)	12.27 (20.50)	12.85 (20.98)
T_3-*Beauveria bassiana* 1× 10^{12} spores/ml	1000	11.67 (19.95)	10.83 (19.20)	9.50 (17.95)	10.33 (18.75)	10.67 (19.06)	10.60 (18.98)
T_4-*Metarrhizium anisopliae* 1× 10^{12} spores/ml	1000	11.33 (19.67)	10.50 (18.90)	9.17 (17.61)	9.67 (18.11)	10.17 (18.59)	10.17 (18.58)
T_5-Neem oil – *Bb* – Neem oil	3000-1000-3000	10.67 (19.06)	9.67 (18.11)	8.33 (16.74)	8.63 (17.09)	9.17 (17.62)	9.29 (17.72)
T_6-Neem oil – *Ma* –Neem oil	3000-1000-3000	10.33 (18.75)	9.33 (17.75)	8.00 (16.35)	8.23 (16.67)	8.77 (17.21)	8.93 (17.35)
T_7-Karanj oil –*Bb* –Karanj oil	3000-1000-3000	14.00 (21.96)	13.00 (21.13)	11.67 (19.97)	12.00 (20.14)	12.33 (20.52)	12.60 (20.74)
T_8-Karanj oil –*Ma* –Karanj oil	3000-1000-3000	12.00 (20.23)	10.67 (19.06)	9.93 (18.37)	10.17 (18.54)	10.77 (19.14)	10.71 (19.07)
T_9-Untreated control	---	23.33 (28.88)	27.67 (31.73)	26.33 (30.87)	25.67 (30.44)	24.00 (29.33)	25.40 (30.25)
S.E.m ±		0.57	0.54	0.68	0.77	0.41	0.60
C.D at 5%		1.72	1.62	2.04	2.31	1.31	1.80

Yield and economics of different treatments

The data on fruit yield recorded under different treatmentsare presented in Table 6.All the treated plots resulted higher yield ranging between 217 – 237.33 q /ha and were proved significantly superior over control (188.67 q /ha). Among the treatments, Neem oil 1% (T_1) recorded higher healthy fruit yield (237.33 q / ha) than other treatments and other treatments were in the order of T_6 (233.13 q/ha) >T_5 (230.53 q/ha) > T_4 (226.47 q/ha) >T_3 (223.03 q/ha) >T_8 (221.10

q/ha) >T_7 (219.13 q/ha) > T_2 (217.00 q/ha). Bhagwan and Kumar (2017) reported that among the biopesticides (Neem oil 2%, NSKE 5%, *Beauveria bassiana*, *Verticillium lecanii* and Neem leaf extract 5%) used for treatment neem oil recorded (163.83q/ha) highest yield. Ashadul *et al.* (2014) recorded that neem has the highest yield among the treatments observed. Khan *et al.* (2017) observed an increase in yield on application of neem oil.

Economic analyses of treatment were made on the basis of fruit yield, treatment cost and marketable value of produce (Table 6). It is clear that the Neem oil 1% (T_1) gave maximum net profit and incremental cost benefit ratio (Rs 46860/ha and 1:26.03) and other treatments were in the order ofT_6 (Rs.42770/ ha and 1:25.31)>T_5 (Rs.40160 / ha and 1:23.62)>T_4 (Rs.36330 / ha and 1:24.71) > T_3 (Rs.32860 / ha and 1:21.91)>T_8 (Rs.30740 / ha and 1:18.19)>T_7 (Rs.28760 / ha and 1:16.92) >T_2 (Rs.26530 / ha and 1:14.74).The present findings are in agreement with Singh *et al.* (2018) who recorded the highest cost benefit ratio of 1:24.40. Likewise Dehariya *et al.* (2018) reported that the application of neem oil 1% registered the cost benefit ratio of 1:1.79 which was the most economical among the treatments. Sangma *et al.* (2019) reported that the maximum cost benefit ratio was registered in the treatment of Neem oil 2% (1:3.11) which proved as an economically valuable treatment.

CONCLUSION

It is concluded from the study that minimum shoot (5.80%) and fruit infestation (6.65%) was recorded with Neem oil 1% followed by Neem oil – *Ma* –Neem oil.The significant highest fruit yield of 237.33 q/ha was obtained from the Neem oil 1% treatment. The Neem oil – *Ma* –Neem oil was second most effective treatment with a yield of 233.13 q/ha. The maximum net profit and incremental cost benefit ratio (ICBR) was observed in plots treated with Neem oil 1% followed by Neem oil1% – *Ma* – Neem oil1%.

REFERENCES

Anonymous. (2019) Horticulture Statistics at a Glance. Annual publication of Department of Agriculture Cooperation and Farmer Welfare, GOI, New Delhi.

Ashadul, M.I., Hussain, M.A., Shapla, S.A., Mehraj, H. and Uddin, AFMJ. (2014) Plant Extract for the Management of Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee). *American-Eurasian Journal of Agricultural and Environmental Sciences* **14** (12): 1409-1414.

Bhagwan, D.S. and Kumar, A. (2017) Field efficacy of cypermethrin and certain biopesticides against brinjal shoot and fruit borer, (*Leucinodes orbonalis* Guenee) on brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry* **6** (4): 1930-1933.

Chakraborti, S. and 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.

Dadmal, S. M., Nemade, S. B. and Khare, M. D. (2004) Field screening of brinjal cultivar for resistance to *Leucinodes orbonalis* (Guenee), *Pest Management in Horticultural Ecosystems* **10** (2): 145-150.

Dehariya, S. K., Shukla, A., Barde, S. K. and Ahirwar, K. (2018) Efficacy of Botanical Pesticides against Sucking Insects Pests in Brinjal. *International Journal of Current Microbiology and Appiled Sciences.* **7** (1): 1930-1935.

Gautam, C. P. N., Verma, R. A., Gautam, R.D. and Khan, M. A. (2008) Comparative efficacy of insecticides, bio-pesticides and botanicals against *Leucinodes orbonalis* Guenee infesting brinjal. *Ann. Pl. Protec. Sci*., **16** (2): 309-311.

Goud, G. S., Bondre, C. M. and Gawali, K.A. (2019) Efficacy of some chemical and botanical pesticides against brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee. *Journal of Pharmacognosy and Phytochemistry*. **8** (4): 2453-2455.

Hedge, J. N. R., Girish, Chakravarthy., A.K. (2009) Integrated management of brinjal shoot and fruit borer, *Leucinodes orbonalis*. Proceding *"International conference on Horticulture for livelihood security and economic growth",*

University of Agriculture Science, Banglore. Pp 1103-1107.

Jagginavar, S.B., Sunitha, N.D. and Biradar, A. P. (2009) Bioefficacy of flubendiamide 480SC against brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. Karnataka *Journal of Agricultural Science*. **22** (3): 712–713.

Karkar, D.B., Korat, D.M. and Dabhi, M.R. (2014) Bio-efficacy of microbial insecticides against insect pests of brinjal. *Karnataka Journal of Agricutural Sciences* **27** (2): 236-238.

Khan, M.A., Khan, S., Ahmad, S., Shinwari, I., Iqbal, T., Hassan, M. and Shah, F. (2017) Impact of various treatments against brinjal shoot and fruit borer. *Journal of Entomology and Zoology Studies.* **5** (4): 57-62.

Mane, P.D. and Kulkarni, S.N. (2010) Bio-efficacy of neem products against *Leucinodes orbonalis* G. on brinjal. *Green Farming* **1** (2): 220.

Misra, H. P. (2008) New promising insecticides for the management of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. *Pest Management in Horicultural Ecosystems* **14** (2): 140–147.

Murugesan, N. and Murugesh, T. (2009) Bioefficacy of some plant products against brinjal fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera ; Pyrallidae). *Journal of Biopesticides* **2** (1): 60-63.

Rakibuzzaman, M., Mahato, A. K., Husna, M. A., Maliha, M. and Uddin, AFMJ. (2019) Influence of natura one and neem oil on growth and yield of brinjal (*Solanum melongena*). *Journal of Bioscience and Agriculture Research* **20** (2): 1694-1699.

Sangma, C. D., Simon, S. and Nagar, S. (2019) Indigenous pest control practices for the management of Brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.). *Journal of Pharmacognosy and Phytochemistry* **8** (3): 4221-4223.

Singh, J. P. and Nath, V. (2007) Field evaluation of insecticides and neem formulations for management of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee in brinjal. *Indian Journal of Entomology* **69** (4): 341-344.

Singh, J.P., Singh, R. and Singh, S. (2018) Efficacy of newer insecticides and biopesticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and phytochemistry* **2** (2): 339-347.

Tiwari, G., Prasad, C. S., Nath, L., Singh, R. (2011) Efficacy of bio-pesticides and insecticides on brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. *Annals of Plant Protection Sciences* **19** (2):345-349.

Tripura, A., Chatterjee, M. L., Pande, R. and 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.