

Research Paper

## Bio-intensive management of pod borer (*Helicoverpa armigera*) in fieldpea (*Pisum sativum*)

Amitava Banerjee<sup>1</sup> and Sabyasachi Ray<sup>2\*</sup>

<sup>1</sup>AICRP on MULLaRP, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia- 741 252, West Bengal, India

<sup>2</sup>Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia- 741 252, West Bengal, India

\*Corresponding author e-mail: sabyasachiray1997@gmail.com

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### ABSTRACT

The experiment was executed to assess the efficacy of different biopesticides including HaNPV, Bt, NSKE, *Beauveria bassiana*, *Metarrhizium anisoplae* along with two chemical pesticides viz. Imidacloprid and Chlorantraniliprole to manage *Helicoverpa armigera* Hubn. in field pea under natural growing conditions. Imidacloprid was used as a seed treatment chemical and integrated with all the treatments. Treatments were implemented when the pest population reached the ETL level. The comparative benefit-cost ratio was also calculated using the yield and current price of the treatments in the local market. Among different treatments, Chlorantraniliprole showed maximum efficacy and caused more than 90% larval reduction over control. Among the biopesticides, Bt provided maximum control of gram pod borer damage and benefit-cost ratio followed by HaNPV, *Beauveria bassiana*, *Metarrhizium anisoplae* and NSKE, respectively.

**Key words:** Benefit cost ratio, Biopesticides, Economics, Efficacy, Field pea, Gram pod borer, Pest control, Pod damage, Population, Yield

### INTRODUCTION

Field pea is a grain legume particularly grown in cool seasons for fresh or dry seeds and fodder in more than 100 countries. It is a self-pollinated, C<sub>3</sub> crop with a diploid genome (2n = 14) belonging to the diverse genus of *Pisum*, within the Fabaceae or Leguminosae family (Lake *et al.* 2021). Linguistic and Archeological evidences suggest that the crop was cultivated in India and Egypt since ancient times (De Candolle 1882). Seeds of field pea contain 23-25% protein, 50% slowly digestible starch, 5% soluble sugars, and other important vitamins, minerals, and fibers (Smýkal *et al.* 2013). In India, the crop occupied an area of 28.33 million hectares with average production and productivity of 25.72 million tonnes and 892 kg/ha, respectively (Anonymous 2021). Different stresses comprising both abiotic stress (such as drought, high temperature during the growing period, humidity, heavy rainfall, frost, etc.) and biotic stresses (including insect pests, diseases, and weed problems) are responsible for lower productivity of field pea. Among the different pest species gram pod borer (*Helicoverpa armigera* Hubn.) is the key limiting factor of grain yield in field pea, particularly in the tropical and subtropical growing areas (Deshmukh *et al.* 2010). During the entire larval period, a single larva

of gram pod borer can consume almost 40 pods (Khan *et al.* 2009). The estimated avoidable yield loss of field pea caused by the pest ranged between 9.39% and 27.66% (Banerjee and Pal 2020). Several beneficial traits, including outstanding adaptability for colonizing different agro-ecological regions, promising dispersal ability, a wide host range, high egg-laying capacity, occurrence in every growing season, and adaptability to the changing climatic conditions enable the pest to overcome the negative effects of different control measures, resulting in reduced or no efficacy of the management practices (Sharma 2007, Ray and Banerjee 2022). In the present situation, overuse of synthetic chemicals neglecting the proper dose, time, proper chemical and proper application method contaminates the surrounding environments and creates selection pressure on the pest population leading to the development of resistance inside the insect body (Tabashnik *et al.* 2014, Ray and Banerjee 2021). The appearance of resistance against several insecticides in gram pod borer is now a common problem (Nguyen *et al.* 2007), particularly for 4<sup>th</sup> and 5<sup>th</sup> instar caterpillars, which are more capable of resisting insecticidal treatments. Additionally, the array of resistance mechanisms in the pest's body has no limitation, encompassing almost all types of conventional insecticides (Rashid

*et al.* 2013). Biopesticides may be the better option to overcome insecticide-related problems. The use of different kinds of bio-pesticides for pest management may be economically beneficial and environmentally sound. There are very few reports encompassing the efficacy of bio-pesticides for managing gram pod borer infesting field pea crop. The present experiment emphasizes increased utilization of various bio-pesticides for managing the mentioned pest.

## MATERIALS AND METHODS

### *Experimental site and layout*

The present study was carried out in the District Seed Farm of Bidhan Chandra Krishi Viswavidyalaya located at A-B Block farm, Kalyani, Nadia, West Bengal, India (22°87'N, 88°20'E). The experiment was performed over two years (2020-2021 and 2021-2022). The layout of the field was done using the randomized block design (RBD) with three replications. Field pea variety 'Rachna' was sown at a rate of 60 kg seeds/ha with a spacing of 30 cm × 10 cm at 4-5 cm sowing depth during the last week of November.

### *Experimental details*

This experiment included seven treatments and one untreated control. Treatment 1 (T1) included seed treatment with Imidacloprid 600 FS @ 3 ml/ kg of seed only while the other six treatments were comprising seed treatment with Imidacloprid 600 FS along with spray application of one bio-pesticide. In untreated control, no seed treatment with insecticide and no pesticide spray were given. Selected biopesticides such as application of neem seed kernel extract (NSKE) [Tigger] @ 5%, HaNPV [Sun Bio Hanpv] (2x10<sup>9</sup> POBs/ml) @ 250 LE/ha, *Bacillus thuringiensis kurstaki* 127 SC [DiPel BT] @ 3 ml/l, *Beauveria bassiana* [Beveroz-P] @ 5 g/l and *Metarhizium anisopliae* [Metkill] @ 5 g/l of water were used for T2, T3, T4, T5 and T6 treatments, respectively. One newer insecticide *viz.* Chlorantraniliprole 18.5 SC [Coragen] @ 0.2 ml/l of water was also evaluated against the pest and designated as a treatment 7 (T7). One control having only a spray of water instead of any toxicant, is considered as treatment 8 (T8). Continued monitoring of the crop was done from the third week after sowing to observe the incidence and population buildup of the pest. Spray application of the treatments was given at 72 days after sowing (7<sup>th</sup> standard meteorological week) when the

pest reached the economic threshold level (ETL) (single 4<sup>th</sup> or 5<sup>th</sup> instar caterpillar more than 1 cm in length/10 sample plants) at pod formation and development stage (Chandrashekar *et al.* 2014, Ray and Banerjee 2021) and distributed uniformly in all the replications. Spraying was done using a battery-operated knapsack sprayer with a spray volume of 500 litres/ha. Spraying was conducted during afternoon hours (4-5 PM) to minimize the exposure time of the bio-pesticides to direct sunlight.

### *Recording observations*

Observations on pest population were recorded as number of larvae per sample plant. For recording population data, five plants were randomly selected and tagged from each replication. The pest population was counted one day before the spraying and recorded as 1 DBT (Day before treatment). After spray application, the population was recorded as 3 DAT (Day after treatment), 7 DAT, and 15 DAT (Banerjee and Pal 2021, Banerjee and Ray 2023). Overall corrected mortality of the pest was carried out using the following formula (Henderson and Tilton 1955).

$$\text{Corrected mortality} = \left(1 - \frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}}\right) \times 100$$

Where, n = Insect population, T = treated plot, Co = control plot

Before harvest, the total number of pods and damaged pods were counted from the sample plants of each replication of each treatment, and the percent pod damage was calculated according to the following formula (Kumar *et al.* 2013, Ray and Banerjee 2022). After harvesting, the yield of the crop from different treatments was also recorded.

$$\text{Per cent pod damage} = \frac{\text{No. of damaged pod per plant}}{\text{Total number of pods per plant}} \times 100$$

### *Statistical analysis*

The recorded data were statistically analyzed using analysis of variance (ANOVA). The significance of the treatment means was evaluated using an "F" test. Following the identification of significant differences among the treatment means, further testing was conducted for critical differences (CD) at a 5% level of significance. Based on the yield data, cost of treatments in the local market and the market price of field pea grains, incremental

cost benefit ratio for different treatments were also carried out.

## RESULTS AND DISCUSSION

### *Occurrence and damage caused by pod borer in field pea during Rabi 2019-20*

Larval reduction and percent mortality of gram pod borer were evident in different management schedules. Each treatment has the potential to reduce the population level of the pest. All of them differed significantly in reducing the pest load in the crop compared to the untreated control. All the practices resulted in significantly higher larval mortality compared to the control (Table 1, Fig. 1, 3). Before the application of the larvicidal solutions, the larval population was distributed almost uniformly among all the replications, and the population ranged from 4.81 to 5.28 larvae per plant. In the case of Treatment 1 comprising only seed treatment with Imidacloprid 600 FS @ 3 ml/kg of seed, the population reduced from 4.81 larvae/plant to 4.57 larvae/plant between 1 DBT (day before treatment) and 15 DAT (Days after treatment) and caused a larval reduction of 23.20% only, compared to the control which was lowest among all the treatments. Treatment 2 (T<sub>1</sub> + spraying with NSKE @ 5%) reduced the larval population from 5.23 larvae/plant during 1 DBT to 4.12, 4.03, and 3.73 larvae/plant at 3, 7 and 15 DAT, respectively, and exhibited a larval mortality of 45.09%, respectively. The application of NPV (Treatment 3) provided significantly higher efficacy compared to the former treatments. It reduced the larval population from 4.82 larvae/plant to 3.34, 2.70, and 1.97 larvae/plant at 3, 7, and 15 DAT, respectively with 66.87% larval mortality which was considerably higher. Among the fungal entomopathogens, white muscardine fungus (*Beauveria bassiana*) (Treatment 5) provided more effective control of the pest compared to green muscardine fungus (*Metarhizium anisopliae*) (Treatment 6). Treatment 5 reduced the larval population from 5.27 larvae/plant to 3.62, 3.07, and 2.37 larvae/plant at 3, 7 and 15 DAT, respectively, while Treatment 6 showed a population reduction from 5.28 larvae/plant to 4.18, 3.53 and 2.77 larvae/plant at 3, 7 and 15 DAT, respectively. They caused larval mortality of 63.61% and 57.64%, respectively compared to the control. Considering all the biopesticides, T4 (T<sub>1</sub> + *Bacillus thuringiensis kurstaki* 127 SC @ 3 ml/l) showed a significant larval reduction of 3.12, 2.53 and 1.43 larvae/plant at 3, 7 and 15 DAT, respectively, and subsequent larval

mortality of 76.83%. Treatment 7 comprising T1 and spraying with chlorantraniliprole 18.5 SC @ 0.2 ml/l provided the highest efficacy compared to the untreated control. The pest population declined from 5.08 larvae/plant to 2.27, 1.97 and 0.37 larvae/plant at 3, 7 and 15 DAT, respectively resulting from the application of chlorantraniliprole. It also exhibited the highest larval mortality of 94.76%. From these results, it was evident that chlorantraniliprole was most effective for controlling the pest followed by *Bacillus thuringiensis*, HaNPV, *Beauveria bassiana* and *Metarhizium anisopliae*. Treatments 1 and 2 showed lower efficacy against the pest compared to the other treatments. In control plots, the pest population increased gradually without any suppressive agent and resulted in the highest pest population (6.37 larvae/plant). Pod damage caused by the pest was minimal (2.33%) in the case of T7 followed by T4 (3.87%), T3 (5.33%), T5 (6.53%), T6 (7.97%), T2 (9.20%) and T1 (10.27) respectively compared to the control where maximum pod damage was recorded (23.57%). Besides suppressing the pest population these biointensive treatments also increased the seed yield compared to the control. The treatments also significantly differed in seed yield. The highest yield (1488.89 kg/ha) was obtained from treatment 7 followed by T4, T3, T5, T6, T2, and T1. The lowest seed yield (464.81 kg/ha) was recorded from the control.

### *Occurrence and damage caused by pod borer in field pea during Rabi 2020-21*

Similar trend of efficacy was observed in the second year also. The results are furnished in Table 2 and Fig. 2. In this season the pest population ranged between 5.7 and 6.1 larvae/plant before application of the pesticides. Seed treatment with Imidacloprid 600 FS at 3 ml/ kg of seed provided only minimal control of the pest, reducing the pest load to 4.67 larvae per plant 15 days after application, down from 6.1 larvae per plant. While this was an improvement compared to the control, its effectiveness was limited. Treatment 2 containing azadirachtin reduced the larval load from 5.7 larvae/plant to 4.87, 4.13, and 3.90 larvae/plant at 3, 7 and 15 DAT, respectively with a larval mortality of 50.99%. Bt (T4) and HaNPV (T6) showed significantly higher efficacy among the considered biopesticides. Bt diminished the population intensity from 5.8 larvae/plant to 3.62, 2.73, and 1.63 larvae/plant while NPV abated the caterpillar numbers from 6.0 larvae/plant to 3.76, 2.87 and 2.07 larvae/plant at 3, 7 and 15 DAT, respectively. Application of NPV and Bt caused

**Table 1.** Efficacy of selected bio-intensive management practices against pod borer (*Helicoverpa armigera*) infesting fieldpea during Rabi 2019-20

Sl. No.	Treatments	Mean pod borer population (No. of larvae/ plant)				Corrected mortality	Pod damage (%)	Yield (kg/ ha)
		1 DBT	3 DAT	7 DAT	15 DAT			
T <sub>1</sub>	Seed Treatment with Imidacloprid 600 FS @ 3 ml/kg of seed	4.81 (2.30)*	4.46 (2.23) ab	4.27 (2.18) b	4.57 (2.25) b	23.20 ** (27.73)c	11.27 ** (19.61)b	679.63de
T <sub>2</sub>	T <sub>1</sub> + NSKE @ 5%	5.23 (2.39)	4.12 (2.15) bc	4.03 (2.13) b	3.73 (2.06) bc	45.09 (41.78)bc	9.20 (17.64)bc	750.00cd
T <sub>3</sub>	T <sub>1</sub> + HaNPV (2X10 <sup>9</sup> POBs/ml) @ 250 LE/ha	4.82 (2.31)	3.34 (1.96) bc	2.70 (1.79) cd	1.97 (1.57) de	66.87 (54.92)b	5.33 (13.33)ef	1153.70b
T <sub>4</sub>	T <sub>1</sub> + <i>Bacillus thuringiensis kurstaki</i> 127 SC @ 3 ml/l	5.00 (2.35)	3.12 (1.90) cd	2.53 (1.74) cd	1.43 (1.39) e	76.83 (61.31)ab	3.87 (11.33)f	1170.37b
T <sub>5</sub>	T <sub>1</sub> + <i>Beauveria bassiana</i> @ 5 g/ l	5.27 (2.40)	3.62 (2.03) bc	3.07 (1.89) bc	2.37 (1.69) de	63.61 (52.95)b	6.53 (14.80)de	1018.52b
T <sub>6</sub>	T <sub>1</sub> + <i>Metarhizium anisopliae</i> @ 5 g/ l	5.28 (2.40)	4.18 (2.16) abc	3.53 (2.01) bc	2.77 (1.81) cd	57.54 (49.37)b	7.97 (16.38)cd	972.22bc
T <sub>7</sub>	T <sub>1</sub> + Chlorantraniliprole 18.5 SC @ 0.2 ml/ l	5.08 (2.36)	2.27 (1.66) d	1.97 (1.57) d	0.37 (0.93)f	94.76 (79.15)a	2.33 (8.75)g	1488.89a
T <sub>8</sub>	Untreated control	5.11 (2.37)	5.43 (2.43)a	6.12 (2.57) a	6.37 (2.62) a	0.00 (0.00)d	23.57 (29.03)a	464.81e
SEm±		NS	0.05	0.06	0.06	4.18	0.51	50.58
CD (p=0.05)		NS	0.17	0.19	0.20	12.70	1.56	153.38

DBT = Day(s) Before Treatment; DAT = Day(s) After Treatment

\*Figures in parentheses are  $\sqrt{(x+0.05)}$  transformed values, \*\*Figures in parentheses are Arc sine transformed values, In each column mean values followed by the different letters are significantly different according to Tukey's honestly significant difference (HSD) tests ( $P < 0.05$ ).**Table 2.** Efficacy of selected bio-intensive management practices against pod borer (*Helicoverpa armigera*) infesting fieldpea during Rabi 2020-21

Sl. No.	Treatments	Mean pod borer population (No. of larvae/ plant)				Corrected mortality	Pod damage (%)	Yield (kg/ ha)
		1 DBT	3 DAT	7 DAT	15 DAT			
T <sub>1</sub>	Seed Treatment with Imidacloprid 600 FS @ 3 ml/kg of seed	6.1 (2.57)	5.16 (2.38) ab	4.37 *(2.21) b	4.67 *(2.27)b	**41.02 (39.80)d	10.37 ** (18.77) b	659.72d
T <sub>2</sub>	T <sub>1</sub> + NSKE @ 5%	5.7 (2.49)	4.87 (2.32) abc	4.13 (2.15) bc	3.90 (2.10) bc	50.99 (45.57)d	10.10 (18.52)b	720.83cd
T <sub>3</sub>	T <sub>1</sub> + HaNPV (2X10 <sup>9</sup> POBs/ml) @ 250 LE/ha	6.0 (2.55)	3.76 (2.06) cd	2.87 (1.83) def	2.07 (1.60) de	76.63 (61.20)bc	5.80 (13.93)cd	1037.22b
T <sub>4</sub>	T <sub>1</sub> + <i>Bacillus thuringiensis kurstaki</i> 127 SC @ 3 ml/l	5.8 (2.51)	3.62 (2.03) cd	2.73 (1.80)ef	1.63 (1.46) e	81.09 (64.31)b	4.17 (11.76)de	1073.61b
T <sub>5</sub>	T <sub>1</sub> + <i>Beauveria bassiana</i> @ 5 g/ l	5.9 (2.53)	4.23 (2.17) bcd	3.13 (1.91) cde	2.43 (1.71) de	71.76 (58.09)bc	7.50 (15.85)bc	991.67b
T <sub>6</sub>	T <sub>1</sub> + <i>Metarhizium anisopliae</i> @ 5 g/ l	6.0 (2.55)	4.67 (2.27) bc	3.70 (2.05) bcd	2.87 (1.83) cd	66.87 (54.98)c	8.37 (16.81)bc	893.06bc
T <sub>7</sub>	T <sub>1</sub> + Chlorantraniliprole 18.5 SC @ 0.2 ml/ l	5.8 (2.51)	3.13 (1.91) d	2.10 (1.61)f	0.47 (0.98)f	94.73 (76.73)a	2.67 (9.39)e	1286.67a
T <sub>8</sub>	Untreated control	5.9 (2.53)	6.27 (2.60)a	6.57 (2.66)a	7.67 (2.86) a	0.00 (0.00)e	23.77 (29.15)a	368.61e
SEm±		NS	0.06	0.05	0.07	-	0.62	38.59
CD (p=0.05)		NS	0.18	0.14	0.21	-	1.89	117.04

DBT = Day Before Treatment; DAT = Days After Treatment

\*Figures in parentheses are  $\sqrt{(x+0.5)}$  transformed values, \*\*Figures in parentheses are Arc sine transformed values, In each column mean values followed by the different letters are significantly different according to Tukey's honestly significant difference (HSD) tests ( $P < 0.05$ ).

a 76.63 and 81.09% death rate among the larval population, respectively. Efficacy unveiled by white (T5) and green muscardine fungus (T6) was almost statistically at par with each other. Between these two, T5 caused more mortality (71.76%) and population reduction (from 5.9 larvae/plant to 4.23, 3.13, and 2.43 larvae/plant at 3, 7 and 15 DAT, respectively) compared to T5 which exhibited a population reduction from 6.0 larvae/plant to 4.67, 3.70 and 2.87 larvae/plant at 3, 7 and 15 DAT, respectively, with larval mortality of 66.87%. Treatment 7, which

involved spraying Chlorantraniliprole 18.5 SC at 0.2 ml/l of water, was superior to all other treatments. This treatment significantly reduced the pest count, decreasing it from 5.8 larvae per plant to 3.13, 2.10, and 0.47 larvae per plant, respectively, and achieved the highest larval death rate of 94.73% compared to the control. Similar to the previous year, the pest population increased exponentially and reached at maximum level (7.67 larvae/plant) at 15 DAT without any interference of the pesticide treatments in the control plots with maximum pod

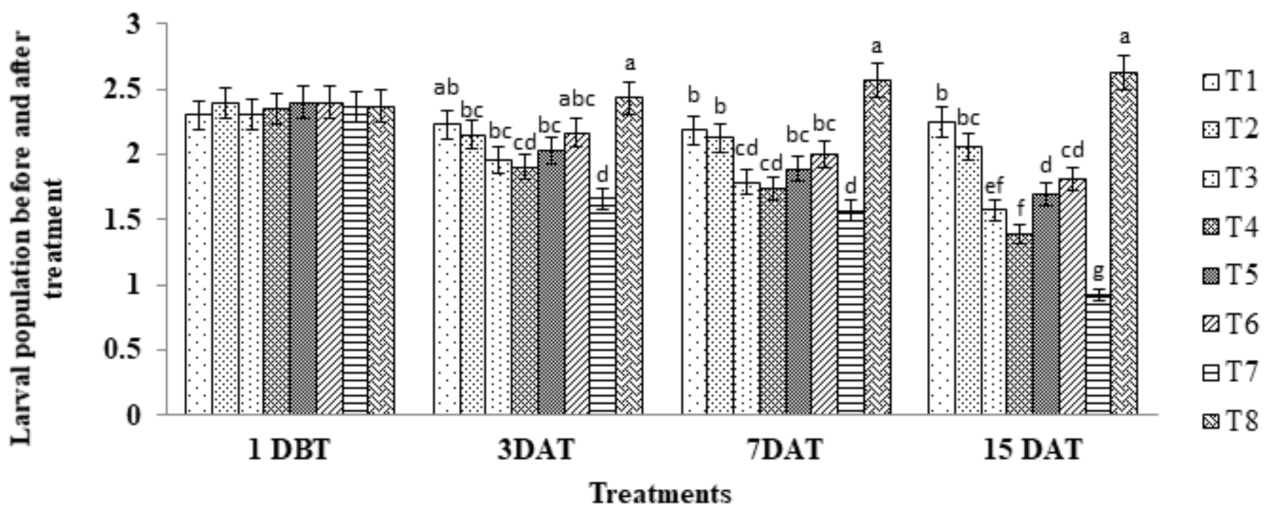


Fig. 1. Population of pod borer (*Helicoverpa armigera*) in fieldpea before and after treatments during Rabi 2019-20

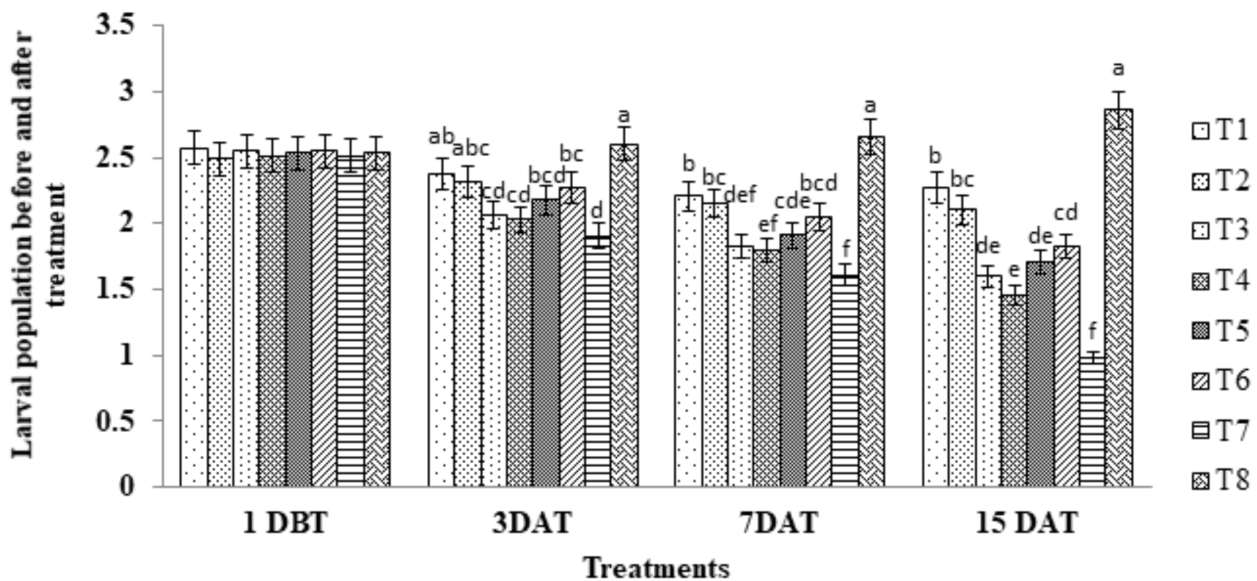


Fig. 2. Population of pod borer (*Helicoverpa armigera*) in fieldpea before and after treatments during Rabi 2020-21

**Table 3.** Yield and economics of selected bio-intensive practices to manage the pod borer pest in fieldpea

Treatments	Rabi 2019-2020						Rabi 2020-2021					
	Yield (kg ha <sup>-1</sup> )	Yield increase over control (kg ha <sup>-1</sup> )	Protection cost (Rs ha <sup>-1</sup> )	Value of increased yield (Rs ha <sup>-1</sup> )	Benefit from increased yield (Rs ha <sup>-1</sup> )	IBCR	Yield (kg ha <sup>-1</sup> )	Yield increase over control (kg ha <sup>-1</sup> )	Protection cost (Rs ha <sup>-1</sup> )	Value of increased yield (Rs ha <sup>-1</sup> )	Benefit from yield increase (Rs ha <sup>-1</sup> )	IBCR
T1	679.63	214.82	1209.00	7519.00	6310.00	5.22	659.72	291.11	1427.00	10,189.00	8762.00	6.14
T2	750.00	285.19	2197.00	9982.00	7785.00	3.54	720.83	352.22	2199.00	12,328.00	10,131.00	4.61
T3	1153.70	688.89	2464.00	24,111.00	21,648.00	8.79	1037.22	668.61	2464.00	23,402.00	20,938.00	8.50
T4	1170.37	705.56	2472.00	24,695.00	22,223.00	8.99	1073.61	705.00	2482.00	24,675.00	22,193.00	8.94
T5	1018.52	553.71	2450.00	19,380.00	16,920.00	6.88	991.67	623.06	2460.00	21,807.00	19,348.00	7.87
T6	972.22	507.41	2485.00	17,760.00	15,275.00	6.15	893.06	524.45	2435.00	18,356.00	15,921.00	6.54
T7	1488.89	1024.08	3302.00	35,842.00	32,541.00	9.85	1286.67	918.06	3202.00	32,132.00	28,930.00	9.04
T8	464.81	-	-	-	-	-	368.61	-	-	-	-	-

Considered costs: Imidacloprid - Rs. 470/100 ml, NSKE- Rs. 250/litre, HaNPV- Rs. 3566/kg, Bt- Rs. 600/litre, *Beauveria bassiana*- Rs. 355/kg, *Metarhizium anisopliae*- Rs 365/kg, Chlorantraniliprole 18.5 SC- Rs. 519/30ml, Selling price of pea grain- Rs. 35/kg

damage (29.15%). The least pod damage (2.67%) was recorded from chlorantraniliprole treated plots (T7) followed by T4, T3, T5, T6, T2, and T1 with a pod damage of 4.17%, 5.80%, 7.50%, 8.37%, 10.10% and 10.37%, respectively. Maximum seed yield was obtained from the plots having T7 (1286.67 kg/ha) followed by T4 (1073.61 kg/ha), T3 (1037.22 kg/ha), T5 (991.67 kg/ha), T6 (893.06 kg/ha), T2 (720.83 kg/ha) and T1 (659.72 kg/ha), respectively. Control plots provided the lowest seed yield (368.61 kg/ha).

#### Yield and economics

Every treatment increased the yield significantly compared to untreated control during both years of experimentation. During the first year, maximum yield increment (1024.08 kg/ha) was gained from T7 (T<sub>1</sub> + Chlorantraniliprole 18.5 SC @ 0.2 ml/ l), followed by T4 (705.56 kg/ ha), T3 (688.89 kg/ha), T5 (553.71 kg/ha), T6 (507.41 kg/ ha), T2 (285.19 kg/ha) and T1 (214.82 kg/ ha), respectively (Table 3). The highest incremental benefit was obtained from Chlorantraniliprole treatment followed by Bt (T4), NPV (T3), white muscardine fungus treatment (T5), and green muscardine fungus treatment (T6). Among the selected bio-intensive treatments T1 and T2 provided less yield compared to the others. The highest Incremental Benefit Cost Ratio (IBCR) (9.85) was also recorded from T7 which was mainly gained from significantly higher yield. After T7, the highest IBCR was recorded from Bt-treated plots (T4) followed by T3, T5, and T6, respectively. In the case of T1 and T2, though T2 provided more yield than T1, it exhibited less IBCR (3.54) compared to T1 (5.22). In the next year similar pattern of outcome was recorded, where all the treatments substantially enhanced the grain

yield compared to the control (Table 3). The highest yield increment (918.06 kg/ ha) was gained from T7 followed by T4 (705.0 kg/ha), T3 (668.61 kg/ha), T5 (623.06 kg/ha), T6 (524.45 kg/ha), T2 (352.22 kg/ha) and T1 (291.11 kg/ha), respectively. Maximum IBCR was recorded from T7 (9.04) followed by T4, T3, T5, T6, T1 and T2, respectively. As a chemical pesticide, Chlorantraniliprole is anticipated to significantly lower pest populations and increase yields. However, the effectiveness of Bt, NPV, and entomopathogenic fungi is nearly comparable to that of Chlorantraniliprole. Therefore, these biopesticides can be effectively utilized to manage gram pod borer in field pea crop and to potentially enhance yields.

Limited studies have been conducted to know the efficacy of biopesticides for controlling gram pod borer in field pea. A study suggested that Bt led to a 79.07-80.50% decrease in the gram pod borer population in pea crops, while Azadirachtin resulted in a 75.22-77.14% reduction in larval population. Both treatments significantly boosted yields compared to the control (Banshtu and Kaith 2020). In another study, cow urine and neem leaf extract provided maximum efficacy against gram pod borer and provided the highest seed yield as well as the highest benefit-cost ratio (Singh *et al.* 2020). These findings are partially agreed with our current outcomes. Another study demonstrated that Emamectin benzoate 5% SG was the most effective treatment for reducing gram pod borer in pea crops, followed by Spinosad 45% SC, NSKE+HaNPV+Bt and *Beauveria bassiana* 1.5% SG. In contrast, NSKE 5%, *Bacillus thuringiensis* 4% WSP, and Neem oil 2% were the least effective against this pest. Emamectin benzoate also yielded the highest cost-benefit ratio

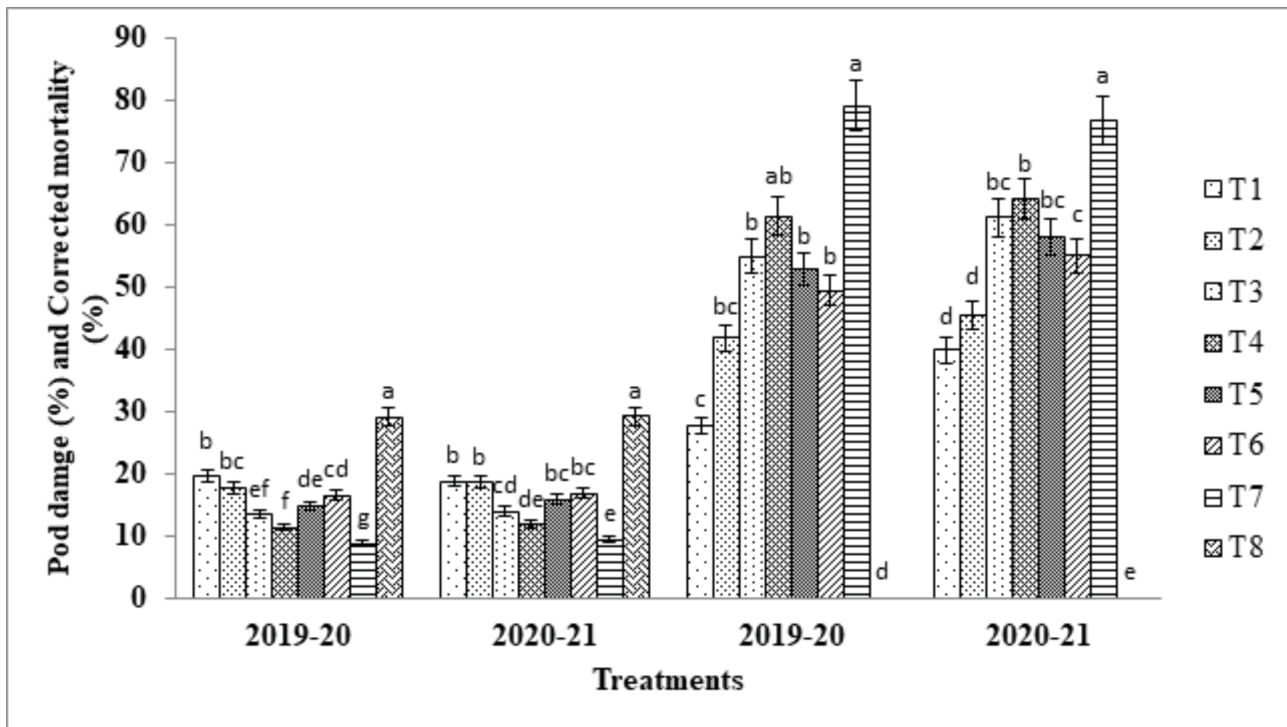


Fig 3. Pod damage caused by pod borer (*Helicoverpa armigera*) in field pea and larval mortality in different treatments

at 1:4.25 and produced a marketable yield of 19.20 q/ha. The next best treatments were Spinosad 45% SC with a CB ratio of 1:3.43 and a yield of 16.40 q/ha, and NSKE+HaNPV+Bt with a ratio of 1:3.00 and a yield of 14.60 q/ha. Other treatments showed decreasing ratios and yields, with Neem oil 2% having the lowest at 1:2.48 and 11.20 q/ha (Saiteja and Kumar 2022). These findings partially corroborate our findings.

Other studies on various pulse crops also provided partial support for our present findings. Several studies demonstrated the superiority of Chlorantraniliprole for managing gram pod borer. In addition to having the highest gain yield among the various insecticides, chlorantraniliprole 18.5 SC @ 25 g a.i./ha was proved to be the most successful in limiting the pod borer larvae population and reducing pod borer damage in field pea crop (Banerjee and Pal 2021). The most successful treatment for reducing the population of gram pod borer larvae in gram was the application of chlorantraniliprole 18.5% SC @ 25 g a.i./ha which also provided maximum yield (Rani *et al.* 2018, Upadhyay *et al.* 2020, Alok *et al.* 2022). Shinde *et al.* (2013) revealed the efficacy of microbials against *H. armigera* in chickpea and found that the HaNPV was the most effective biopesticide which registered the utmost yield. An experiment by

Rathod *et al.* (2014) revealed that *Bt* and *Beauveria bassiana* caused 56.25 and 54.20% larval mortality of gram pod borer at 15 DAS in pigeon pea. Yogesh and Kumar (2014) also demonstrated the maximum efficacy of NPV 250 LE + imidacloprid 17.8 SL in pod borer suppression. HaNPV and *BtK* (*kurstaki*) caused 43.29 and 40.82% reduction of gram pod borer population in chickpea. They also induced crop yield significantly compared to the control and showed a benefit-cost ratio of 1.35 and 1.22, respectively (Dinesh *et al.* 2017). In chickpea, among the selected microbial pesticides, HaNPV was most effective for controlling gram pod borer followed by *Beauveria bassiana* and *Metarhizium anisopliae*. The benefit-cost ratio was higher in *Beauveria bassiana* (7.09) followed by Ha NPV (6.09) and *Metarhizium anisopliae* (3.79), respectively (Kumar *et al.* 2018). In pigeon pea, the application of NPV and *Metarhizium anisopliae* caused considerably less pod damage (42.01 and 46.71%) and higher seed yield compared to the control (Agale *et al.* 2021). In green gram application of NPV reduced the pod borer population up to 61.69% while NSKE caused a 56.45% population reduction of pod borer. These two biopesticides also increased seed yield considerably compared to unsprayed control with a benefit-cost ratio of 10.80 and 8.26, respectively (Meena *et al.* 2022). The aforementioned reports by

several workers are partially in line with the present experimental results.

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