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Evaluation of the efficacy of some insecticides against fruit borer, *Helicoverpa armigera* (Hubner) infesting tomato

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Abstract
The present investigation entitled "Efficacy of some insecticides against fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) infesting tomato" was carried out during *rabi* season of 2015-16 at Central Experimental Station, Wakawali, Dist.-Ratnagiri. The study revealed that the overall efficacy of pesticides from all the three sprays revealed that the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent was the best treatment which recorded minimum (13.82%) mean fruit infestation and was significantly superior over all other treatments. It was followed by spinosad which recorded 17.39 per cent fruit infestation. The next treatments in descending order of effectiveness were indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC 0.0025 per cent, *B. thuringiensis* 1.5 g^{-1}, azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent which recorded 21.64, 23.50, 27.26, 30.51 and 32.70 per cent fruit infestation, respectively. All the above treatments were found to be superior over untreated control which recorded highest fruit infestation (38.65%).

Keywords: *Helicoverpa armigera*, tomato, management, fruit borer

Introduction

Tomato (*Solanum lycopersicon* L.) is one of the major and remunerative vegetable crops which have achieved tremendous popularity over the last century. It is grown worldwide either in the field, green houses or net houses. It is one of the most important protective crops. It is grown either for fresh fruits or for processing. Tomatoes provide an excellent amount of vitamin C, a very good amount of the mineral manganese and vitamin E. In terms of phytonutrients, it includes flavanones, flavonols and carotenoids like lycopene, zeaxanthin and beta-carotene. Reduced risk of heart disease is an area of health benefits in which tomatoes truly excel. There are two basic lines of research that have repeatedly linked tomatoes to heart health. The first line of research involves antioxidant support and the second line involves regulation of fats in the blood stream (Mateljan, 2006) [9].

India ranks second in tomato production after China. The total area of various vegetables in India is 92.05 million hectares with production of 162.18 million tonnes, of which tomato is cultivated in an area of 882,000 hectares with total production of 18735.9 MT and average productivity of 21.2 tonnes per hectare in 2013-14. It contributes 9.4 per cent of total vegetable area and 11.5 per cent of total vegetable production. The major tomato producing states are Andhra Pradesh (17.90%), Karnataka (11.04%), Madhya Pradesh (10.34%), Maharashtra (6.40%), Bihar (5.67%), Uttar Pradesh, Orissa and Assam. In Maharashtra, tomato is grown over an area of 50,000 hectares with a production of 1200 metric tons and productivity is 24 tons per ha during 2013-14 (Anon., 2014) [3].

More than 100 insect pests and 25 non-insect pests are reported to ravage the tomato fields (Lange and Bronson, 1981) [8] and among them, fruit borers are of much significance and causes extensive damage to fruits. Among fruit borers, *Helicoverpa armigera* (Hubner) is responsible for considerable losses in quantity as well as quality of tomato fruits (Reddy and Zehr, 2004) [13]. *H. armigera* is a cosmopolitan, polyphagous pest. Fruit borer infesting tomato has been found to cause a yield loss of up to 35 per cent in tomato and up to 37.79 per cent loss in Karnataka (Dhandapani *et al*., 2003) [7].

Though the farmers rely solely on the chemical insecticides for the management of *H. armigera*, development of resistance is widely reported besides the residual toxicity in the fruits, which are to be consumed afresh.

In addition, resurgence of non-target pests is also encountered with many insecticides. New insecticides and bio-pesticides have been reported to reduce *H. armigera* population and fruit damage in tomato (Singh and Yadav, 2007) [16]. The current need is to find out novel insecticides which are selective, less persistant and eco- friendly for management of fruit borer, *H. armigera*.

Materials and Methods

A field experiment was conducted during *rabi* season of 2015-16 to study the effectiveness of some insecticides against fruit borer, *H. armigera* (cv. Arka Alok).

Cultural Operations

The land was prepared as per the requirements of tomato crop and cleared by removing the residues of the previous crop. The experiment was laid out in Randomized Block Design (RBD). The half dose of urea fertilizer and full dose of phosphorous and potash was applied at time of sowing and remaining half dose of urea was applied at 30 days after sowing. The experimental area was sown with good seed of tomato (cv. Arka Alok) in each plot.

The transplanting of seedlings was done twenty five days after sowing. The other agronomic operations *viz.*, intercultural operations and weeding were done as per recommendation.

Experimental Details

The details of experiment are given in Table 4, while the treatment details are given below.

Experimental details

Location : Central Experiment Station, Wakawali, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri
Period of study : October 2015 to April 2016
Variety : Arka Alok
Spacing : 60 cm × 60 cm
Total plot size : 95.04 m^2
Date of sowing : 14th October, 2015
Method of planting : On ridges and furrows
Design : Randomized Block Design (RBD)
Number of replication : Three
Number of treatment : Eight

Spraying

The quantity of spray suspension required for each treatment was calibrated by spraying water over three plots in the experiment prior to the application of insecticide. Spray suspension of desired strength of each insecticide was prepared against *H. armigera* in the field.

The insecticides were sprayed thrice. First spray of each insecticide was applied when incidence was noticed on fruits, while remaining two sprays were given at an interval of 15 days with manually operated knapsack sprayer. The observations were recorded in each treatment on all the plants.

Treatment details

Tr. No.	Treatment	Concentration (%)/ Dose
T_1	Spinosad 45 SC	0.014
T_2	Azadirachtin 1%	0.003
T_3	*Bacillus thuringiensis* var. *kurstaki* Berliner	1.5 g^{-1}
T_4	Chlorantraniliprole 18.5 SC	0.005
T_5	Lambda cyhalothrin 5 EC	0.0025
T_6	Quinalphos 25 EC	0.025
T_7	Indoxacarb 14.5 SC	0.012
T_8	Untreated control	-

3.3.4 Method of recording observations

To study the efficacy of different insecticides against fruit borer, infested fruits were counted in each treatment at 3, 7, 10 and 14 days after application of insecticides. The pre count observations were recorded one day before application of insecticides. The observations at 14 days after first spray were considered as pre count observation of second spray. The per cent fruit infestation was computed on the basis of number of infested fruits, out of total number of fruits per plot. The data thus obtained were converted into arcsine transformation and then statistically analysed.

Results and Discussion

Data pertaining to the efficacy of some insecticides against fruit borer, *H. armigera* infesting tomato are given in Table 1.

Table 1: Efficacy of insecticides against fruit borer *H. armigera* infesting tomato after first spray

S. No	Treatment	Conc.(%)/ Dose	Per cent fruit infested					Cumulative per cent infestation
			Pre-count	3 DAS**	7 DAS	10 DAS	14 DAS	
1	Spinosad 45 SC	0.014	27.34(31.52)*	22.57(28.36)	19.80(26.42)	20.73(27.08)	19.89(26.46)	20.75 (27.08)
2	Azadirachtin 1 EC	0.003	29.65(32.56)	28.98(32.57)	27.52(31.64)	32.19(34.57)	32.06(34.48)	30.19(33.32)
3	*Bacillus thuringiensis* var. *kurstaki* Berliner	1.5 g^{-1}	27.53(31.61)	26.89(31.23)	25.52(30.34)	24.91(29.94)	31.23(33.97)	27.14(31.37)
4	Chlorantraniliprole 18.5 SC	0.005	28.63(32.27)	20.83(27.16)	18.17(25.23)	15.58(23.25)	14.50(22.31)	17.27(24.49)
5	Lambda cyhalothrin 5 EC	0.0025	31.40(34.07)	26.13(30.74)	23.83(29.22)	25.25(30.16)	27.93(31.90)	25.79(30.51)
6	Quinalphos 25 EC	0.025	27.69(31.47)	30.33(33.42)	30.05(33.24)	33.35(35.27)	35.27(36.43)	32.25(34.59)
7	Indoxacarb 14.5 SC	0.012	30.13(33.25)	23.15(28.76)	21.24(27.44)	21.60(27.69)	25.77(30.50)	22.94(28.60)
8	Untreated Control	-	29.78(33.08)	32.55(34.79)	35.17(36.37)	35.82(36.76)	38.34(38.26)	35.47(36.55)
S.Em.±			2.66	0.17	0.22	0.27	0.75	0.35
CD (p=0.05)			8.06	0.53	0.67	0.82	2.27	1.07

*Figures in parentheses are arcsine values
**DAS: Days After Spraying

Efficacy of some insecticides against fruit borer, *H. armigera* infesting tomato recorded at different intervals after first spray

From the data it could be found that no infestation was observed on the experimental plot during vegetative phase of the crop and hence the data on infestation during vegetative phase could not be presented.

The infestation of the fruit borer prior to application of insecticides ranged from 27.34 to 31.40 per cent. The differences among the treatments and replications were non-significant indicating uniform distribution of pest in both treatments and replications.

The observations recorded on third day after first spray indicated that the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent was found to be most effective treatment which

recorded 20.83 per cent fruit infestation and found significantly superior over rest of the treatments. Spinosad 45 SC @ 0.014 per cent (22.57 %) and indoxacarb 14.5 SC @ 0.012 per cent (23.15 %) were also at par with each other. Lambda cyhalothrin 5 EC @ 0.0025 per cent was at par with *Bacillus thuringiensis* var. *kurstaki* Berliner 1.5 g^{-1} which recorded 26.13 and 26.89 per cent fruit infestation, respectively.

The remaining treatments *viz.*, azadirachtin 1 EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 28.98 and 30.33 per cent fruit infestation, respectively. The maximum (32.55%) per cent of fruit infestation was noticed in untreated control.

On the seventh day after first spray the minimum (18.17%) per cent fruit infestation recorded in the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent which was significantly superior over rest of the treatments. The remaining treatments *viz.*, spinosad 45 SC @ 0.014 per cent, indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC @ 0.0025 per cent, *B. thuringiensis* 1.5 g^{-1}, azadirachtin 1EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 19.80, 21.24, 23.83, 25.52, 27.52 and 30.05 per cent of fruit infestation, respectively. The maximum (35.17%) per cent fruit infestation was noticed in untreated control.

The observations recorded on 10th day after first spray revealed that the per cent fruit infestation in the treatment with chlorantraniliprole 18.5 SC @ 0.005 per cent was minimum (15.58%) and found significantly superior over rest of the treatments, followed by spinosad 45 SC @ 0.014 per cent which recorded 20.73 per cent fruit infestation, which was at par with *B. thuringiensis* 1.5 g^{-1} (24.91%). *B. thuringiensis* 1.5 g^{-1} (24.91%) was also at par with and lambda cyhalothrin 5 EC @ 0.0025 per cent (25.25%). Similarly azadirachtin 1EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 recorded 32.19 and 33.35 per cent fruit infestation, respectively and were also at par with each other. The treatment with indoxacarb 14.5 SC @ 0.012 per cent was recorded 21.60 per cent infestation. The maximum (35.82%) fruit infestation was recorded in untreated plot.

At 14th day of observation, the minimum (14.50%) fruit infestation was recorded in chlorantraniliprole 18.5 SC @ 0.005 per cent which was at par with spinosad 45 SC @ 0.014 per cent which recorded 19.89 per cent fruit infestation. Indoxacarb 14.5 SC @ 0.012 per cent with 25.77 per cent fruit infestation and lambda cyhalothrin 5 EC @ 0.0025 per cent with 27.93 per cent fruit infestation and were at par with each other. Lambda cyhalothrin 5 EC @ 0.0025 per cent with 27.93 per cent fruit infestation was at par with *B. thuringiensis* 1.5 g^{-1} (31.23%). *B. thuringiensis* 1.5 g^{-1} (31.23%) was at par with azadirachtin 1EC @ 0.003 per cent (32.06%). Azadirachtin 1EC @ 0.003 per cent (32.06%) was at par with quinalphos 25 EC 0.025 per cent (35.27 %). Quinalphos 25 EC 0.025 per cent recorded higher (38.34%) per cent fruit infestation and was at par with untreated plot (35.27%).

Results of overall per cent mean infestation revealed that the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent was found to be significantly superior over rest of the treatments which recorded 17.27 per cent mean fruit infestation. The treatments *B. thuringiensis* 1.5 g^{-1} (27.14%) and quinalphos 25 EC @ 0.025 per cent (32.25%) were at par with each other. Lambda cyhalothrin 5 EC @ 0.0025 per cent, spinosad 45 SC @ 0.014 per cent, indoxacarb 14.5 SC @ 0.012 per cent and azadirachtin 1 EC @ 0.003 per cent recorded 25.79, 20.75, 22.94, 30.19 per cent fruit infestation, respectively. The maximum (35.47%) mean per cent fruit infestation was recorded in untreated control.

Efficacy of some insecticides against fruit borer, *H. armigera* infesting tomato recorded at different intervals after second spray

The results on effect of second spray are presented in Table 2. The observations recorded on third day after second spray indicated that the treatment with chlorantraniliprole 18.5 SC @ 0.005 per cent was found to be most effective treatment which recorded 14.32 per cent fruit infestation and was at par with spinosad 45 SC @ 0.014 per cent (16.37%). The treatment indoxacarb 14.5 SC @ 0.012 per cent recorded 21.37 per cent fruit infestation and lambda cyhalothrin 5 EC @ 0.0025 per cent recorded 22.32 per cent fruit infestation and both these treatments were at par with each other. The treatments *B. thuringiensis* 1.5 g^{-1} (26.81%) and quinalphos 25 EC @ 0.025 per cent (32.39%) were also at par with each other. The treatment azadirachtin 1 EC @ 0.003 per cent recorded 35.03 per cent fruit infestation. The maximum (38.40%) per cent of fruit infestation was noticed in untreated control.

Table 2: Efficacy of insecticides against fruit borer *H. armigera* infesting tomato after second spray

S. No	Treatment	Conc.(%) /Dose	Per cent fruit infested					Cumulative per cent infestation
			Pre-count	3 DAS**	7 DAS	10 DAS	14 DAS	
1	Spinosad 45 SC	0.014	19.89(26.46)*	16.37(23.84)	15.74(23.37)	14.61(22.47)	16.62(24.05)	15.84(23.43)
2	Azadirachtin 1EC	0.003	32.06(34.48)	35.03(36.29)	26.77(31.16)	31.78(34.31)	29.46(32.87)	30.76(33.66)
3	*Bacillus thuringiensis* var. *kurstaki* Berliner	1.5 g^{-1}	31.23(33.97)	26.81(31.18)	24.85(29.90)	29.97(33.19)	26.35(30.89)	26.99(31.29)
4	Chlorantraniliprole 18.5 SC	0.005	14.50(22.31)	14.32(22.22)	12.88(21.03)	11.68(19.98)	13.40(21.45)	13.07(21.17)
5	Lambda cyhalothrin 5 EC	0.0025	27.93(31.90)	22.32(28.18)	20.75(27.10)	19.91(26.50)	24.58(29.72)	21.89(27.88)
6	Quinalphos 25 EC	0.025	35.27(36.43)	32.39(34.68)	28.35(32.17)	37.17(37.56)	38.88(38.57)	34.20(35.75)
7	Indoxacarb 14.5 SC	0.012	25.77(30.50)	21.37(27.53)	19.37(26.11)	18.26(25.30)	22.26(28.14)	20.32(26.77)
8	Untreated Control	-	38.34(38.26)	38.40(38.29)	40.89(39.75)	41.08(39.86)	40.99(39.81)	40.34(39.43)
S.Em.±			0.75	0.60	0.31	0.41	0.50	0.46
CD (p=0.05)			2.27	1.82	0.95	1.26	1.53	1.39

*Figures in parentheses are arcsine values

**DAS: Days After Spraying

On 7th day after second spray, the minimum fruit infestation was recorded in the treatment chlorantraniliprole 18.5 SC@ 0.005 per cent (12.88) and which was significantly superior over rest of the treatments. The treatments *viz.*, spinosad 45 SC @ 0.014 per cent, indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC @ 0.0025 per cent, *B. thuringiensis* 1.5 g^{-1}, azadirachtin 1 EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent were recorded 15.74, 19.37, 20.75,

24.85, 26.77 and 28.35 per cent fruit infestation, respectively while, maximum (40.89%) per cent fruit infestation was observed in untreated control.

The observations recorded on 10th day after second spray revealed that the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent recorded 11.68 per cent fruit infestation and was significantly superior over rest of the treatments followed by spinosad 45 SC @ 0.014 per cent (14.61%). The treatments indoxacarb 14.5 SC @ 0.012 per cent (18.26%) and lambda cyhalothrin 5 EC @ 0.0025 per cent (19.91%) were at par with each other. The treatments *B. thuringiensis* 1.5 g^{-1} (29.97%) and azadirachtin 1EC @ 0.003 per cent (31.78%) were also at par with each other. The remaining treatments showed different levels of per cent fruit infestation were quinalphos 25 EC @ 0.025 per cent (31.17%) and untreated control (41.08%).

At 14th day of observation, the minimum (13.40%) fruit infestation was recorded in chlorantraniliprole 18.5 SC @ 0.005 per cent which was significantly superior over rest of the treatments followed by spinosad 45 SC @ 0.014 per cent (16.62%) and indoxacarb 14.5 SC @ 0.012 per cent (22.26%). The next best treatments were lambda cyhalothrin 5 EC @ 0.0025 per cent (24.58%) and *B. thuringiensis* 1.5 g-^{1} (26.35%) which were at par with each other. The treatment azadirachtin 1 EC @ 0.003 per cent recorded 29.46 per cent fruit infestation. Quinalphos 25 EC @ 0.025 per cent recorded higher (38.88%) per cent fruit infestation and was at par with untreated control (40.99%).

The data on mean fruit infestation indicated that among the treatments, chlorantraniliprole 18.5 SC @ 0.005 per cent recorded minimum (13.07%) fruit infestation which was significantly superior over rest of the treatments followed by spinosad 45 SC @ 0.014 per cent (15.84%). The treatments indoxacarb 14.5 SC @ 0.012 per cent (20.32%) and lambda cyhalothrin 5 EC 0.0025 per cent (21.89%) were at par with each other. The treatments *B. thuringiensis* 1.5 g^{-1}, azadirachtin 1EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 26.99, 30.76 and 34.20 per cent fruit infestation, respectively. The highest mean per cent fruit infestation was recorded in untreated control (40.34%).

Efficacy of some insecticides against fruit borer, *H. armigera* infesting tomato recorded at different intervals after third spray

The results on effect of third spray are presented in Table 3. After 3 days of third spray, the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent was found superior which recorded 11.23 per cent fruit infestation followed by spinosad 45 SC @ 0.014 per cent, indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC @ 0.0025 per cent, *B. thuringiensis* 1.5 g-^{1}, azadirachtin 1 EC @ 0.003 per cent and quinalphos 25 EC 0.025 per cent which recorded 16.78, 20.50, 22.49, 28.26, 30.45 and 32.78 per cent fruit infestation, respectively. The highest per cent of fruit infestation was noticed in untreated control (41.20%).

Table 3: Efficacy of insecticides against fruit borer *H. armigera* infesting tomato after third spray'

S. No	Treatment	Conc.(%)/ Dose	Per cent fruit infested					Cumulative per cent infestation
			Pre-count	3 DAS**	7 DAS	10 DAS	14 DAS	
1	Spinosad 45 SC	0.014	16.62(24.05)*	16.78(24.16)	15.50(23.17)	14.15(22.09)	15.88(23.49)	15.58(23.23)
2	Azadirachtin 1EC	0.003	29.46(32.87)	30.45(33.49)	29.66(33.00)	32.73(34.89)	29.51(32.90)	30.59(33.57)
3	*Bacillus thuringiensis* var. *kurstaki* Berliner	1.5 g^{-1}	26.35(30.89)	28.26(32.11)	27.07(31.35)	28.61(32.34)	26.68(31.10)	27.66(31.73)
4	Chlorantraniliprole 18.5 SC	0.005	13.40(21.45)	11.23(19.57)	10.93(19.27)	10.22(18.63)	12.12(20.36)	11.13(19.46)
5	Lambda cyhalothrin 5 EC	0.0025	24.58(29.72)	22.49(28.30)	20.84(27.16)	23.11(28.73)	24.90(29.93)	22.84(28.53)
6	Quinalphos 25 EC	0.025	38.88(38.57)	32.78(34.92)	30.42(33.47)	33.05(35.09)	30.34(33.42)	31.65(34.23)
7	Indoxacarb 14.5 SC	0.012	22.26(28.14)	20.50(26.92)	19.90(26.49)	22.12(28.05)	24.11(29.41)	21.66(27.72)
8	Untreated Control	-	40.99(39.81)	41.20(39.93)	42.40(40.63)	42.23(40.53)	34.75(36.12)	40.14(39.30)
S.Em.±			0.50	0.44	0.47	0.38	0.28	0.39
CD (p=0.05)			1.52	1.34	1.43	1.17	0.84	1.20

*Figure in parentheses are arcsine values

**DAS: Days After Spraying

The data on 7th day of third spray indicated that chlorantraniliprole 18.5 SC @ 0.005 per cent recorded 10.93 per cent fruit infestation and was significantly superior over rest of the treatments which was followed by spinosad 45 SC @ 0.014 per cent (15.50%). Indoxacarb 14.5 SC @ 0.012 per cent and lambda cyhalothrin 5 EC @ 0.0025 per cent recorded with 19.90 and 20.84 per cent fruit infestation, respectively and both the treatments were at par with each other. The treatments azadirachtin 1 EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 29.66 and 30.42 per cent fruit infestation, respectively and were also at par with each other while, the treatment *B. thuringiensis* 1.5 g-^{1} recorded 27.07 per cent fruit infestation. Maximum (42.40%) fruit infestation was noticed in untreated control.

The observations recorded on 10th day after third spray revealed that chlorantraniliprole 18.5 SC @ 0.005 per cent showed better result amongst the treatments with 10.22 per cent of fruit infestation and was significantly superior over rest of the treatments followed by spinosad 45 SC @ 0.014 per cent (14.15%). Indoxacarb 14.5 SC @ 0.012 per cent and lambda cyhalothrin @ 5 EC 0.0025 per cent recorded 22.12 and 23.11 per cent of fruit infestation, respectively and both were at par with each other. Azadirachtin 1 EC @ 0.003 per cent and quinalphos 25 EC 0.025 per cent recorded 32.73 and 33.05 per cent fruit infestation, respectively and were also at par with each other. The treatment with *B. thuringiensis* 1.5 g^{-1} recorded 28.61 per cent fruit infestation. Untreated plot recorded highest (42.23%) per cent fruit infestation.

At 14th day of observation, the minimum (12.12%) fruit infestation was recorded in chlorantraniliprole 18.5 SC @ 0.005 per cent which was significantly superior over rest of the treatments followed by spinosad 45 SC @ 0.014 per cent (15.88%). The treatments indoxacarb 14.5 SC @ 0.012 per cent and lambda cyhalothrin 5 EC @ 0.0025 per cent recorded 24.11 and 24.90 per cent of fruit infestation, respectively and both were at par with each other. Azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 29.51 and 30.34 per cent fruit infestation, respectively and which were also at par with each other. The treatment *B. thuringiensis* 1.5 g^{-1} recorded 26.68 per cent fruit infestation,

while untreated control recorded maximum per cent fruit infestation (34.75%).

The data on mean fruit infestation indicated that among the treatments, chlorantraniliprole 18.5 SC @ 0.005 per cent was significantly superior which recorded lowest per cent fruit infestation (11.13%) followed by spinosad 45 SC @ 0.014 per cent with 15.58 per cent fruit infestation. The treatments indoxacarb 14.5 SC @ 0.012 per cent (21.66%) and lambda cyhalothrin 5 EC @ 0.0025 per cent (22.84%) were at par with each other. Similarly, azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 30.59 and 31.65 per cent fruit infestation, respectively and were also at par with each other. The treatment *B. thuringiensis* 1.5 g^{-1} recorded 27.66 per cent fruit infestation. The highest per cent of fruit infestation was noticed in untreated control (40.15%).

Cumulative efficacy of different insecticides against fruit borer, *H. armigera* infesting tomato.

The data pertaining to the cumulative efficacy of different insecticides against fruit borer, *H. armigera* infesting tomato are presented in Table 4.

Table 4: Cumulative efficacy of different insecticides against fruit borer, *H. armigera* infesting tomato

Sr. No.	Treatment	Conc.(%)/Dose	Per cent fruit infested			Cumulative per cent infestation
			First spray	Second spray	Third spray	
1	Spinosad 45 SC	0.014	20.75(27.08)*	15.84(23.43)	15.58(23.23)	17.39(24.58)
2	Azadirachtin 1EC	0.003	30.19(33.32)	30.76(33.66)	30.59(33.57)	30.51(33.51)
3	*Bacillus thuringiensis* var. *kurstaki* Berliner	1.5 g^{-1}	27.14(31.37)	26.99(31.29)	27.66(31.73)	27.26(31.46)
4	Chlorantraniliprole 18.5 SC	0.005	17.27(24.49)	13.07(21.17)	11.13(19.46)	13.82(21.70)
5	Lambda cyhalothrin 5 EC	0.0025	25.79(30.15)	21.89(27.88)	22.84(28.53)	23.50(28.97)
6	Quinalphos 25 EC	0.025	32.25(34.59)	34.20(35.75)	31.65(34.23)	32.70(34.85)
7	Indoxacarb 14.5 SC	0.012	22.94(28.60)	20.32(26.77)	21.66(27.72)	21.64(27.70)
8	Untreated Control	-	35.47(36.55)	40.33(39.43)	40.14(39.30)	38.65(38.43)
S.Em.±			0.35	0.45	0.39	0.40
CD (p=0.05)			1.07	1.39	1.20	1.22

*Figure in parentheses are arcsine values

The results regarding overall mean of all sprays revealed that chlorantraniliprole 18.5 SC @ 0.005 per cent was the best treatment which recorded minimum (13.82%) mean fruit infestation and was significantly superior over all other treatments. It was followed by spinosad which recorded 17.39 per cent fruit infestation. The next treatments in descending order of effectiveness were indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC 0.0025 per cent, *B. thuringiensis* 1.5 g^{-1}, azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent which recorded 21.64, 23.50, 27.26, 30.51 and 32.70 per cent fruit infestation, respectively. All the above treatments were found to be superior over untreated control which recorded highest fruit infestation (38.65%).

Present findings are in agreement with Chaudhari and Senapati (2001) [4]. They reported that Azadirachtin was found least effective against fruit borer infestation (31.89%). Sharma and Bharadwaj (2008) [14] observed that mean percent fruit damage in treatments *viz*., *Bt*. var. *kurstaki*, neemgold and azadirachtin were 25.0, 29.0 and 31.3 per cent, respectively. Dhaka *et al*. (2010) [6] observed that indoxacarb with lowest fruit infestation of 2.53 per cent followed by lambda cyhalothrin (6.7%). Among bio pesticides, neemarin (13.9%) followed by Bt (14.7%).

Ali *et al*. (2011) [1] revealed that *B. thuringiensis* was found to be more effective with lower per cent fruit damage (15.1%) than that of NSKE (16.7%). Sinha and Nath (2011) [17] founded that indoxacarb showed 15.1 per cent fruit infestation in tomato.

Ambule *et al*. (2012) [2] reported that chlorantraniliprole 0.0055 per cent showed 10.62 per cent fruit damage followed by spinosad @ 0.0068 per cent with 11.34 per cent fruit damage. Mishra *et al*. (2014) revealed that among insecticides, spinosad 45 SC was found most effective with 3.3 per cent pod damage against *H. armigera* and proved significantly over all the treatments except indoxacarb (3.6%) which was found statistically on par to spinosad.

Sherzad and Kumar (2014) [15] founded that among chemical insecticides, spinosad 45 SC with fruit damage 0.53 per cent. Misra (2015) [12] revealed that *H. armigera* showed 85.5 to 86.3 per cent reduction on number basis over control in the treatments cyantraniliprole (HGW86) 10 per cent OD @ 90 and 105 g *a.i.* per ha, respectively which was significantly superior to other treatments.

Chavan *et al.* (2015) [5] recorded significantly lower infestation of *H. armigera* in *Bt* (8.00%, 7.15%, 12.10% at 3, 7 and 14 DAS, respectively) and azadiractin (8.20%, 7.60%, 12.40% at 3, 7 and 14 DAS, respectively). Meena and Raju (2015) revealed that spinosad was the best with lowest fruit infestation (17.32%) and indoxacarb (27.15%) was less effective.

Conclusion

The data on mean fruit infestation after first spray indicated that among the treatments, chlorantraniliprole 18.5 SC @ 0.005 per cent was found to be significantly superior over rest of the treatments which recorded 17.27 per cent mean fruit infestation. The treatments *B. thuringiensis* 1.5 g^{-1} (27.14%) and quinalphos 25 EC @ 0.025 per cent (32.25%) were at par with each other. Lambda cyhalothrin 5 EC @ 0.0025 per cent, spinosad 45 SC @ 0.014 per cent, indoxacarb 14.5 SC @ 0.012 per cent and azadirachtin 1 EC @ 0.003 per cent recorded 25.79, 20.75, 22.94, 30.19 per cent fruit infestation, respectively. The maximum (35.47%) mean per cent fruit infestation was recorded in untreated control.

The data on mean fruit infestation after second spray indicated that among the treatments, chlorantraniliprole 18.5 SC @ 0.005 per cent recorded minimum (13.07%) fruit infestation which was significantly superior over rest of the treatments followed by spinosad 45 SC @ 0.014 per cent (15.84%). The treatments indoxacarb 14.5 SC @ 0.012 per cent (20.32%) and lambda cyhalothrin 5 EC 0.0025 per cent (21.89%) were at par with each other. The treatments *B. thuringiensis* 1.5 g^{-1}, azadirachtin 1EC @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 26.99, 30.76 and

34.20 per cent fruit infestation, respectively. The highest mean per cent fruit infestation was recorded in untreated control (40.34%).

The data on mean fruit infestation after third spray indicated that among the treatments, chlorantraniliprole 18.5 SC @ 0.005 per cent was significantly superior which recorded lowest per cent fruit infestation (11.13%) followed by spinosad 45 SC @ 0.014 per cent with 15.58 per cent fruit infestation. The treatments indoxacarb 14.5 SC @ 0.012 per cent (21.66%) and lambda cyhalothrin 5 EC @ 0.0025 per cent (22.84%) were at par with each other. Similarly, azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent recorded 30.59 and 31.65 per cent fruit infestation, respectively and were also at par with each other. The treatment *B. thuringiensis* 1.5 g^{-1} recorded 27.66 per cent fruit infestation. The highest per cent of fruit infestation was noticed in untreated control (40.15%).

Based on overall results of field experiment, it was revealed that the treatment chlorantraniliprole 18.5 SC @ 0.005 per cent was the best treatment which recorded minimum (13.82%) mean fruit infestation and was significantly superior over all other treatments. It was followed by spinosad which recorded 17.39 per cent fruit infestation. The next treatments in descending order of effectiveness were indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC 0.0025 per cent, *B. thuringiensis* 1.5 g^{-1}, azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent which recorded 21.64, 23.50, 27.26, 30.51 and 32.70 per cent fruit infestation, respectively. All the above treatments were found to be superior over untreated control which recorded highest fruit infestation (38.65%).

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