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To evaluate the bioefficacy of different biopesticides and insecticides against *Helicoverpa armigera* (Hubner) at Bilaspur (Chhattisgarh)

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Abstract
The field experiment was conducted at Instructional farm of BTC CARS, Bilaspur, (C.G.) during *Rab*i 2022-23, to know the bioefficacy of different biopesticides and insecticides against *Helicoverpa armigera* on chickpea. After first and second spray all the treatments were observed more or less similar in action against the pest, however, Novaluron + Indoxacarb 5.25% + 4.5% SC recorded with the lowest larvae 1.43 larvae/plant, highest grain yield 8.25 q/ha and maximum cost benefit ratio 1:1.36, while Spinosad 45% SC (1.84 larvae/plant) was the second best treatment. Among the biopesticides, *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) recorded with 7.80 q/ha yield and 1:1.31 cost benefit ratio.

Keywords: Bioefficacy, chickpea, field**,** Instructional, maximum, spinosad, treatment

Introduction
Chickpea (*Cicer arietinum* L.) a member of family Fabaceae, is an ancient self-pollinated leguminous crop. In India Chickpea commonly known as gram, Bengal gram or Chana. It plays an important role in the vegetarian diet as a major source of protein. It is a very important component of dry, rain fed cropping systems since it can repair nitrogen fixation of eighty to one hundred and twenty kilogram (Golding and Dong, 2010) [6] It is an essential energy, protein and soluble and insoluble fiber are supply. The grain consists of 52-70% carbohydrates, 18-22.2% protein. Besides, it is a rich source of calcium, iron, vitamin C (green stage) and 'B_1' (Kumar *et al.*, 2019) [7].

It is the most important *Rabi* season pulse crop of India. Globally, chickpea is grown in an area of 148.42 lakh hectares with a production of 150.84 lakh tonnes and productivity of 1016 kg/ha (FAO STAT, 2020). During 2020-21, India contributed 70% of total global chickpea production, with 119.9 lakh tonnes grown on 112 lakh hectares with a productivity of 1070 kg/hectare (agricoop.nic.in). During 2020-21, Chhattisgarh contributed 3.06% of total India chickpea production, with 0.27 million tonnes grown on 0.30 million hectares with a productivity of 887 kg/ha (Directorate of Economics and Statistics). During 2017-18, in Bilaspur district, chickpea is grown in area of 1950 hectares with a production of 1910 metric tons and productivity of 979 kg/ha (Directorate Agriculture, Chhattisgarh Raipur).

There are many reasons responsible for the poor production of this crop. In field condition and storage condition insect pest and diseases are plays a very important role against crop production (Bentley and Clements, 1989) [4]. About sixty insect species are known to feed on chickpea (Parsai, 2005) [9]. Among the many arthropods sap sucking pests, particularly Aphids, Jassids, Thrips, Whitefly are the most destructive chickpea pests in Asia, Africa and Australia (Balikai *et al.*, 2001; Devendra and Binay 2002) [3, 5].

On chickpea the number of sucking pests are observed by scientist such as Aphids, *Aphis craccivora* Koch, its belongs to order Hemiptera, Aphididae which cause the suck the juice from flower, newly emergence leaves, another pest is jassids, *Empoasca kerri*, Thrips, *Megalurothrips usitatus*, Whitefly, *Bemisia tabaci* (Mosier *et al.*, 2004; Anandhi *et al.*, 2011) [8, 2].

Gram pod borer *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera) is one of the major pest of chickpea. The pest starts its attack at early stage and become severe during maturity stage of the crop. The pest accounts for 90-95% of total damage. A single larva of *Helicoverpa armigera* can damage 30-40 pods of chickpea before its maturity (Singh *et al.*, 2015) [10].

It feeds on tender shoots and young pods.

Materials and Methods

A field experiment was conducted at Instructional farm of BTC CARS, Bilaspur, (C.G.) during *Rab*i 2022-23, to know the bioefficacy of different biopesticides and insecticides against *Helicoverpa armigera* (Hubner) on chickpea.

Methodology: The solution will be prepared by thoroughly mixing insecticides in a known quantity of water and thus insecticidal spray solution will be used for spraying wih a knapsack sprayer.

Bio-rational insecticides such as *Beauveria bassiana*, *Metarrhizium anisopliae*, *Bacillus thuringiensis* (Crystal) 1% formulation, *Bacillus thuringiensis* (Crystal) 2% formulation, *Bacillus thuringiensis* 10% (Broth), Spinosad 45% SC, Novaluron + Indoxacarb 5.25% + 4.5% SC was sprayed when pest population reaches the ETL level (1-2 larvae/plant) (Kumar *et al*. 2019) [7]. The observation of gram pod borer will be recorded on ten randomly selected tagged plants from the net plot at one day before and 1, 3, 7, 10, 15 days after application of insecticides. When the crop attained maturity net plot will be harvested and pods will also being separated to record the yield in different treatments.

Percent increase in yield over control and percent avoidable loss

The weight of total grain yield was recorded at harvest. The percent increase in yield and avoidable losses due to bio-pesticide treatments will be computed using the formula:

Percent increase in yield over control = (T-C)/C × 100

Where,
T =Yield of respective treatment
C = Yield of untreated control plot
Percent avoidable loss = T-C/T × 100
Where, T = Yield of best treatment
C = Yield of corresponding treatment

Results and Discussion

First Spray

The data on number of larvae/plant recorded at one day before, 1, 3, 7, 10 and 15 days after first spray presented in Table 1 and depicted in Fig. 1 showed that No significant difference was observed among the treatments one day before spray showed normal distribution of pest. Larval population data 1, 3 and 7 days after spray were also found non significant and varied from 2.00 to 4.00, 1.67 to 3.67 and 1.00 to 4.00 larvae/plant, respectively. However, Treatment Novaluron + Indoxacarb 5.25% + 4.5% SC recorded the with minumum larval population 2.00, 1.67 and 1.00 larvae/plant at 1, 3 and 7 days after spray, respectively.

The data on number of larvae/plant recorded at ten days after first spray presented in Table 1 and depicted in Fig. 1 showed that average gram pod borer survival larval population per plant varied from 0.67 to 4.67. All chemical and biopesticides treatment were significantly superior over untreated control but at par to each other, however treatment Novaluron + Indoxacarb 5.25% + 4.5% SC recorded the lowest larvae (0.67 larvae/plant) and followed by *Metarhizium anisopliae* 10% (1×10^9 CFU/ml), Spinosad 45% SC, *Beauveria bassiana* 10% (1×10^9 CFU/ml) (1.00 larvae/plant), *Bacillus thuringiensis (Crystal) 2%* (1.33 larvae/plant), *Bacillus thuringiensis* (Broth) 10% and *Bacillus thuringiensis* (Crystal) 1% (1.67 larvae/plant). Maximum 4.67 larvae/plant was recorded in untreated control.

The data on number of larvae/plant recorded at fifteen days after first spray presented in Table 1 and depicted in Fig. 1 showed that all chemical and biopesticides treatment significantly reduced the larval population as compared to untreated control. Average gram pod borer survival larval population per plant varied from 0.33 to 4.67. Chemical treatment, Novaluron + Indoxacarb 5.25% + 4.5% SC recorded the best treatment in terms of lowest larvae (0.33 larvae/plant) which was at par with Spinosad 45% SC (0.67 larvae/plant), *Bacillus thuringiensis (Crystal)* 2%, *Bacillus thuringiensis* (Broth) 10% (1.00 larvae/plant), *Bacillus thuringiensis* (Crystal) 1% (1.33 larvae/plant) and *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) (1.67 larvae/plant). *Beauveria bassiana* 10% (1×10^9 CFU/ml) (2.00 larvae/plant) was least effective.

Second Spray

The data on number of larvae/plant recorded one day before spray was found not significant and presented in Table and depicted in Fig. 2. The data one day after second spray showed that all treatments were found significantly effective in reducing the larval population of pod borer in comparision to untreated control with average gram pod borer larval population varied from 1.00 to 4.67 /plant. In chemical and biopesticides treatment, *Bacillus thuringiensis* (Broth) 10% was recorded with the lowest larvae (1.00 larvae/plant) and found significantly superior then *Bacillus thuringiensis* (Crystal) 1% (3.00 larvae/plant) and *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) (2.67 larvae/plant) while other treatments, Novaluron + Indoxacarb 5.25% + 4.5% SC and Spinosad 45% SC (2.00 larvae/plant), *Beauveria bassiana* 10% (1×10^9 CFU/ml) and *Bacillus thuringiensis (Crystal) 2%* (2.33 larvae/plant) were recorded at par.

The data on number of larvae/plant observed at three days after second spray presented in Table 1 and depicted in Fig. 2 showed that all treatments were significantly superior then untreated control. Average gram pod borer survival larval population per plant was recorded in range from 1.00 to 5.00. All treatments seems to be more or less similar as they all are at par to each other, however, Novaluron + Indoxacarb 5.25% + 4.5% SC recorded with the lowest larvae (1.00 larvae/plant) followed by with *Metarhizium anisopliae* 10% (1×10^9 CFU/ml), *Beauveria bassiana* 10% (1×10^9 CFU/ml) both with 1.33 larvae/plant), Spinosad 45% SC (1.67 larvae/plant), *Bacillus thuringiensis (Crystal) 2%* (2.00 larvae/plant), *Bacillus thuringiensis* (Broth) 10% and *Bacillus thuringiensis* (Crystal) 1% (2.33 larvae/plant). Maximum 5.00 larvae/plant was found in untreated control.

The data on number of larvae/plant recorded at seven days after second spray presented in Table 1 and depicted in Fig. 2. showed that all the treatment was effectively reduced the larval population as compared to untreated control. Average gram pod borer survival larval population per plant was found to vary from 0.67 to 6.33. All treatments were found more or less same in their efficacy. The treatment Novaluron + Indoxacarb 5.25% + 4.5% SC with lowest larvae (0.67 larvae/plant), *Metarhizium anisopliae* 10% (1×10^9 CFU/ml), Spinosad 45% SC, *Beauveria bassiana* 10% (1×10^9 CFU/ml) (1.00 larvae/plant), *Bacillus thuringiensis* (Broth) 10% and *Bacillus thuringiensis* (Crystal) 1% (1.67 larvae/plant) and *Bacillus thuringiensis* (*Crystal*) 2% (2.00 larvae/plant) were decreasing in order of their efficacy. Whereas, in control plot maximum 6.33 larvae/plant was found.

The data on number of larvae/plant recorded at ten days after second spray presented in Table 1 and depicted in Fig. 2 indicated that the response of all the treatments were significantly superior over untreated control. Average larval population among the various treatments varied from 0.33 to 6.00 including untreated control. In chemical and biopesticides treatment, Novaluron + Indoxacarb 5.25% + 4.5% SC recorded one of the best treatment with lowest 0.33 larvae/plant and followed by *Metarhizium anisopliae* 10% (1×10^9 CFU/ml), *Beauveria bassiana* 10% (1×10^9 CFU/ml) (1.33 larvae/plant) and Spinosad 45% SC (1.67 larvae/plant). The treatment, *Bacillus thuringiensis* (Crystal) 1% (2.00 larvae/plant), *Bacillus thuringiensis (Crystal) 2%* (2.33 larvae/plant) and *Bacillus thuringiensis* (Broth) 10% (2.67 larvae/plant) were found next in order of their efficacy.

The data on number of larvae/plant recorded at fifteen day after second spray presented in Table 1 and depicted in Fig. 2. exhibited that all The treatments in comparision to untreated control showed their efficacy significantly. Average gram pod borer survival larval population per plant were ranging from 0.67 to 5.33. In chemical and biopesticides treatment, Novaluron + Indoxacarb 5.25% + 4.5% SC again recorded the most effective with lowest larvae 0.67 larvae/plant and found significantly superior over rest of the treatments except treatment Spinosad 45% SC (1.33 larvae/plant) and *Bacillus thuringiensis* (Crystal) 1% (1.67 larvae/plant). The treatments *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) (2.00 larvae/plant), *Bacillus thuringiensis (Crystal) 2%, Bacillus thuringiensis* (Broth) 10% *and Beauveria bassiana* 10% (1×10^9 CFU/ml) (2.67 larvae/plant) were observed less effective.

Overall mean of number of larvae/plant (average of two sprays)

The overall mean data on number of larvae/plant showed that all treatments significantly reduced the larval population of pod borer as compared to untreated control, while among the treatments no significant difference was observed, thus, they were found at par to each other. In descending order of their efficacy, treatments were Novaluron + Indoxacarb 5.25% + 4.5% SC (1.43 larvae/plant), Spinosad 45% SC (1.84 larvae/plant), *Beauveria bassiana* 10% (1×10^9 CFU/ml) (1.92 larvae/plant), *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) (1.92 larvae/plant), *Bacillus thuringiensis* (Broth) 10% (1.99 larvae/plant), *Bacillus thuringiensis* (Crystal) 1% (2.36 larvae/plant) and *Bacillus thuringiensis (Crystal) 2%*, (2.37 larvae/plant. Whereas untreated control plot recorded with maximum number 4.83 larvae/plant.

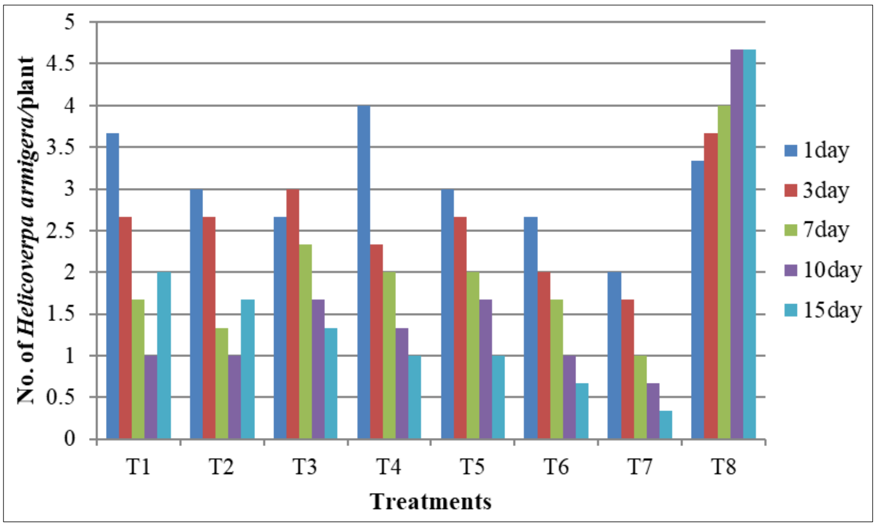

Fig 1: Number of larvae/plant after first spray

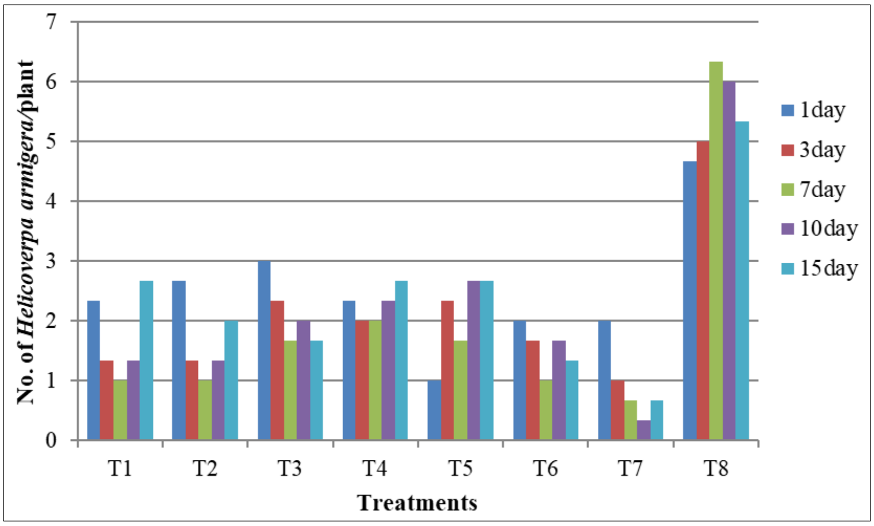

Fig 2: Number of larvae/plant after second spray

Table 1: Effect of different biopesticide and insecticides on gram pod borer (*Helicoverpa armigera*) after first and second spray

	Treatments	Dose (g or ml/ lit. of water)	Average larval population* (no.) of Gram pod borer												Overall mean
			Ist Spray						IInd Spray						
			PTO	1 DAS	3 DAS	7 DAS	10 DAS	15 DAS	PTO	1 DAS	3 DAS	7 DAS	10 DAS	15 DAS	
T_1	*Beauveria bassiana* 10% (1×10^9 CFU/ml)	10 ml	3.33 (2.07)	3.67 (2.16)	2.67 (1.91)	1.67 (1.61)	1.00 (1.38)^{b}	2.00 (1.72)^{b}	2.81 (1.95)	2.33 (1.82)^{bc}	1.33 (1.52)^{b}	1.00 (1.41)^{b}	1.33 (1.47)^{bc}	2.67 (1.91)^{b}	1.92 (1.71)^{b}
T_2	*Metarhizium anisopliae* 10% (1×10^9 CFU/ml)	10 ml	3.00 (1.99)	3.00 (2.00)	2.67 (1.90)	1.33 (1.47)	1.00 (1.38)^{b}	1.67 (1.63)^{bc}	3.09 (2.01)	2.67 (1.90)^{b}	1.33 (1.52)^{b}	1.00 (1.38)^{b}	1.33 (1.47)^{bc}	2.00 (1.73)^{bc}	1.92 (1.71)^{b}
T_3	*Bacillus thuringiensis* (Crystal) 1%	10 ml	2.33 (1.81)	2.67 (1.90)	3.00 (2.00)	2.33 (1.79)	1.67 (1.58)^{b}	1.33 (1.49)^{bc}	3.45 (2.10)	3.00 (1.97)^{b}	2.33^{b} (1.82)	1.67 (1.61)^{b}	2.00 (1.73)^{b}	1.67 (1.63)^{bcd}	2.36 (1.83)^{b}
T_4	*Bacillus thuringiensis* (Crystal) 2%	10 ml	3.00 (2.00)	4.00 (2.21)	2.33 (1.82)	2.00 (1.73)	1.33 (1.49)^{b}	1.00 (1.38)^{bc}	2.88 (1.96)	2.33 (1.81)^{bc}	2.00 (1.67)^{b}	2.00 (1.72)^{b}	2.33 (1.79)^{b}	2.67 (1.88)^{b}	2.37 (1.84)^{b}
T_5	*Bacillus thuringiensis* (Broth) 10%	10 ml	3.67 (2.15)	3.00 (1.99)	2.67 (1.88)	2.00 (1.73)	1.67 (1.55)^{b}	1.00 (1.33)^{bc}	1.68 (1.62)	1.00 (1.38)^{c}	2.33 (1.82)^{b}	1.67 (1.55)^{b}	2.67 (1.91)^{b}	2.67 (1.88)^{b}	1.99 (1.73)^{b}
T_6	Spinosad 45% SC	0.35 ml	3.33 (2.08)	2.67 (1.91)	2.00 (1.73)	1.67 (1.63)	1.00 (1.41)b	0.67 (1.24)^{bc}	2.57 (1.88)	2.00 (1.73)^{bc}	1.67 (1.63)^{b}	1.00 (1.38)^{b}	1.67 (1.63)^{bc}	1.33 (1.52)^{cd}	1.84 (1.69)^{b}
T_7	Novaluron + Indoxacarb 5.25% + 4.5% SC	1.75 ml	3.67 (2.14)	2.00 (1.72)	1.67 (1.63)	1.00 (1.41)	0.67 (1.28)^{b}	0.33 (1.14)^{c}	2.63 (1.89)	2.00 (1.66)^{bc}	1.00 (1.38)^{b}	0.67 (1.24)^{b}	0.33 (1.14)^{c}	0.67 (1.28)^{d}	1.43 (1.56)^{b}
T_8	Untreated Control	-	3.67 (2.16)	3.33 (2.08)	3.67 (2.16)	4.00 (2.24)	4.67 (2.36)^{a}	4.67 (2.37)^{a}	6.18 (2.68)	4.66 (2.38)^{a}	5.00 (2.43)^{a}	6.33 (2.71)^{a}	6.00 (2.60)^{a}	5.33 (2.52)^{a}	4.84 (2.41)^{a}
C.D. (5%)			NS	NS	NS	NS	0.58	0.65	NS	0.52	0.56	0.65	0.68	0.45	0.53 (0.12)
SE(m)			0.15	0.14	0.12	0.16	0.19	0.21	0.131	0.17	0.18	0.21	0.22	0.15	0.17 (0.04)
C.V.			12.73	12.55	10.61	16.37	17.16	18.96	11.271	16.06	18.52	18.54	18.63	14.22	12.92 (3.65)

Table 2: Effect of different biopesticide and insecticides on gram pod borer (*Helicoverpa armigera*) (Avg. of two sprays)

Sr. no.	Treatment	Number of larvae/plant
T_1	*Beauveria bassiana* 10% (1×10^8 CFU/ml)	1.92
T_2	*Metarhizium anisopliae* 10% (1×10^8 CFU/ml)	1.92
T_3	*Bacillus thuringiensis* (Crystal) 1%	2.36
T_4	*Bacillus thuringiensis* (Crystal) 2%	2.37
T_5	*Bacillus thuringiensis* (Broth) 10%	1.99
T_6	Spinosad 45% SC	1.84
T_7	Novaluron + Indoxacarb 5.25% + 4.5% SC	1.43
T_8	Untreated Control	4.83

Table 3: Yield and economics of different insecticides applied for the management of *Helicoverpa armigera* on chickpea

Tr. No.	Treatments	Dose ml/g/ litre	Seed yield (q./ha)	Cost of treatments +Spraying (Rs./ha)	Cost of cultivation + Cost of insecticides (Rs./ha)	Gross monetary return (Rs.)	Net monetary return (Rs.)	Additional income over control (Rs.)	B: C ratio
T_1	*Beauveria bassiana* 10% (1×10^8 CFU/ml)	10 ml	7.74	3550	31675	41292	9617	9816	1:1.30
T_2	*Metarhizium anisopliae* 10% (1×10^8 CFU/ml)	10 ml	7.8	3550	31675	41613	9938	10137	1:1.31
T_3	*Bacillus thuringiensis* (Crystal) 1%	10 ml	7.6	3550	31675	40546	8871	9070	1:1.28
T_4	*Bacillus thuringiensis* (Crystal) 2%	10 ml	7.4	3550	31675	39479	7804	8003	1:1.24
T_5	*Bacillus thuringiensis* (Broth) 10%	10 ml	7.55	3550	31675	40279	8604	8803	1:1.27
T_6	Spinosad 45% SC	0.35 ml	8.1	5390	33515	43213	9698	11737	1:1.29
T_7	Novaluron + Indoxacarb 5.25% + 4.5% SC	1.75 ml	8.25	4150	32275	44013	11738	12537	1:1.36
T_8	Untreated Control	-	6.9	-	28125	31476	3351		1:1.11

Table 4: Insecticides and spraying costs

Tr. No.	Treatments	Quantity need for 2 sprays (ml or g/ha)	Cost of insecticide/ kg or L	Cost (Rs/ha)	Application fare for spray (Rs/ha)	Total cost (insecticide and spraying)
T_1	*Beauveria bassiana* 10% (1×10^8 CFU/ml)	10,000 ml/ha	150	1500	2050	3550
T_2	*Metarhizium anisopliae* 10% (1×10^8 CFU/ml)	10,000 ml/ha	150	1500	2050	3550
T_3	*Bacillus thuringiensis* (Crystal) 1%	10,000 ml/ha	150	1500	2050	3550
T_4	*Bacillus thuringiensis* (Crystal) 2%	10,000 ml/ha	150	1500	2050	3550
T_5	*Bacillus thuringiensis* (Broth) 10%	10,000 ml/ha	150	1500	2050	3550
T_6	*Spinosad 45% SC*	350 ml/ha	9545	3340	2050	5390
T_7	*Novaluron + Indoxacarb 5.25% + 4.5% SC*	1750 ml/ha.	1200	2100	2050	4150
T_8	Untreated Control	-	-	-	-	-

Labour rate per day = Rs. 300 per laborer (2 laborer required for spraying in one hectare per day),
Price of chickpea=5335 Rs per quintal

Yield of chickpea in different treatments given below

The yield data is presented in table 3, which indicate that, all the treatments after spray of insecticides and biopesticides significantly increased the yield over untreated control. The yield of treated plot was ranged between 7.40 to 8.25 q/ha as against 5.9 q/ha in untreated plot, which was recorded lowest in the trial.

The highest grain yield 8.25 q/ha and cost benefit ratio 1:1.36 was obtained in the plot treated with Novaluron + Indoxacarb 5.25% + 4.5% SC, followed by *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) was recorded with 7.80 q/ha yield and 1:1.31 cost benefit ratio, *Beauveria bassiana* 10% (1×10^9 CFU/ml) with 7.74 q/ha yield and 1:1.30 cost benefit ratio, Spinosad 45% SC with yield 8.10 q/ha and cost benefit ratio 1:1.29, *Bacillus thuringiensis* (Crystal) 1% 7.55 q/ha and 1:1.28 cost benefit ratio, *Bacillus thuringiensis* (Broth) 10% with 7.55 q/ha and 1:1.27 cost benefit ratio, *Bacillus thuringiensis* (Crystal) 2% with 7.40 q/ha yield and 1:1.24 cost benefit ratio.

Conclusions

- After first and second spray lowest larval population 1.43 larvae/plant was recorded in treatment Novaluron + Indoxacarb 5.25% + 4.5% SC, while Spinosad 45% SC was recorded the second best treatment with 1.84 larvae/plant.
- Among the biopesticides *Beauveria bassiana* 10% (1×10^9 CFU/ml) and *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) both were recorded with less no. of larvae 1.92 larvae/plant.
- The highest grain yield 8.25 q/ha and cost benefit ratio 1:1.36 was obtained in the plot treated with Novaluron + Indoxacarb 5.25% + 4.5% SC, followed by *Metarhizium anisopliae* 10% (1×10^9 CFU/ml) recorded with 7.80 q/ha yield and 1:1.31 cost benefit ratio.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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