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Management of major insect pests of brinjal (*Solanum melongena* L.)

Rahul Salwe, MM Sonkamble and SK Patil

Abstract
The field experiment was under taken to evaluate the efficacy of different seven insecticides *viz*., emamectin benzoate 5 SG @ 0.002%, imidacloprid 17.8 SL @ 0.017%, fipronil 5 SC @ 0.01%, spinosad 45 SC @ 0.009%, azadiractin 3000 ppm @ 0.03%, NSKE @ 5% and triazophos 40 EC @ 0.08% against major insect pests of brinjal during *Kharif* 2018-19. The results revealed that imidacloprid 17.8 SL was most superior in minimising sucking pests i.e. jassid ((*Amrasca bigutulla bigutulla* Ishida) and whitefly (*Bemisia tabaci* Gennadius) population of 1.27 jassids/3 leaves and 1.21 whiteflies/3 leaves, respectively) and it was found at par with fipronil 5 SC (2.18 jassids and 2.07 whiteflies), spinosad 45 SC (2.41 jassids and 2.30 whiteflies) and emamectin benzoate 5 SG (2.46 jassids and 2.46 whiteflies). As regards brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) infestation, spinosad 45 SC was found highly effective with least mean per cent damaged shoots (1.60%) followed by emamectin benzoate 5 SG (1.73%), fipronil 5 SC (2.03%) and triazophos 40 EC (2.14%). While in case of fruit infestation on number and weight basis, plots treated with spinosad 45 SC was also found to be the most superior treatment shows lowest fruit damage of 12.47 and 10.69 per cent on number as well as weight basis, respectively and it was statistically at par with emamectin benzoate 5 SG @ (13.74 and 11.59%) and fipronil 5 SC (15.32 and 11.65%), respectively.
Irrespective of infestation, the highest marketable fruit yield, gross return and net return (139 q/ha, Rs. 170000/ha and Rs.161000/ha) registered in plot treated with spinosad 45 SC followed by emamectin benzoate 5 SG (136 q/ha, Rs.160000/ha and Rs.158000/ha), fipronil 5 SC (132 q/ha, Rs.156000/ha and Rs.150200/ha). Amongst the treatments, emamectin benzoate 5 SG was the most economical by recording maximum ICBR of 1: 26.33 followed by fipronil 5 SC (1:25.90), imidacloprid 17.8 SL (21.13), azardiractin 3000 ppm (1:20.50), spinosad 45 SC (1: 19.24), triazophos 40 EC (1: 13.67) and NSKE 5% (1:11.33).

Keywords: Brinjal, jassid, whitefly, shoot and fruit borer, insecticides

Introduction

Brinjal or eggplant (*Solanum melongena* L.) is an important Solanaceous crop of subtropics and tropics. It is native of India and locally called ‘Wangi’ in Maharashtra often described as poor man's vegetable. After potato, it ranks second highest consumed vegetable in India, along with tomato and onion. After China, India is second largest producer of vegetable in the world. In India, area under brinjal cultivation was occupies at 729 million ha with production of 12616 million metric tons with the productivity of 200 to 350 q/ha in 2017. The major growing brinjal states in India are Andhra Pradesh, Bihar, Karnataka, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal (Anonymous, 2017) [1].

This crop is prone to be attacked by many insect pests particularly, whitefly (*Bemisia tabaci* Gennadius), aphid (*Aphis gossypii* Glover), jassid (*Amrasca bigutulla bigutulla* Ishida), thrips (*Thrips tabaci* Lindemann), epilachna beetle (*Henosepilachna vigintioctopmctata* Fabricius), mites (*Tetranychus macfuslanii* Baker and Pricthaid) and shoot and fruit borer (*Leucinodes orbonalis* Guenee). Both nymphs and adults of sucking pests *viz., A. gossypii, A. bigutulla bigutulla* and *B. tabaci* occur regularly on the crop from the early stage and remains till harvest of the crop causing enormous damage by sucking cell sap from the leaves and tender plant parts. Among the lepidopteran pests, brinjal shoot and fruit borer, *L. orbonalis*is considered as the main constraint as it damage the crop throughout the year. This pest not only reduce the yield but also deteriorate the quality of fruits. The pest is very active during rainy and summer season and often causes more than 90% damage in Bangladesh and up to 95% in India (Naresh *et al*., 1986) [7]. It is also reported that the infestation of fruit borer causes reduction in Vitamin ‘C’ content to the extent of 68% in the infested fruits (Hemi, 1955) [3].

Overall losses due to insect pests vary from 26.3 to 65.5% with a maximum of 95.8%. It has been estimated that annual crop losses in India due to these pests are much more. These losses are qualitative as well as quantitative in nature, more particular so in vegetable crop like brinjal where carryover of pests is relatively more as they are grown round the year.

Vegetable growers depend on insecticides for their managements and take number of sprays at regular intervals that pose many problems including resistance to insecticides and resurgence of secondary pests as well as toxic effect on natural enemies. Similarly, to save the crop from disastrous pests by using newer and safer insecticides for effective management and to obtain maximum fruit yield of brinjal, hence the present investigation was undertaked to manage the infestation of majaor insect pests on brinjal.

Material and Methods

The field experiment was conducted on "Management of major insect pests of brinjal (*Solanum melongena* L.)" on the Research Farm of Department of Agricultural Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Dist. Parbhani during *Kharif* 2018-19. It was laid in Randomized Block Design in trice replicated with eight treatments *viz*., T_1: Emamectin benzoate 5 SG @ 0.002%, T_2: Imidacloprid 17.8 SL @ 0.017%, T_3: Fipronil 5 SC @ 0.01%, T_4: Spinosad 45 SC @ 0.009%, T_5: Azadiractin 3000 ppm @ 0.03%, T_6: NSKE 5%, T_7: Triazophos 40 EC @ 0.08% and T_8: Untreated control. The row to row and plant to plant distance was maintained at 60x60 cm having 3.6 x 3.6 m net plot size. The brinjal crop cv. Manjiri Gota was transplanted on 13th July, 2018. Application of the treatments was applied at 15 day interval starting from 30 days after transplanting i.e 12/08/2018 and total four sprays were given. With the beginning of attack insects infestation the first two sprays of insecticides given for sucking pests and next two sprays for brinjal shoot and fruit borer at fortnightly interval. Spraying was done using high volume knapsack sprayer with hollow cone nozzle in the early morning hours by using spray volume of 500 litre water.

Observations recorded

1. Sucking pests

Five plants were selected randomly from the net plot of each treatment in each replication and properly labelled. The observations on total number of survival jassid and whitefly population was recorded on the leaf each from top, middle and bottom canopy i.e. 3 leaves of the observation plants at one day before and 1, 3, 7 and 14 days after application of insecticides.

2. Shoot and fruit borer

A. Per cent shoot infestation

For recording shoot infestation, healthy and infested shoots were recorded from five randomly selected plants from each plot. Observations were recorded one day before spray and 1, 3, 7 and 14 days after treatment. All the infested shoots from selected plants were marked using a ribbon tied around the shoot to avoid recounting during the next observation. Per cent shoot infestation was calculated by using the following formula:

$$\text{Per cent shoot infestation} = \frac{\text{No. of infested shoots}}{\text{Total no. of shoots}} \times 100$$

B. Per cent fruit infestation

Picking wise observations were recorded on the number basis as well as weight basis of infested fruits and number and weight of marketable fruits on five randomly selected plants from each plot. The per cent fruit damage was worked out fruit infestation on number basis and weight basis by using following the formula.

$$\text{Per cent fruit infestation (Number basis)} = \frac{\text{No. of infested fruits}}{\text{Total no. of fruits}} \times 100$$

$$\text{Per cent fruit infestation (Weight basis)} = \frac{\text{Weight of infested fruit}}{\text{Weight of total fruit}} \times 100$$

Statistical analysis

The data on number of jassid and whitefly recorded at different intervals was transformed into square root transformation ($\sqrt{x+0.5}$) before statistical analysis. In case of shoot and fruit borer, the data obtained in number was subjected to transformation using arc sine transformation before statistical analysis. The mean data were statistically analyzed and subjected to the analysis of variance outlined by Panse and Sukhatme (1978) [8] and Gomez and Gomez (1984) [2] by adopting "Fishers analysis of variance technique".

Results and Discussion

The observations were recorded on sucking pests i.e. jassid and whitfly and shoot and fruit borer and results are presented in Table 1 to 4.

1. Jassid (*Amrasca bigutulla bigutulla*)

The data from Table 1, revealed that the pre-treatment population of jassids was uniform and it was statistically non-significant with the population in the range of 5.11 to 5.67 nymphs and adults/3 leaves / plant.

A. After first spray

The post treatment observations recorded on first day (Table 1) indicated that all the insecticide treatments were significantly superior over untreated control in reducing jassid population. Among these treatments, the plants treated with imidacloprid 17.8 SL recorded lowest jassid population (1.39 jassids/3 leaves) which was statistically at par with fipronil 5 SC (2.20 jassids), emamectin benzoate 5 SG (2.58 jassids) and spinosad 45 SC (2.63 jassids). Rest of the insecticide treatments *viz*., triazophos 40 EC (3.76 jassids), NSKE 5% (3.83 jassids) and azadiractin 0.03% (4.06 jassids) significantly reduced the jassids population as against untreated control plots (5.67 jassids).

On 3, 7 and 14 DAS, the treatment of imidacloprid 17.8 SL (1.16, 0.95 and 1.54 jassids) was most superior in minimising the jassid population and which was statistically at par with fipronil 5 SC (2.05, 1.88 and 2.23 jassids), emamectin benzoate 5 SG (2.32, 2.13 and 2.69 jassids), spinosad 45 SC (2.43, 2.20 and 2.43 jassids), respectively. Other treatments *viz*., triazophos 40 EC (3.40, 3.16 and 3.32 jassids), NSKE 5% (3.53, 3.33 and 3.60 jassids), azadiractin 0.03% (3.87,3.67 and 4.13 jassids) were also effective over utreated control (5.40, 5.15 and 5.58 jassids), respectively.

B. After second spray

The post treatment observations recorded on first day (Table

1) indicated that all the insecticidal treatments were significantly superior over untreated control in reducing jassid population. During second spray, there was a slow increase in live count of jassids on untreated control plots (6.77 to 6.43 jassids/3 leaves) over a period of 14 days.

One day after second spray, the lowest jassid population was recorded in imidacloprid 17.8 SL (1.44 jassids) and it was statistically at par with fipronil 5 SC (2.41 jassids), spinosad 45 SC (2.53 jassids) and emamectin benzoate 5 SG (2.62 jassids). The next effective treatments were triazophos 40 EC (4.03 jassids), azadiractin 0.03% (4.13 jassids), and NSKE 5% (4.23 jassids).

On 3, 7 and 14 DAS, the most superior treatment of imidacloprid 17.8 SL (1.33, 0.93 and 1.43 jassids) was recorded as compared to other test insecticides, which was statistically at par with fipronil 5 SC (2.20, 2.00 and 2.48 jassids), spinosad 45 SC (2.33, 2.23 and 2.57 jassids), and emamectin benzoate 5 SG (2.47, 2.27 and 2.63 jassids), respectively. The next effective treatments were azadiractin 0.03% (3.80, 3.47 and 3.83 jassids), triazophos 40 EC (3.83, 3.47 and 3.70 jassids) and NSKE 5% (3.97, 3.57 and 3.93 jassids), respectively.

Overall effect after 1st and 2st spray shows that treatment of imidacloprid 17.8 SL was most superior (1.27 jassids) and it was statistically at par with fipronil 5 SC (2.18 jassids), spinosad 45 SC (2.41 jassids) and emamectin benzoate 5 SG (2.46 jassids) followed by triazophos 40 EC (3.6 jassid), NSKE 5% (3.74 jassid) and azadiractin 0.03% (3.86 jassids).

The present findings are supported with results reported by Kumar *et al.* (2017) [5] observed that imidacloprid (0.5ml/lit) was most effective against jassids followed by fipronil (1 ml/lit) emamectin benzoate (0.2 g/lit) and spinosad (0.1 ml/lit).

2. Whitefly (*Bemisia tabaci*)

The pre and post treatment data on whitefly incidence are presented in Table 2. The average pre-treatment population was in the range of 1.36 to 3.48 nymphs and adults /3 leaves / plant and it was statistically non-significant.

A. After first spray

The observations recorded on first day noted that imidacloprid 17.8 SL recorded lowest whitefly population (1.30 whiteflies/3 leaves) which was statistically at par with fipronil 5 SC (2.03 whiteflies) and spinosad 45 SC (2.47 whiteflies). Rest of the treatments *viz*., triazophos 40 EC (2.54 whiteflies), and emamectin benzoate 5 SG (2.63 whiteflies), NSKE 5% (3.44 whiteflies) and azadiractin 0.03% (3.77 whiteflies) were effective to minimise the whitefly population.

On 3 and 7 DAS, the lowest whitefly population (1.01 and 0.89 whiteflies) was recorded in plants treated with imidacloprid 17.8 SL and which was statistically at par with fipronil 5 SC (1.74 and 1.60 whiteflies), spinosad 45 SC (2.13 and 1.87 whiteflies). Other treatments *viz*., triazophos 40 EC (2.24 and 2.03 whiteflies), emamectin benzoate 5 SG (2.33 and 2.00 whiteflies), NSKE 5% (3.23 and 2.83 whiteflies) and azadiractin 0.03% (3.30 and 3.10 whiteflies) were also reduce the pest population.

On 14 DAS, the plants treated with imidacloprid 17.8 SL recorded lowest whitefly population (1.33 whiteflies) and it was statistically at par with, fipronil 5 SC (1.93 whiteflies), spinosad 45 SC (2.13 whiteflies) and emamectin benzoate 5 SG (2.27 whiteflies) followed by triazophos 40 EC (2.43 whiteflies), NSKE 5% (3.20 whiteflies) and azadiractin 0.03% (3.53 whiteflies).

B. After second spray

The results recorded on first day indicated that all the insecticide treatments were significantly superior over untreated control in reducing whitefly population. During second spray, there was a slow increase in live count of whitefly on untreated control plots (4.17 to 4.26 whitefly/3 leaves) over a period of 14 days.

On 1, 3 and 7 days after second spray, the plants treated with imidacloprid 17.8 SL recorded lowest whitefly population (1.43, 1.30 and 1.13 whiteflies) which was statistically at par with fipronil 5 SC (2.57, 2.20 and 2.03 whiteflies), spinosad 45 SC (2.60, 2.37 and 2.20 whiteflies) followed by emamectin benzoate 5 SG (2.87, 2.60 and 2.37 whiteflies), NSKE 5% (3.57, 3.40 and 3.07 whiteflies), triazophos 40 EC (3.80, 3.43 and 3.13 whiteflies) and azadiractin 0.03% (3.80, .50 and 3.23 whiteflies), respectively,

On 14 day after second spray, the lowest whitefly population was recorded in imidacloprid 17.8 SL (1.33 whiteflies) and it was statistically at par with fipronil 5 SC, (2.53 whiteflies), spinosad 45 SC (2.70 whiteflies) emamectin benzoate 5 SG (2.67 whiteflies) and followed by NSKE 5% (3.40 whiteflies), triazophos 40 EC (3.60 whiteflies), and azadiractin 0.03% (3.70 whiteflies).

Overall effect after 1st and 2nd sprays, the plots treated with imidacloprid 17.8 SL treatment recorded lowest whitefly population (1.21 whiteflies) which was statistically at par with fipronil 5 SC (2.07 whiteflies), spinosad 45 SC (2.30 whiteflies) emamectin benzoate 5 SG (2.46 whiteflies) and azadiractin 0.03% (2.83 whiteflies). Next treatments i.e. NSKE 5% (3.26 whiteflies) and triazophos 40 EC (3.45 whiteflies) was found also effective against whitefly population over untreated control (4.59 whiteflies).

The present findings are accordance with results reported by Kumar *et al.* (2017) [5] they reported that imidacloprid (0.5ml/lit) was most effective against whitefly followed by fipronil (1 ml/lit) emamectin benzoate (0.2 g/lit) and spinosad (0.1 ml/lit).

3. Shoot infestation caused by *Leucinodes orbonalis*

A. After first spray

The data from Table 3, the pre-count observations on the per cent shoot infestation caused by brinjal shoot borer, *L. orbonalis* were ranged from 3.03 to 4.53 per cent and it was statistically non-significant.

All the insecticides were found to be significantly superior over untreated control in minimizing incidence of brinjal shoot borer at all the days of observations. However, spinosad 45 SC (1.80, 1.67,1.50 and 1.87%) found most promising treatment against *L. orbonalis* to reduce the shoot infestataion after 1, 3, 7 and 14 days after first spray, respectively and which was statistically at par with emamectin benzoate 5 SG, (1.93, 1.85, 1.67 and 1.93%), fipronil 5 SC, (2.10, 2.00,1.80 and 2.03%) and followed by triazophos 40 EC, (2.30, 2.13, 1.93 and 2.23%), imidacloprid 17.8 SL (2.70, 2.50, 2.30 and 2.70%), azadiractin 0.03 (2.73, 2.60, 2.40 and 2.63%) and NSKE 5% (2.77, 2.57, 2.33 and 2.73%).

B. After second spray

The results revealed that all insecticide treatments were significantly superior over untreated control in minimizing the infestation of brinjal shoot borer after second spray. The shoot infestation caused by *L. orbonalis* was decreased at 7 days after spraying but gradually increased at 14 DAS.

The spraying of spinosad 45 SC was reduced the shoot infestation by 1.57, 1.37, 1.30 and 1.73 per cent at 1, 3, 7 and 14 days after second spray followed by emamectin benzoate 5 SG, (1.77, 1.53, 1.33 and 1.88%), triazophos 40 EC (1.90, 1.70, 1.73 and 1.70%), fipronil 5 SC, (2.43, 2.10, 1.97 and 1.83%), respectivelly and it statistically at par with each other. Rest of the treatments i.e. imidacloprid 17.8 SL (2.67, 2.47, 2.23 and 2.61%), NSKE 5% (2.83, 2.60, 2.40 and 2.81%) and azadiractin 0.03% (3.47, 3.17, 3.03 and 3.62%) was also reduced shoot infestation of *L. orbonalis*.

It observed that all the insecticide treatments were reduced the shoot infestation over untreated control after1st and 2nd spray. However, spinosad 45 SC was the most superior treatment shows mean lowest shoot damage (1.6%) and it was statistically at par with emamectin benzoate 5 SG, (1.73%), fipronil 5 SC, (2.03%), triazophos 35 EC (2.14), imidacloprid 17.8 SL (2.31%), NSKE 5% (2.60%) and followed by azadiractin 0.03 (2.95%).

These findings are agreements with the results reported by Sinha and Nath (2012) [12] they revealed that spinosad @ 0.01% was most effective in reduction of shoot infestation of *L. orbonalis*. Shah *et al.* (2012) [10] concluded that emamectin benzoate at 0.0025% recorded comparatively lower shoot damage and were found promising insecticides for the management of BSFB. Nayak *et al.* (2011) [6] reported that rynaxypyr resulted in lowest shoot damage (1.8%) followed by flubendiamide (2.3%) and spinosad (2.3%) and these treatments were statistically at par with each other. Sharma and Tayde (2017) [11] noted that minimum per cent of shoot infestation caused by brinjal shoot and fruit borer (*L.orbonalis*) was recorded in cypermethrin (check) with (6.69%) followed by spinosad (13.2%) < emamectin benzoate (14.03%) < neem oil (16.96%).

4. Fruit infestation caused by *Leucinodes orbonalis*

The data on brinjal fruit infestation on number basis as well as weight basis caused by *L. orbonalis* by using two sprays i.e. first (third) and second (fourth) spray and results are presented in Table 4.

1. Number basis

The results of pre-treatment count of fruit infestation on number basis caused by *L. orbonalis* ranged from 18.67-25.67 per cent and it was non-significant.

After first and second sprays, the treatment of spinosad 45 SC (13.58 and 11.37%) was recorded minimum fruit infestation caused by *L. orbonalis* and it was statistically at par with emamectin benzoate 5 SG (15.20 and 12.28%) and fipronil 5 SC, (17.30 and 13.34%), triazophos 40 EC (18.36 and 16.41%), respectively. Rest of the treatments *viz*., imidacloprid 17.8 SL (19.35 and 15.65%), azadiractin 0.03% (20.36 and 18.12%) and NSKE 5% (20.48 and 17.23%) were also reduced the per cent fruit infestation on number basis at first and second sprays, respectively. The maximum fruit infestation on number basis (23.27 and 21.34%) was observed in untreated control at first and second spray, repectively.

Overall mean effect of 1st and 2nd sprays, the fruit infestation in descending order was spinosad 45 SC (12.47%) > emamectin benzoate 5 SG (13.74%) > fipronil 5 SC (15.32%) > triazophos 40 EC (17.38%) > imidacloprid 17.8 SL (17.5%) > (NSKE 5% 18.85%) > azadiractin 0.03% (19.24%) > untreated control (22.30%).

2. Weight basis

It is evident from Table 4, indicated that all the insecticides were found to be significantly superior in reducing infestation of *L. orbonalis* on brinjal fruits on weight basis over untreated control after first and second sprays of 20.41 and 19.89 per cent, respectively.

Similarly, spinosad 45 SC (11.36 and 10.02%) was the most superior treatment shows lowest fruit damage on weight basis and it was statistically at par with emamectin benzoate 5 SG (12.07 and 11.11%), fipronil 5 SC (12.44 and 10.87%) at 1st and 2nd spray, respectivelly. The treatments *viz*., triazophos 40 EC (16.22 and 14.36%), imidacloprid 17.8 SL (17.08 and 15.32%), NSKE 5% (19.04 and 18.13%) and azadiractin 0.03 (19.31 and 17.49%) were also reduced the per cent fruit infestation on weight basis at first and second sparys, respectively.

It was also clearly indicated that the mean fruit infestation on weight basis observed in descending order was spinosad 45 SC (10.69%) > emamectin benzoate 5 SG (11.59%) > fipronil 5 SC (11.65%) > triazophos 40 EC (15.29%) > imidacloprid 17.8 SL (16.2%) > azadiractin 0.03 (18.4%) > NSKE 5% (18.58%).

These present findings are corroboted with the results reported by various researchers, Singh *et al.* (2018) [13] reported that emamectin benzoate 5 SG @ 12.5 g a.i./ha treated plots showed lowest infestation of shoot and fruit borer, *Leucinodes orbonalis* Guenee brinjal followed by flubendiamide 480 SC and novaluron 10 EC. Shah *et al.* (2012) [10] concluded that emamectin benzoate at 0.0025% recorded comparatively lower fruit damage and were found promising insecticides for the management of BSFB. Nayak *et al.* (2011) [6] reported that rynaxypyr resulted in lowest fruit damage (8.2%) followed by flubendiamide (8.5%) and spinosad (8.3%) and these treatments were statistically at par with each other. Sharma and Tayde (2017) [11] reported that shoot and fruit borer, *Leucinodes orbonalis*, minimum per cent of fruit infestation was recorded in cypermethrin (check) with (9.33%) followed by spinosad (10.66%) < emamectin benzoate (14.60%).

Yield

The data from Table 5, regarding fruit yield of brinjal revealed that all the treatments were statistically significant in increasing yield over untreated control. The fruit yield in different treatments varied from 139 to 54 q/ha. The significantly highest fruit yield (139 q/ha) was obtained in spinosad 45% SC treated plot. Rest of the treatments *viz*., emamectin benzoate 5 SG (136 q/ha), fipronil 5 SC (132 q/ha), imidacloprid 17.8 SL (108 q/ha), triazophos 40 EC (98 q/ha), azadiractin 0.03% (97 q/ha) and NSKE 5% (91 q/ha) were found statistically higher marketable fruit yield over untreated control (54 q/ha).

Present findings are accordance with earlier researcher; Singh *et al.* (2018) [13] emamectin benzoate 5 SG @ 12.5 g a.i./ha treated plots showed gave higher fruit yield (253.12) followed by flubendiamide 480 SC (249.33) and novaluron 10 EC (243.63). Similarly, Shah *et al.* (2012) [10] recorded comparatively higher fruit yield in the treatment emamectin benzoate at 0.0025% and were found promising insecticides for the management of BSFB. Singh *et al*. (2016) [14] stated that emamectin benzoate recorded highest fruit yield (253.12 q/ha) with tested insecticides. Kumar *et al.* (2017) [5] reported that the highest marketable yield of 28.69 kg/plot was recorded in case of imidacloprid 17.8 SL @ 0.5 ml/lit followed by fipronil 5 SC @ 1 ml/lit and emamectin benzoate 5 SG @ 0.2 g/lit, which yielded 27.69 and 24.43 kg/plot, respectively. NSKE 5%, azadiractin 3000 ppm, and spinosad 0.1 ml/lit yielded the lowest marketable of 15.90, 18.06, 22.93 and 23.51 kg/plot, respectively. Nayak *et al.* (2011) [6] reported that rynaxypyr resulted in highest marketable fruit yield (63.7 q/acre) followed by flubendiamide (63.3 q/acre) and spinosad (63.2 q/acre) and these treatments were statistically at par with each other. Kameshwaran and Kumar (2015) [4] reported that the highest yield was observed in the treatment with chlorantraniliprole 20 SC @ 40 g a.i./ha (27.08 t/ha) followed by emamectin benzoate 25 WG @ 11 g a.i. /ha (23.61 t/ha) and spinosad 45 SC @ 75 g a.i. /ha (20.83 t/ha).

Table 1: Efficacy of newer insecticides against brinjal jassid after 1st and 2nd sprays

Tr. No	Treatment	Conc. (%)	Number of Jassids/ 3 leaves											
			After 1st spray						After 2nd spray					Pooled mean of 1st & 2nd sprays
			Pre count	1DAS	3DAS	7DAS	14DAS	Mean	1DAS	3DAS	7DAS	14DAS	Mean	
T_1	Emamectin benzoate 5 SG	0.002	5.23 (2.47)*	2.58 (1.89)	2.32 (1.81)	2.13 (1.76)	2.69 (1.91)	2.43 (1.84)	2.62 (1.90)	2.47 (1.85)	2.27 (1.78)	2.63 (1.85)	2.49 (1.83)	2.46 (1.85)
T_2	Imidacloprid 17.8 SL	0.017	5.38 (2.51)	1.39 (1.54)	1.16 (1.46)	0.95 (1.39)	1.54 (1.59)	1.26 (1.49)	1.44 (1.56)	1.33 (1.51)	0.93 (1.38)	1.43 (1.64)	1.28 (1.50)	1.27 (1.49)
T_3	Fipronil 5 SC	0.01	5.55 (2.55)	2.20 (1.78)	2.05 (1.74)	1.88 (1.69)	2.23 (1.79)	2.09 (1.75)	2.41 (1.84)	2.20 (1.78)	2.00 (1.71)	2.48 (1.86)	2.27 (1.98)	2.18 (1.77)
T_4	Spinosad 45 SC	0.009	5.46 (2.54)	2.63 (1.90)	2.43 (1.84)	2.20 (1.84)	2.43 (1.84)	2.42 (1.85)	2.53 (1.87)	2.33 (1.82)	2.23 (1.77)	2.57 (1.88)	2.41 (1.81)	2.41 (1.84)
T_5	Azadiractin 3000 ppm	0.03	5.33 (2.48)	4.06 (2.24)	3.87 (2.20)	3.67 (2.20)	4.13 (2.26)	3.93 (2.22)	4.13 (2.26)	3.80 (2.19)	3.47 (2.11)	3.83 (2.19)	3.80 (2.17)	3.86 (2.20)
T_6	NSKE	5.0	5.41 (2.53)	3.83 (2.16)	3.53 (2.09)	3.33 (2.09)	3.60 (2.11)	3.57 (2.11)	4.23 (2.25)	3.97 (2.21)	3.57 (2,11)	3.93 (2.19)	3.92 (2.21)	3.74 (2.18)
T_7	Triazophos 40 EC	0.08	5.11 (2.47)	3.76 (2.17)	3.40 (2.09)	3.16 (2.03)	3.32 (2.07)	3.41 (2.09)	4.03 (2.23)	3.83 (2.19)	3.47 (2.11)	3.70 (2.15)	3.79 (2.16)	3.60 (2.12)
T_8	Untreated Control	-	5.67 (2.53)	5.67 (2.57)	5.40 (2.51)	5.15 (2.46)	5.58 (2.56)	5.45 (2.52)	6.77 (2.77)	6.49 (2.71)	6.03 (2.65)	6.43 (2.71)	6.43 (2.71)	5.94 (2.61)
S.E±			0.18	0.12	0.13	0.13	0.10	0.8	0.14	0.13	0.14	0.11	0.14	0.14
C.D. at 5%			NS	0.39	0.41	0.41	0.33	0.26	0.44	0.39	0.44	0.34	0.42	0.43

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed value DAS= Days after spray NS= Non significant

Table 2: Efficacy of newer insecticides against brinjal whitefly after 1st and 2nd sprays

Tr. No.	Treatment	Conc. (%)	Number of whitefly/ 3 leaves											
			After 1st spray						After 2nd spray					Pooled mean of 1st & 2nd sprays
			Pre count	1DAS	3DAS	7DAS	14DAS	Mean	1DAS	3DAS	7DAS	14DAS	Mean	
T_1	Emamectin benzoate 5 SG	0.002	1.36 (1.86)*	2.63 (1.87)	2.33 (1.81)	2.00 (1.73)	2.27 (1.80)	2.30 (1.79)	2.87 (1.96)	2.60 (1.89)	2.37 (1.83)	2.67 (1.91)	2.62 (1.89)	2.46 (1.85)
T_2	Imidacloprid 17.8 SL	0.017	2.93 (1.96)	1.30 (1.51)	1.01 (1.41)	0.89 (1.37)	1.33 (1.52)	1.13 (1.45)	1.43 (1.55)	1.30 (1.51)	1.13 (1.45)	1.33 (1.51)	1.29 (1.5)	1.21 (1.48)
T_3	Fipronil 5 SC	0.01	2.91 (1.93)	2.03 (1.83)	1.74 (1.64)	1.60 (1.60)	1.93 (1.69)	1.82 (1.66)	2.57 (1.88)	2.20 (1.77)	2.03 (1.74)	2.53 (1.87)	2.33 (1.81)	2.07 (1.75)
T_4	Spinosad 45 SC	0.009	3.16 (2.03)	2.47 (1.85)	2.13 (1.75)	1.87 (1.69)	2.13 (1.75)	2.15 (1.77)	2.60 (1.70)	2.37 (1.80)	2.20 (1.76)	2.70 (1.88)	2.46 (1.83)	2.30 (1.79)
T_5	Azadiractin 3000 ppm	0.03	3.71 (2.16)	3.77 (2.17)	3.30 (2.04)	3.10 (2.02)	3.53 (2.12)	3.42 (2.09)	3.80 (2.18)	3.50 (2.26)	3.23 (2.03)	3.70 (2.16)	3.36 (2.08)	2.83 (1.94)
T_6	NSKE	5.0	2.83 (1.95)	3.44 (2.10)	3.23 (2.06)	2.83 (1.91)	3.20 (2.04)	3.17 (2.04)	3.57 (2.11)	3.40 (2.07)	3.07 (2.00)	3.40 (2.07)	3.36 (2.08)	3.26 (2.06)
T_7	Triazophos 40 EC	0.08	2.34 (1.81)	2.54 (1.85)	2.24 (1.79)	2.03 (1.74)	2.43 (1.85)	2.31 (1.79)	3.80 (2.19)	3.43 (2.10)	3.13 (2.03)	3.60 (2.14)	3.49 (2.09)	3.45 (2.05)
T_8	Untreated Control	-	3.48 (2.10)	5.33 (2.50)	4.93 (2.43)	4.40 (2.32)	5.07 (2.45)	4.93 (2.41)	4.17 (2.26)	4.40 (2.32)	4.10 (2.25)	4.40 (2.32)	4.26 (2.28)	4.59 (2.36)
S.E±			0.10	0.12	0.12	0.11	0.10	0.11	0.12	0.12	0.12	0.14	0.12	0.14
C.D. at 5%			NS	0.39	0.36	0.34	0.32	0.35	0.36	0.37	0.37	0.43	0.38	0.44

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed value DAS= Days after spray NS= Non significant

Table 3: Efficacy of different insecticides against brinjal shoot infestation caused by *L. orbonalis* after 1st and 2nd spray

Tr. No.	Treatment	Conc. (%)	Per cent shoot infestation by *L. orbonalis*											
			After 1 st spray						After 2nd spray					Pooled mean of 1st & 2nd sprays
			Pre count	1DAS	3DAS	7DAS	14DAS	Mean	1DAS	3DAS	7DAS	14DAS	Mean	
T_1	Emamectin benzoate 5 SG	0.002	3.61 (10.80)*	1.93 (7.94)	1.85 (8.24)	1.67 (7.30)	1.93 (7.98)	1.84 (7.64)	1.77 (7.51)	1.53 (7.02)	1.33 (6.46)	1.88 (7.72)	1.62 (7.21)	1.73 (7.43)
T_2	Imidacloprid 17.8 SL	0.017	3.03 (10.00)	2.70 (9.41)	2.50 (9.07)	2.30 (8.83)	2.70 (9.44)	2.55 (9.15)	2.67 (9.35)	2.47 (9.01)	2.23 (8.57)	2.61 (9.25)	2.49 (9.04)	2.31 (8.72)
T_3	Fipronil 5 SC	0.01	3.40 (10.50)	2.10 (8.31)	2.00 (8.12)	1.80 (7.65)	2.03 (8.16)	1.98 (7.90)	2.43 (8.67)	2.10 (8.19)	1.97 (7.89)	1.83 (7.63)	2.08 (8.28)	2.03 (8.18)
T_4	Spinosad	0.009	3.20	1.80	1.67	1.50	1.87	1.71	1.57	1.37	1.30	1.73	1.49	1.6

	45 SC		(10.20)	(7.69)	(7.39)	(6.93)	(7.75)	(7.39)	(7.11)	(6.67)	(6.51)	(7.43)	(6.94)	(7.16)
T_5	Azadiractin 3000 ppm	0.03	4.23 (11.80)	2.73 (9.50)	2.60 (9.27)	2.40 (8.89)	2.63 (9.32)	2.59 (9.21)	3.47 (10.71)	3.17 (10.24)	3.03 (10.02)	3.62 (10.93)	3.32 (10.45)	2.95 (9.79)
T_6	NSKE	5%	3.87 (11.30)	2.77 (9.55)	2.57 (9.18)	2.33 (8.76)	2.73 (9.50)	2.59 (9.25)	2.83 (9.61)	2.60 (9.22)	2.40 (8.88)	2.81 (9.26)	2.66 (9.33)	2.60 (8.94)
T_7	Triazophos 40 EC	0.08	3.13 (10.10)	2.30 (8.70)	2.13 (8.37)	1.93 (7.96)	2.23 (8.55)	2.14 (8.40)	1.90 (7.76)	1.70 (7.37)	1.43 (6.81)	1.70 (7.37)	1.68 (7.33)	2.14 (8.40)
T_8	Untreated Control	-	4.53 (12.20)	3.47 (10.70)	3.27 (10.30)	3.10 (10.10)	3.47 (10.60)	3.32 (10.48)	3.57 (10.86)	3.33 (10.50)	3.10 (10.13)	2.11 (8.34)	3.02 (10.00)	3.17 (10.24)
S.E±			0.58	0.41	0.38	0.60	0.48	0.53	0.60	0.61	0.62	0.52	0.52	0.58
C.D. at 5%			NS	1.27	1.16	1.84	1.48	1.64	1.84	1.87	1.91	1.60	1.59	1.79

*Figures in parenthesis are arc sin transformed values. DAS – Days after spray NS= Non significant

Table 4: Effect of different insecticides on brinjal fruit infestation caused by *L. orbonalis* on number and weight basis after 1st and 2nd spray

Tr. No.	Treatment	Conc. (%)	Per cent of fruit infestation							
			Number basis				Weight basis			
			Pre count	1st spray	2nd spray	Mean	Pre count	1st spray	2nd spray	Mean
T_1	Emamectin benzoate 5 SG	0.002	22.67 (28.20)*	15.20 (22.93)	12.28 (20.45)	13.74 (21.74)	20.33 (32.10)*	12.07 (19.89)	11.11 (19.46)	11.59 (19.39)
T_2	Imidacloprid 17.8 SL	0.017	25.67 (30.27)	19.35 (26.06)	15.65 (23.30)	17.5 (24.71)	24.33 (29.53)	17.08 (24.40)	15.32 (23.03)	16.20 (23.71)
T_3	Fipronil 5 SC	0.01	18.67 (25.56)	17.30 (24.52)	13.34 (21.36)	15.32 (23.02)	25.00 (29.94)	12.44 (20.64)	10.87 (19.23)	11.65 (20.53)
T_4	Spinosad 45 SC	0.009	23.00 (28.59)	13.58 (22.16)	11.37 (19.66)	12.47 (20.66)	25.67 (30.42)	11.36 (19.68)	10.02 (18.44)	10.69 (19.04)
T_5	Azadiractin 3000 ppm	0.03	20.67 (26.97)	20.36 (26.80)	18.12 (25.17)	19.24 (26.00)	26.00 (30.57)	19.31 (26.04)	17.49 (24.71)	18.40 (25.38)
T_6	NSKE	5.0	21.36 (27.37)	20.48 (26.87)	17.23 (24.50)	18.85 (25.71)	22.33 (28.13)	19.04 (25.86)	18.13 (25.19)	18.58 (25.49)
T_7	Triazophos 40 EC	0.08	24.30 (29.51)	18.36 (25.33)	16.41 (23.87)	17.38 (24.29)	20.33 (26.72)	16.22 (23.66)	14.36 (21.78)	15.29 (22.97)
T_8	Untreated Control	-	25.00 (29.94)	23.27 (28.81)	21.34 (27.50)	22.30 (28.16)	25.00 (29.94)	20.41 (26.84)	19.89 (26.47)	20.15 (26.69)
S.E±			2.00	0.86	0.79	1.12	1.32	1.07	1.21	1.06
CD at 5%			NS	2.63	2.42	3.44	NS	3.30	3.72	3.27

* Figures in parenthesis are Arc sin transformed values DAS – Days after spray NS= Non significant

Table 5: Economics of different newer insecticides in brinjal

Tr. No.	Treatment	Conc. (%)	Yield (q/ha)	Increased yield over control (q/ha)	Quantity of insecticides for 4 sprays (kg/lit/ha)	Cost of insecticide (Rs/L. or kg)	Cost of insecticides for 4 sprays (Rs./ha)	Labour charges for 4 sprays (Rs./ha)	Total cost (Rs./ ha)	Value of additional yield over untreated control (Rs./ha)	Incremental benefit (Rs./ha)	Incremental Cost Benefit Ratio (ICBR)
1	2	3	4	5	6	7	8	9	10	11	12	13
T_1	Emamectin benzoate 5 SG	0.002	136	82	0.80	5000	4000	2000	6000	164000	158000	1:26.33
T_2	Imidacloprid 17.8 SL	0.017	108	54	1.92	1500	2880	2000	4880	108000	103120	1:21.13
T_3	Fipronil 5 SC	0.01	132	78	4.00	950	3800	2000	5800	156000	150200	1:25.90
T_4	Spinosad 45 SC	0.009	139	85	0.40	16000	6400	2000	8400	170000	161600	1:19.24
T_5	Azadiractin 3000 ppm	0.03	97	43	2.00	1000	2000	2000	4000	86000	82200	1:20.50
T_6	NSKE	5.0	91	37	100.00	40	4000	2000	6000	74000	68000	1:11.33
T_7	Triazophos 40 EC	0.08	98	44	4.00	1000	4000	2000	6000	88000	82000	1:13.67
T_8	Untreated Control	-	54	-		-	-	-	-	-	-	-
S.E±		1.56										
C.D at 5%		4.72										

\# Brinjal fruits @ Rs. 20/kg

Economics of the insecticides

The economics of different treatments used against sucking pests and brinjal shoot and fruit borer during *kharif* 2018 represented that spinosad 45 SC registered the highest gross returns (Rs. 170000/ha) and net reurns (Rs.161000/ha) followed by emamectin benzoate 5 SG (Rs.164000/ha and Rs. 158000/ha), fipronil 5 SC (Rs. 156000/ha and Rs. 150200/ha), imidacloprid 17.8 SL (Rs.108000/ha and Rs. 103120/ha), triazophos 40 EC (Rs. 88000/ha and Rs.82000/ha), azadiractin 0.03% (Rs. 86000/ha and Rs. 82000/ha) and NSKE 5% (Rs.74000/ha and Rs. 68000/ha), respectively.

As regards ICBR, emamectin benzoate 5 SG registerd highest cost benefit ratio (ICBR) with 1:26.33 followed by fipronil 5 SC (1:25.90), imidacloprid 17.8 SL (1:21.13), azadiractin

0.03 (1:20.50), Spinosad 45 SC (1:19.24), triazophos 40 EC (1:13.67) and NSKE 5% (1:11.30).

Singh *et al.* (2018) [13] reported that the highest cost: benefit ratio was obtained from NSKE 5% (1:24.40) followed by indoxacarb 14.5 SC (1:24.13) and emamectin benzoate 5 SG (1:24.03) which were also economical than other treatments. Sharma and Tayde (2017) [11] recorded minimum per cent shoot and fruit borer, *Leucinodes orbonalis* and obationed higher B:C ratio in cypermethrin (check) with (1:8.01) followed by spinosad (1:7.63) < emamectin benzoate (1:7.54). Sarnabati and Ray (2017) revealed that the cost benefit ratio was highest in coragen (1: 26.27) followed by imidacloprid (1: 17.78), dichlorvos (1: 16.26) and thiomethoxam (1: 13.60). These findings are supported with the present results.

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