Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(3): 346-352

Received: 26-03-2020
Accepted: 28-04-2020

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Bioefficacy of newer insecticides against tomato fruit borer (*Helicoverpa armigera* Hubner) and leaf miner (*Tuta absoluta* Meyrick)

DR Kachave, MM Sonkamble and SK Patil

Abstract
Field experiment was undertaken to study the bioefficacy of insecticides against lepidopteran pests i.e. tomato fruit borer (*Helicoverpa armigera* Hubner) and leaf miner (*Tuta absoluta* Meyrick) at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431402 (M.S.) during *Kharif* 2018-19. The results indicated that the minimum mean larval population of *H. armigera* was observed in Flubendiamide 20 WG @ 100 g/ha (0.54 larva/plant) and which was at par with Spinosad 45 SC @ 100 L/ha (0.63 larva/plant), Indoxacarb 14.5 SC @ 200 L/ha (0.71 larva/plant), Novaluron 10 EC @ 375 L/ha (0.86 larva/plant), Emamectin benzoate 5 SG @ 200 g/ha (0.92 larva/plant) and Profenophos 50 EC @ 1250 L/ha (0.92 larva/plant). Whereas, the minimum mean larval population of *T. absoluta* was observed in Emamectin benzoate 5 SG @ 200 g/ha (0.33 larva/plant) and which was at par with Spinosad 45 SC @ 100 L/ha (0.44 larva/plant) and Indoxacarb 14.5 SC @ 200 L/ha (0.52 larva/plant).
As regards the fruit damage, significantly maximum per cent reduction of fruit damage by *H. armigera* and *T. absoluta* was observed in Flubendiamide 20 WG @ 100 g/ha (66.31%) and Emamectin benzoate 5 SG @ 200 g/ha (71.39%), respectively. Rest of the insecticides treatment were also significantly superior in reduced fruit damage in the range of 64.25 - 49.69 and 68.20 -51.14 per cent by *H. armigera* and *T. absoluta*, respectively over untreated control.
The highest marketable fruit yield of tomato was recorded in Flubendiamide 20 WG @ 100 g/ha (59.72 q/ha) and it was at par with Spinosad 45 SC @ 100 L/ha (57.14 q/ha). Rest of the insecticides treatment were also significantly harvested higher fruit yield in the range of 55.62 – 45.15 q/ha over untreated control (25.15 q/ha). The highest ICBR was recorded in Lambda cyhalothrin 5 EC @ 300 L/ha (1:12.99), followed by Indoxacarb 14.5 SC @ 200 L/ha (1:12.08), Profenophos 50 EC @ 1250 L/ha (1:10.48), Spinosad 45 SC @ 100 L/ha (1:7.05) and Emamectin benzoate 5 SG @ 200 g/ha (1:6.82).

Keywords: Bioefficacy, insecticides, tomato, *H. armigera, T. absoluta*

Introduction
Vegetables play important role in human nutrition. Tomato, *Lycopersicon esculentum* (Miller) new name *Solanum lycopersicon*, is an important vegetable crop grown around the world occupying the daily food regime of a majority of people (Hussain and Bilal, 2007) [7]. Tomato is premier vegetable crop round the year and one of the prominent eco-industrial crops of Indian generating sizeable employment. Globally, India ranks second in tomato production after China. The area under cultivation of vegetables was 10383 thousand hectare with production of 179692 thousand metric tons during 2017-18. In India, tomato was grown in an area of 786 thousand hectare with production of 19377 metric tons during 2017- 18. Around 11% of the total world produce of tomatoes is cultivated in India. Andhra Pradesh still holds top position in tomato production, even after creation of Telengana. However, the area of tomato in Maharashtra was 50 thousands hectare with production of 1200 thousands metric ton and productivity 24 metric tons per hectare (Anonymous, 2018) [3].
The biotic and abiotic factors influence for low production potential. In biotic factor, the insect pests infestation is one of the major factors are responsible for reduction in productivity. In India, fruit borer *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is one of the most important pests of tomato, limiting production and market value of produce, which is commonly known as gram pod borer, American bollworm and tomato fruit borer. Young larvae feed exclusively on foliage, flower buds and flowers, while the later instars of these insects bore into fruit and render them unmarketable (Meena and Raju 2014) [11]. Considerable economic losses due to *H.armigera* reported by many workers to the extent about 50-80%

(Tewari and Moorthy 1984) [18]. Another important pest is tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the most economically important pest of tomato (Desneux *et al.*, 2010) [4]. The tomato moth, *T.absoluta* or tomato leaf miner or South American tomato leaf miner or tomato pin worm is native to South America and was detected in Europe for the first time in Spain during 2006. *T. absoluta* has been reported from different parts of India throughout the year though the incidence levels vary (Sridhar *et al*., 2014) [16]. After hatching, larvae penetrate the leaf/fruit epidermis and bore galleries in the plant tissues and fruits making fruits unfit for marketing (Roditakis and Seraphides, 2011) [13]. Larvae can form extensive galleries in the stems which damage the development of the plant. Potential yield loss is significant and can reach 100% if the pest is not adequately managed (IRAC, 2009) [8].

Various methods have been tried for the control of insect-pests. But use of chemical method is an important approach for their control because of its quick action, effectiveness and adaptability to various situations. Several insecticides have been recommended and used for the effective management of tomato insect-pests. But according to several reports many of these label claimed insecticides could not achieved effective results. Hence these label claimed insecticides with some new insecticides have been evaluated against *H. armigera* and *T. absoluta* infesting to the tomato crop.

Material and Methods

The field experiment was conducted on "Management of fruit borer, *H. armigera* and leaf miner, *T. absoluta* infesting the tomato (*Lycopersicon esculentum* (Miller)" crop at Research Farm of Department of Agricultural Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Dist. Parbhani, (M.S.), India during *Kharif* 2018-19. The experiment was laid in Randomized Block Design in three replication with nine treatments *viz*., T_1: Spinosad 45% SC @100 L/ha, T_2: Indoxacarb 14.5 SC @ 200 L/ha, T_3: Profenophos 50% EC @ 1250 L/ha, T_4: Cartap hydrochloride 75% SG @ 500 g/ha, T_5: Emamectin benzoate 5% SG @ 200 g/ha, T_6: Lambda cyhalothrin 5% EC @ 300 L/ha, T_7: Flubendiamide 20% WG @100 g/ha, T_8: Novaluron 10% EC @ 375 L/ha and T_9:Untreated control. The row to row and plant to plant distance was maintained at 60 cm x 60 cm in 3.6 x 3.6 m net plot size. The tomato crop cv. Laxmi was transplanted on 06th July, 2018. Application of the treatments was applied at 20 day interval starting from 40 days after transplanting three sprays application were given. 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

The observation on larval population of tomato fruit borer was recorded on five randomly selected and tagged plants. Similarly, the tomato leaf miner larval was recorded on three leaves per plant from the top, middle and bottom in five randomly selected plants The per cent fruit damage was worked out by observing the total number of fruits and number of damaged fruits due to fruit borers at each picking on 5 randomly selected and tagged plants as per following formula.

$$\text{Per cent fruit damage} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruits}} \text{x } 100$$

The matured tomato fruits of good marketing quality were selected for harvesting. Tomato fruits from each plot were picked and weighed separately. Six pickings were carried out at different intervals at the time of maturity of fruits. Total yield from each plot was calculated and computed on hectare basis.

Statistical analysis

The data on larval population and per cent fruit damage by fruit borer and leaf miner was subjected to square root ($\sqrt{x+0.5}$) and arc sine transformation, respectively before statistical analysis. The mean data were statistically analyzed and subjected to the analysis of variance outlined by Panse and Sukhatme (1978) [12].

Results and Discussion

The present investigation pertaining to study the bioefficacy of insecticides against *Helicoverpa armigera* (Hubner) and *Tuta absoluta* (Meyvick) on tomato was carried out during *kharif* 2018-19 and results are presented in Table 1 to 5.

Larval population

i) Fruit borer (*Helicoverpa armigera*)

The data on *Helicoverpa armigera* population on one day before each spray is presented in Table 1. The results indicated that statistically non significant before application of insecticides indicating uniform distribution of *H. armigera* population on tomato.

All the treatments were recorded significantly lower population of *H. armigera* on one, three, seven, and fourteen days after first, second and third spray applications than untreated control. Among the treatment, Flubendiamide 20 WG @ 100 g/ha was found to be superior in reducing the larval population of *H. armigera* by 0.33, 0.38, 0.47 and 0.60 larva/ plant on first spray, 0.37, 0.47, 0.57 and 0.75 larva/ plant on second spray and 0.43, 0.63, 0.70 and 0.83 larva/plant at one, three, seven, and fourteen days after spray applications, respectively. The next best insecticides were Spinosad 45 SC @ 100 ml/ha (0.40, 0.46, 0.53 and 0.78 larva/ plant on first spray, 0.43, 0.57, 0.63 and 0.89 larva/ plant on second spray and 0.50, 0.70, 0.77 and 0.93 larva/plant and Indoxacarb 14.5 SC @ 200 ml/ha (0.47, 0.60, 0.60 and 0.86 larva/ plant on first spray, 0.50, 0.63, 0.63 and 0.97 larva/ plant on second spray and 0.60, 0.77, 0.90 and 0.1.03 larvae/plant) at one, three, seven and fourteen days after each spray applications, respectively and found at par with Flubendiamide 20 WG @ 100 g/ha. Moreover, Emamectin benzoate 5 SG @ 200 g/ha treatment was at par with it on second and third spray application with the larval population of *H.armigera* of 0.77 and 1.03 and 0.96 and 1.10 larvae /plant at seven and fourteen days after spray application, respectively.

The mean of three sprays application, all the insecticides treatment was at par with each other in minimizing the larval population of *H. armigera* except Cartap hydrochloride 75 SG @ 500 g/ha. However, the descending order in larval population per plant was Flubendiamide 20 WG @ 100 g/ha (0.54) > Spinosad 45 SC @ 100 ml/ha (0.63) > Indoxacarb 14.5 SC @ 200 ml/ha (0.71) > Emamectin benzoate 5 SG @ 200 g/ha (0.92) > Novaluron 10 EC @ 375 ml/ha (1.36) > Profenophos 50 EC @ 1250 ml/ha (0.92) > Lambda cyhalothrin 5 EC @ 200 ml/ha (1.40) > Cartap hydrochloride 75 SG @ 500 g/ha (1.59) > untreated control (2.82).

The above findings are accordance with Jat and Ameta (2013)

[9] who reported that the three application of Flubendiamide 480 SC was found most effective against *H armigera* on tomato followed by Spinosad 45 SC. Ambule *et al.* (2015) [2] reported that Flubendiamide 0.004% recorded minimum larval population of *H armigera* on tomato was 0.43 larva/plant followed by Chlorantraniliprole 0.0055% (0.58 larva/plant) and Spinosad 0.0068 % (0.68 larva/plant). Meena and Raju (2014) [11] found Spinosad was most effective insecticide against *H armigera* on tomato as compare to indoxacarb. Also Kumar *et al.* (2017) [10] shows that the Profenophos (1000 g a.i./ha) was found to be the most effective with a maximum reduction in tomato fruit borer, *H armigera* population (65.20%).

Table 1: Efficacy of different insecticides against tomato fruit borer, *Helicoverpa armigera*

Treatments	Dose (L or g/ha)	Number of larvae of *H. armigera* / plant															
		First spray					Second spray					Third spray					Mean of 3 sprays
		Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	
T_1: Spinosad 45% SC	100	1.86 (1.69)	0.40 (1.18)	0.46 (1.21)	0.53 (1.23)	0.78 (1.33)	1.80 (1.67)	0.43 (1.19)	0.57 (1.25)	0.63 (1.27)	0.89 (1.37)	1.86 (1.69)	0.50 (1.22)	0.70 (1.30)	0.77 (1.32)	0.93 (1.39)	0.63 (1.27)
T_2: Indoxacarb 14.5 SC	200	1.72 (1.65)	0.47 (1.21)	0.60 (1.26)	0.60 (1.26)	0.86 (1.36)	1.93 (1.71)	0.50 (1.22)	0.63 (1.27)	0.63 (1.28)	0.97 (1.40)	2.00 (1.73)	0.60 (1.26)	0.77 (1.32)	0.90 (1.37)	1.03 (1.42)	0.71 (1.30)
T_3: Profenophos 50% EC	1250	2.27 (1.80)	0.73 (1.31)	0.73 (1.31)	0.67 (1.29)	1.06 (1.43)	2.20 (1.78)	0.77 (1.32)	0.81 (1.35)	0.86 (1.36)	1.16 (1.47)	2.29 (1.81)	0.83 (1.35)	0.97 (1.40)	1.17 (1.47)	1.23 (1.49)	0.92 (1.38)
T4: Cartap hydrochloride 75% SG	500	2.13 (1.77)	2.20 (1.78)	2.20 (1.78)	2.40 (1.84)	2.47 (1.86)	2.27 (1.80)	1.07 (1.43)	1.13 (1.46)	1.20 (1.48)	1.40 (1.54)	2.33 (1.82)	1.13 (1.46)	1.19 (1.48)	1.30 (1.51)	1.37 (1.53)	1.59 (1.60)
T_5: Emamectin benzoate 5% SG	200	2.05 (1.74)	0.53 (1.23)	0.59 (1.26)	2.00 (1.73)	0.93 (1.39)	2.13 (1.77)	0.63 (1.27)	0.70 (1.30)	0.77 (1.32)	1.03 (1.42)	2.30 (1.81)	0.66 (1.29)	1.13 (1.46)	0.96 (1.40)	1.10 (1.44)	0.92 (1.38)
T_6: Lambda cyhalothrin 5% EC	300	1.98 (1.72)	0.73 (1.31)	0.80 (1.34)	0.85 (1.36)	0.78 (1.33)	2.05 (1.74)	0.80 (1.34)	0.90 (1.37)	1.03 (1.42)	1.23 (1.49)	2.15 (1.77)	0.87 (1.36)	1.10 (1.44)	1.23 (1.49)	1.33 (1.52)	0.97 (1.40)
T_7: Flubendiamide 20% WG	100	1.78 (1.67)	0.33 (1.15)	0.38 (1.18)	0.47 (1.21)	0.60 (1.26)	1.87 (1.69)	0.37 (1.16)	0.47 (1.21)	0.57 (1.25)	0.75 (1.32)	1.83 (1.68)	0.43 (1.19)	0.63 (1.27)	0.70 (1.30)	0.83 (1.36)	0.54 (1.24)
T_8: Novaluron 10% EC	375	1.93 (1.71)	0.66 (1.29)	0.66 (1.29)	0.73 (1.31)	1.06 (1.43)	2.00 (1.73)	0.70 (1.30)	0.77 (1.32)	0.80 (1.34)	1.10 (1.44)	2.07 (1.75)	0.72 (1.31)	0.88 (1.37)	1.09 (1.44)	1.16 (1.47)	0.86 (1.36)
T_9:Untreated control	--	2.33 (1.82)	2.40 (1.84)	2.60 (1.89)	2.73 (1.93)	2.87 (1.96)	2.50 (1.87)	2.67 (1.91)	3.00 (2.00)	3.17 (2.04)	3.29 (2.07)	2.40 (1.84)	2.53 (1.88)	2.77 (1.94)	2.86 (1.96)	2.93 (1.98)	2.82 (1.98)
SE±		0.049	0.022	0.024	0.029	0.037	0.049	0.016	0.027	0.033	0.035	0.051	0.023	0.032	0.031	0.037	0.049
C.D. at 5%		NS	0.065	0.074	0.087	0.113	NS	0.049	0.083	0.100	0.106	NS	0.070	0.096	0.094	0.113	0.147

*Figures in parenthesis are under root square ($\sqrt{x + 0.5}$) transformed values
NS: Non Significant
DAS: Days after Spraying

ii) Leaf miner (*Tuta absoluta*)

The data on *Tuta absoluta* population on one day before eacht spray is presented in Table 2 and results were found statistically non-significant before application of insecticides indicating uniform distribution of T *absoluta* population on tomato.

All the treatments were recorded significantly lower population of *T. absoluta* on one, three, seven, and fourteen days after first, second and third spray applications than untreated control. The plot treated with Emamectin benzoate 5 SG @ 200 g/ha treatment was found to minimize the larval population of *T. absoluta* by 0.04, 0.13, 0.20 and 0.53 larva/ plant on first spray, 0.13, 0.26, 0.33 and 0.53 larva/ plant on second spray and 0.20, 0.33, 0.47 and 0.80 larva/plant at one, three, seven, and fourteen days after spray applications, respectively followed by Spinosad 45 SC @ 100 ml/ha (0.10, 0.23, 0.47 and 0.66 larva/ plant on first spray, 0.20 0.33, 0.60 and 0.67 larva/ plant on second spray and 0.26, 0.40, 0.53 and 0.86 larva/plant at one, three, seven and fourteen days after spray applications, respectively and found at par with Emamectin benzoate 5 SG @ 200 g/ha. Rest of the insecticide treatment s was also effective in reducing the larval population in the range of 0.13 to 1.26 larvae /plant as against untreated control (1.13 to 3.06 larvae /plant) over the three spray applications.

Overall the mean of three sprays application, Emamectin benzoate 5 SG @ 200 g/ha was observed the minimum larval population of *T.absoluta* (0.33 larva/plant) and it was at par with Spinosad 45 SC @ 100 ml/ha (0.44) and Indoxacarb 14.5 SC @ 200 ml/ha (0.52). Other chemical treatments *viz*., Flubendiamide 20 WG @ 100 g/ha, Novaluron 10 EC @ 375 ml/ha, Profenophos 50 EC @ 1250 ml/ha, Lambda cyhalothrin 5 EC @ 200 ml/ha and Cartap hydrochloride 75 SG @ 500 g/ha was also significantly effective in reducing the larval population of *T. absoluta* by 0.63, 0.69, 0.75, 0.84 and 0.91 larva/plant, respectively over untreated control (2.22 larvae/plant).

The present findings are in similar with results of Abdelhamid Gacemi and Yamina Guenaoui (2012) [1] reported that the 87% larvae mortality of tomato leaf miner was recorded from Emamectin benzoate and Spinosad. Saad *et al.* (2013) [14] reported that chemical pesticides such as Indoxacarb 15% EC, Spinosad 24% SC, Emamectin benzoate 50% SG and Imidacloprid 20% SC provide excellent control against tomato leaf miner, *T. absoluta*. Hanafy and Walaa (2013) [5] results revealed that application of Spinosad and Emamectin was most effective in reducing infestation of tomato leaf miner, *T. absoluta* followed by Chlorantraniliprole and Indoxcarb. Sridhar *et al*., (2016) [17] they reported that the most efficacious insecticides against South American tomato moth, *T. absoluta* were Flubendiamide 480 SC @ 0.3 ml/L and Spinosad 45 SC @ 0.3 ml/L on leaf infestation.

Table 2: Efficacy of different insecticides against tomato leaf miner, *Tuta absoluta*

Treatments	Dose (L or g/ha)	Number of larvae of *Tuta absoluta* / plant															
		First spray					Second spray					Third spray					Mean of 3 sprays
		Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	
T_1: Spinosad 45% SC	100	0.70 (1.30)	0.10 (1.04)	0.23 (1.11)	0.47 (1.21)	0.66 (1.26)	1.26 (1.50)	0.20 (1.09)	0.33 (1.15)	0.60 (1.26)	0.67 (1.29)	1.38 (1.54)	0.26 (1.12)	0.40 (1.18)	0.53 (1.23)	0.86 (1.36)	0.44 (1.19)
T_2: Indoxacarb 14.5 SC	200	0.80 (1.34)	0.13 (1.06)	0.33 (1.15)	0.53 (1.23)	0.80 (1.34)	1.33 (1.52)	0.33 (1.15)	0.46 (1.21)	0.60 (1.26)	0.73 (1.31)	1.51 (1.58)	0.33 (1.15)	0.47 (1.21)	0.60 (1.26)	0.93 (1.39)	0.52 (1.23)
T_3: Profenophos 50% EC	1250	0.89 (1.38)	0.47 (1.21)	0.53 (1.23)	0.73 (1.31)	1.07 (1.43)	1.50 (1.58)	0.53 (1.23)	0.73 (1.31)	0.80 (1.34)	0.93 (1.39)	1.67 (1.63)	0.60 (1.26)	0.67 (1.29)	0.86 (1.36)	1.13 (1.46)	0.75 (1.32)
T4: Cartap hydrochloride 75% SG	500	1.00 (1.41)	0.67 (1.29)	0.80 (1.34)	0.87 (1.36)	1.20 (1.48)	1.73 (1.65)	0.66 (1.29)	0.86 (1.36)	0.99 (1.41)	1.06 (1.43)	1.80 (1.67)	0.73 (1.31)	0.80 (1.34)	1.06 (1.43)	1.26 (1.50)	0.91 (1.38)
T_5: Emamectin benzoate 5% SG	200	1.00 (1.41)	0.04 (1.03)	0.13 (1.06)	0.20 (1.09)	0.53 (1.23)	1.19 (1.48)	0.13 (1.06)	0.26 (1.12)	0.33 (1.15)	0.53 (1.23)	1.40 (1.54)	0.20 (1.09)	0.33 (1.15)	0.47 (1.21)	0.80 (1.34)	0.33 (1.15)
T_6: Lambda cyhalothrin 5% EC	300	0.80 (1.34)	0.60 (1.26)	0.73 (1.31)	0.80 (1.34)	1.13 (1.46)	1.47 (1.57)	0.53 (1.23)	0.80 (1.34)	0.93 (1.39)	0.99 (1.41)	1.73 (1.65)	0.66 (1.29)	0.73 (1.31)	1.00 (1.41)	1.20 (1.48)	0.84 (1.35)
T_7: Flubendiamide 20% WG	100	0.87 (1.36)	0.26 (1.12)	0.40 (1.18)	0.67 (1.29)	1.00 (1.41)	1.40 (1.54)	0.40 (1.18)	0.60 (1.26)	0.66 (1.29)	0.79 (1.34)	1.60 (1.61)	0.47 (1.21)	0.53 (1.23)	0.73 (1.31)	1.00 (1.41)	0.63 (1.27)
T_8: Novaluron 10% EC	375	1.00 (1.41)	0.40 (1.18)	0.47 (1.21)	0.67 (1.29)	1.06 (1.43)	1.46 (1.56)	0.46 (1.21)	0.66 (1.29)	0.73 (1.31)	0.86 (1.36)	1.60 (1.61)	0.53 (1.23)	0.59 (1.26)	0.80 (1.34)	1.06 (1.43)	0.69 (1.30)
T_9:Untreated control	--	1.06 (1.43)	1.13 (1.46)	1.33 (1.52)	1.73 (1.65)	1.93 (1.71)	1.90 (1.70)	2.07 (1.75)	2.33 (1.82)	2.73 (1.93)	2.93 (1.98)	2.00 (1.73)	2.27 (1.80)	2.47 (1.86)	2.67 (1.91)	3.06 (2.01)	2.22 (1.78)
SE±		0.033	0.014	0.016	0.011	0.019	0.044	0.019	0.021	0.017	0.024	0.043	0.015	0.020	0.020	0.024	0.030
C.D. at 5%		NS	0.041	0.047	0.033	0.058	NS	0.058	0.064	0.050	0.073	NS	0.047	0.060	0.060	0.072	0.089

*Figures in parenthesis are under root square ($\sqrt{x} + 0.5$) transformed values
NS: Non Significant
DAS: Days after Spraying

Per cent Fruit damage

i) Fruit borer (*Helicoverpa armigera*)

The data on per cent reduction of fruit damage by tomato borer, *H. armigera* before spraying were statistically non significant (Table 3).

The results revealed that the maximum per cent fruit reduction of fruit damage was observed with Flubendiamide 20 WG @ 100 g/ha by 40.00, 70.00, 72.00 and 69.67 per cent at one, three, seven, and fourteen days after first spray applications over untreated control and it was at par with rest of the chemical treatments except Cartap hydrochloride. Similarly, Flubendiamide 20 WG @ 100 g/ha (40.00%) was also found superior treatment in reducing the fruit damage by 44.00, 71.33, 80.00 and 76.33 per cent at one, three, seven, and fourteen days after second spray applications followed by Spinosad 45 SC @ 100 ml/ha (42.33, 69.33, 76.67 and 75.00%) and Indoxacarb 14.5 SC @ 200 ml/ha (41.33, 68.00, 74.67 and 73.67 %), respectively and it was at par with it. During third spray application, Flubendiamide 20 WG @ 100 g/ha (40.00%) was also found superior treatment in reducing the fruit damage by 45.00, 72.67, 78.67 and 76.00 per cent at one, three, seven, and fourteen days after spray applications followed by Spinosad 45 SC @ 100 ml/ha (44.00, 71.00, 75.33 and 74.67%) and Indoxacarb 14.5 SC @ 200 ml/ha (43.00, 69.33, 74.00 and 71.33 %), respectively and it was at par with it. The treatment *viz*., Profenophos 50 EC @ 1250 ml/ha (69.33%) and Emamectin benzoate 5 SG @ 200 g/ha (67.67%) was also at par with the best treatments at fourteen days after third spray applications.

The results of mean per cent reduction of fruit damage of three sprays application revealed that all the insecticides treatment was at par with each other in minimizing the tomato fruit damage by *H.armigera* over untreated control. However, the significantly reduced fruit damage by 66.31 per cent in the plot treated with Flubendiamide 20 WG @ 100 g/ha. The next effective treatment in descending order was Spinosad 45 SC @ 100 ml/ha (64.25%) > Indoxacarb 14.5 SC @ 200 ml/ha (62.44%) > Profenophos 50 EC @ 1250 ml/ha (60.42%) > Emamectin benzoate 5 SG @ 200 g/ha (58.47%) > Novaluron 10 EC @ 375 ml/ha (55.75%) > Lambda cyhalothrin 5 EC @ 200 ml/ha (53.42%) > Cartap hydrochloride 75 SG @ 500 g/ha (49.69%).

The present finding are corroborated with the results of Wajid *et al*. (2016) [19] who reported that the per cent damage of fruit borer by *H.armigera* was observed in Indoxacarb 75 and 60 g a.i./ha doses with 7.0 and 8.0 per cent fruit damage of tomato. Safna *et al.,* (2018) [15] revealed that the treatment Chlorantraniliprole 18.5 SC and Spinosad recorded 17.39 per cent fruit infestation followed by Indoxacarb 14.5 SC (21.64%) and Lambda cyhalothrin 5 EC (23.50%) fruit infestation by *H. armigera* on tomato. Ambule *et al.* (2015) [2] reported that Flubendiamide 0.004% recorded minimum (10.09%) tomato fruit damage on weight basis followed by Chlorantraniliprole 0.0055% (10.62%) and Spinosad 0.0068% (11.34%). Hassan *et al.* (2016) reported that Indoxacarb at 30, 40 and 50 g a.i./ha reduced per cent fruit damage by *H. armigera* with 35.94, 40.57 and 48.72 per cent, respectively in tomato. Kumar *et al.* (2017) [10] reported that Profenophos (1000 g a.i./ha) was found to be the most effective with a minimum per cent of tomato fruit damage by *H. armigera* (28.80%).

Table 3: Percent reduction of tomato fruit borer, *Helicoverpa armigera* infestation

Treatments	Dose (L or g/ha)	Percent reduction of *H. armigera* infestation															
		First spray					Second spray					Third spray					Mean of 3 sprays
		Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	
T_1: Spinosad 45% SC	100	4.80 (12.63)	39.33 (38.79)	67.67 (55.79)	69.00 (56.65)	66.67 (54.79)	2.27 (8.65)	42.33 (40.56)	69.33 (56.92)	76.67 (61.55)	75.00 (60.36)	1.83 (7.77)	44.00 (41.53)	71.00 (57.88)	75.33 (60.62)	74.67 (60.16)	64.25 (53.80)
T_2: Indoxacarb 14.5 SC	200	4.87 (12.73)	37.67 (37.80)	65.33 (54.21)	66.67 (54.98)	64.33 (53.34)	2.87 (9.73)	41.33 (39.97)	68.00 (55.99)	74.67 (60.20)	73.67 (59.45)	1.90 (7.88)	43.00 (40.95)	69.33 (56.76)	74.00 (59.74)	71.33 (57.77)	62.44 (52.60)
T_3: Profenophos 50% EC	1250	4.73 (12.54)	35.67 (36.62)	64.33 (53.59)	65.67 (54.13)	63.67 (53.13)	2.80 (9.59)	35.67 (36.62)	66.33 (54.95)	72.33 (58.62)	71.00 (57.71)	1.93 (7.98)	40.67 (39.59)	68.00 (55.92)	72.33 (58.65)	69.33 (56.69)	60.42 (51.35)
T4: Cartap hydrochloride 75% SG	500	5.17 (13.12)	26.00 (30.28)	52.00 (46.12)	53.33 (46.89)	51.67 (45.93)	3.00 (9.97)	26.00 (30.28)	59.67 (50.55)	57.67 (49.39)	57.33 (49.20)	2.03 (8.19)	32.00 (34.39)	60.33 (50.94)	62.00 (51.95)	58.33 (49.78)	49.69 (44.64)
T_5: Emamectin benzoate 5% SG	200	5.53 (13.59)	33.67 (35.41)	61.67 (52.11)	63.33 (52.63)	61.33 (51.60)	3.07 (10.05)	33.67 (35.41)	65.33 (53.92)	70.33 (57.30)	69.00 (56.37)	1.97 (8.05)	38.00 (38.02)	66.67 (54.72)	71.33 (57.94)	67.33 (55.23)	58.47 (50.06)
T_6: Lambda cyhalothrin 5% EC	300	5.07 (12.99)	27.33 (31.39)	57.33 (49.19)	59.67 (50.55)	57.33 (49.19)	3.67 (11.03)	27.33 (31.39)	60.33 (50.94)	66.00 (54.46)	59.00 (50.26)	2.17 (8.45)	34.67 (36.02)	62.33 (52.12)	67.00 (55.05)	62.67 (52.40)	53.42 (46.91)
T_7: Flubendiamide 20% WG	100	5.03 (12.95)	40.00 (39.19)	70.00 (57.31)	72.00 (58.15)	69.67 (56.74)	2.03 (8.19)	44.00 (41.52)	71.33 (58.18)	80.00 (63.90)	76.33 (61.17)	1.80 (7.69)	45.00 (42.10)	72.67 (59.07)	78.67 (62.48)	76.00 (60.78)	66.31 (55.05)
T_8: Novaluron 10% EC	375	5.50 (13.55)	32.00 (34.39)	58.67 (49.97)	60.00 (50.74)	58.00 (49.58)	2.70 (9.44)	32.00 (34.39)	62.00 (51.92)	68.00 (55.76)	63.00 (52.68)	2.13 (8.39)	36.67 (37.22)	64.00 (53.11)	69.33 (56.56)	65.33 (54.04)	55.75 (48.34)
T_9:Untreated control	--	5.97 (14.13)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SE±		0.286	1.430	4.020	2.628	2.499	0.311	1.427	3.045	1.888	1.861	0.197	0.580	2.748	2.231	1.907	0.276
C.D. at 5%		NS	4.325	12.15	7.946	7.558	NS	4.316	9.209	5.710	5.626	NS	1.755	8.308	6.747	5.766	0.827

*Figures in parenthesis are arc sine transformed values
NS: Non Significant
DAS: Days After Spraying

ii) Tomato leaf miner, *Tuta absoluta*

The data on per cent reduction of fruit borer before each spraying (Table 4) revealed that the results were statistically non-significant.

The results indicated that all the insecticide treatment was significantly superior over control in the three sprays application. Spinosad showed highest efficacy of 50 per cent reduction in fruit damage by *T.absoluta* was recorded by 50.00, 83.67, 80.67 and 75.33 per cent at first spray, 52.33, 80.33, 75.67 and 73.67 per cent on second spray and 54.00, 76.33, 74.33 and 80.33 per cent on third spray after one, three, seven and fourteen days spray application, respectively. and it was par with Flubendiamide 20 WG @ 100 g/ha (49.00, 76.33, 74.33 and 70.67 % at first spray, 51.67, 78.33, 72.67 and 71.33% on second spray and 51.67, 74.67, 71.67 and 76.00% on third spray) after one, three, seven and fourteen days spray application, respectively. The treatments *viz*., Indoxacarb 14.5 SC @ 200 ml/ha (74.00%), Emamectin benzoate 5 SG @ 200 g/ha (72.33%) and Novaluron 10 EC @ 375 ml/ha (70.33%) was also at par with the best treatments at fourteen days after third spray applications.

The results of mean per cent reduction of fruit damage of three sprays, revealed that all the insecticides treatment was at par with each other in minimizing the tomato fruit damage by *T.absoluta* over untreated control. However, the significantly reduced fruit damage by 71.39 per cent in the plot treated with Spinosad 45 SC @ 100 ml/ha. The next effective treatment in descending order was Flubendiamide 20 WG @ 100 g/ha (68.20%) > Indoxacarb 14.5 SC @ 200 ml/ha (62.50%) > Emamectin benzoate 5 SG @ 200 g/ha (60.14%) > Novaluron 10 EC @ 375 ml/ha (58.08%) > Profenophos 50 EC @ 1250 ml/ha (56.00%) > Lambda cyhalothrin 5 EC @ 200 ml/ha (53.95%) > Cartap hydrochloride 75 SG @ 500 g/ha (51.14%).

The present results are supported with the finding of Sridhar *et.al*. (2016) [17] they reported that the most efficacious insecticides against South American tomato moth, *T. absoluta* was Flubendiamide 480 SC @ 0.3 ml/L and Spinosad 45 SC @ 0.3 ml/L on fruits infestation.

Table 4: Percent reduction of tomato leaf miner, *Tuta absoluta* infestation

Treatments	Dose (L or g/ha)	Percent reduction of *Tuta absoluta* infestation															
		First spray					Second spray					Third spray					Mean of 3 sprays
		Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	Pre count	1 DAS	3 DAS	7 DAS	14 DAS	
T_1: Spinosad 45% SC	100	6.07 (14.23)	50.00 (44.98)	83.67 (66.15)	80.67 (64.32)	75.33 (60.86)	5.70 (13.77)	52.33 (46.33)	80.33 (63.65)	75.67 (60.42)	73.67 (59.64)	4.93 (12.82)	54.00 (49.19)	76.33 (60.87)	74.33 (60.05)	80.33 (64.13)	71.39 (58.38)
T_2: Indoxacarb 14.5 SC	200	5.40 (13.42)	47.67 (43.64)	65.33 (54.21)	61.67 (51.93)	60.00 (50.94)	5.30 (13.29)	49.33 (44.60)	73.33 (60.51)	65.00 (53.70)	62.00 (52.10)	4.10 (11.67)	48.33 (44.02)	73.33 (60.51)	70.00 (56.81)	74.00 (59.35)	62.50 (52.69)
T_3: Profenophos 50% EC	1250	5.20 (13.17)	40.33 (39.40)	59.00 (50.17)	57.00 (49.03)	55.67 (48.30)	3.93 (11.40)	44.67 (41.91)	60.00 (50.75)	58.00 (49.61)	55.00 (47.89)	3.47 (10.71)	45.00 (42.05)	66.33 (54.51)	64.00 (53.14)	67.00 (54.92)	56.00 (48.47)
T4: Cartap hydrochloride 75% SG	500	5.00 (12.90)	34.00 (35.82)	55.00 (47.86)	52.67 (46.51)	49.33 (44.59)	5.00 (12.90)	38.67 (38.36)	56.33 (48.62)	52.33 (46.32)	49.33 (44.59)	3.00 (9.97)	40.00 (39.21)	63.00 (52.59)	59.00 (50.16)	64.00 (53.10)	51.14 (45.64)
T_5: Emamectin benzoate 5% SG	200	5.67 (13.76)	45.00 (42.10)	62.67 (52.85)	60.67 (51.21)	58.67 (50.22)	5.10 (13.04)	47.00 (43.26)	66.67 (54.81)	63.67 (53.05)	61.67 (51.76)	4.07 (11.62)	46.67 (43.07)	70.00 (57.07)	66.67 (55.16)	72.33 (58.33)	60.14 (51.07)

T_6: Lambda cyhalothrin 5% EC	300	5.27 (13.25)	38.00 (38.02)	57.67 (49.39)	55.67 (48.24)	52.67 (46.51)	4.20 (11.82)	41.00 (39.78)	58.33 (49.77)	56.33 (48.62)	52.67 (46.51)	3.20 (10.30)	42.67 (40.76)	64.67 (53.53)	61.33 (51.53)	66.33 (54.51)	53.95 (47.26)
T_7: Flubendiamide 20% WG	100	5.60 (13.68)	49.00 (44.39)	76.33 (61.23)	74.33 (59.82)	70.67 (57.34)	5.43 (13.46)	51.67 (45.93)	78.33 (62.47)	72.67 (58.56)	71.33 (57.87)	4.47 (12.19)	51.67 (45.93)	74.67 (59.79)	71.67 (57.87)	76.00 (61.80)	68.20 (56.08)
T_8: Novaluron 10% EC	375	5.50 (13.55)	43.33 (41.09)	60.33 (50.94)	58.67 (49.97)	56.00 (48.43)	4.90 (12.77)	46.67 (43.05)	63.00 (52.51)	60.33 (50.94)	59.00 (50.17)	3.63 (10.98)	46.00 (42.68)	67.33 (55.14)	66.00 (54.35)	70.33 (57.09)	58.08 (49.70)
T_9:Untreated control	--	5.97 (14.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SE±		0.273	1.914	2.700	2.862	2.854	0.405	1.902	3.104	1.810	2.549	0.171	1.497	3.152	2.996	2.971	0.675
C.D. at 5%		NS	5.787	8.163	8.653	8.629	NS	5.750	9.387	5.475	7.707	NS	4.526	9.530	9.061	8.982	2.024

*Figures in parenthesis are arc sine transformed values
NS: Non Significant
DAS: Days After Spraying

Yield

The results from Table 5 revealed that all the insecticidal treatment were significantly superior over untreated control in increasing yield. The highest marketable fruit yield of tomato was recorded in plots treated with Flubendiamide 20 WG @ 100 g/ha (59.72 q/ha) and which was at par with Spinosad 45 SC @ 100 ml/ha (57.14 q/ha). Rest of the treatments *viz*., Indoxacarb 14.5 SC @ 200 ml/ha (55.62 q/ha), Profenophos 50 EC @1250 ml/ha (52.48 q/ha), Emamectin benzoate 5 SG @ 200 g /ha (50.45 q/ha), Novaluron 10 EC @ 375 ml/ha (46.85 q/ha), Lambda cyhalothrin 5 EC @ 300 ml/ha (45.15 q/ha), Cartap hydrochloride 75 SG @ 500 g/ha (40.36 q/ha) also significantly obtained higher fruit yield as against untreated plot (28.15 qt/ha). As regards ICBR, the highest ICBR was recorded in Lambda cyhalothrin 5 EC @ 300 L/ha (1:12.99) followed by Indoxacarb 14.5 SC @ 200 ml/ha (1: 12.08), Profenophos 50 EC @1250 ml/ha (1: 10.48), Spinosad 45 SC @ 100 ml/ha (1: 7.05), Emamectin benzoate 5 SG @ 200 g /ha (1: 6.82), Novaluron 10 EC @ 375 ml/ha (1:5.02) Cartap hydrochloride 75 SG @ 500 g/ha (1: 4.52). Whereas, the less ICBR was found in Flubendiamide 20 WG @ 100 g/ha (1:1.84), it may be due to cost of theproduct.

The above findings are supported with the results reported by Ambule *et al.* (2015) [2] reported that higher marketable tomato fruit yield was recorded from treatment of Flubendiamide and spinosad. Wajid *et al*. (2016) [19] revealed that Indoxacarb treated treatment at 60 and 70 g a.i./ha dosages yielded the highest yield of marketable fruits of tomato was 29.16 and 29.50 tons/ha, respectively. Kumar *et al.* (2017) [10] reported that Profenophos (1000 g a.i./ha) was found to be the most effective with a maximum tomato fruit yield (26.43 kg/ha).

Table 5: Yield and economics of various insecticides treatments in tomato

Treatments	Dose (L or g/ha)	Mean Yield (qt/ha)	Increased yield over control (qt/ha)	Cost of insecticides (Rs/L or kg)	Total quantity of Insecticides required for 3 spray (L or g/ha)	Total cost of Insecticide (Rs/ha)	Labour charges (Rs/ha)	Total cost of plant protection (Rs/ha)	Gross realization over control (Rs/ha)	Net realization (Rs/ha)	ICBR
T_1: Spinosad 45% SC	100	57.14	28.99	18000	0.30	5400	1800	7200	57980	50780	1:7.05
T_2: Indoxacarb 14.5 SC	200	55.62	27.47	4000	0.60	2400	1800	4200	54940	50740	1:12.08
T_3: Profenophos 50% EC	1250	52.48	24.33	650	3.75	2437	1800	4237	48660	44423	1:10.48
T4: Cartap hydrochloride 75% SG	500	40.36	12.21	1750	1.50	2625	1800	4425	24420	19995	1:4.52
T_5:Emamectin benzoate 5% SG	200	50.45	22.3	6500	0.60	3900	1800	5700	44600	38900	1:6.82
T_6: Lambda cyhalothrin 5% EC	300	45.15	17	700	0.90	630	1800	2430	34000	31570	1:12.99
T_7: Flubendiamide 20% WG	100	59.72	31.57	17000	1.20	20400	1800	22200	63140	40940	1:1.84
T_8: Novaluron 10% EC	375	46.85	18.7	3924	1.125	4414	1800	6214	37400	31186	1:5.02
T_9:Untreated control	-	28.15	-	-	-	-	-	-	-	-	-
SE ±		0.95									
CD 5 %		2.88									

*Market value of fruit Rs. 2000=00/q.

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