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Field efficacy of selected bio-pesticides against *Helicoverpa armigera* (Hübner) and their effect on pod damage and grain yield of chickpea (*Cicer arietinum* L.)

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Abstract

Helicoverpa armigera (Hübner) is the most destructive insect pest of chickpea and causes substantial yield losses under field conditions. A field study was undertaken to evaluate the efficacy of selected bio-pesticides against *H. armigera* in chickpea. Among the tested treatments, *Bt* commercial (Delfin) proved to be the most effective by recording the lowest mean larval population after the first spray (0.33 larva plant⁻¹), second spray (0.15 larva plant⁻¹) and on a cumulative basis (0.24 larva plant⁻¹). (PDKV *Bt* strain) PDKV SY-4 25% WP was the next most effective treatment with a cumulative mean larval population of 0.54 larva plant⁻¹ and was statistically at par with *HaNPV* (0.66 larva plant⁻¹). *Bt* commercial (Delfin) also recorded the lowest pod damage (1.81%) and the highest grain yield (18.20 q ha⁻¹), whereas the untreated control recorded the highest cumulative larval population (2.24 larvae plant⁻¹), maximum pod damage (11.97%) and the lowest grain yield (9.69 q ha⁻¹). The findings of the present investigation demonstrate that *Bt* commercial (Delfin), followed by (PDKV *Bt* strain) PDKV SY-4 25% WP and *HaNPV*, effectively suppressed *H. armigera*, minimized pod damage and enhanced grain yield. These bio-pesticides offer effective and environmentally compatible options for the sustainable management of gram pod borer in chickpea.

Keywords: chickpea, *Helicoverpa armigera*, bio-pesticides, *Bacillus thuringiensis*, grain yield

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops cultivated in India because of its high nutritional value and its significant contribution to food and nutritional security. The crop is an excellent source of protein, carbohydrates, minerals and vitamins and plays an important role in maintaining soil fertility through biological nitrogen fixation (Bhatt and Patel, 2001; Lamesgen Yegrem, 2021) [3, 11]. India is the largest producer of chickpea, cultivating the crop on 9.58 million ha with an annual production of 11.03 million tonnes during 2023–24 (Anonymous, 2023–24) [1]. In Maharashtra, chickpea occupied 2.82 million ha with a production of 3.53 million tonnes during 2024–25 (Anonymous, 2024–25) [2]. Despite its importance, the productivity of chickpea is considerably affected by several insect pests.

Among the insect pests attacking chickpea, the gram pod borer, *Helicoverpa armigera* (Hübner), is recognized as the most destructive species owing to its wide host range, high reproductive potential and destructive feeding behaviour (Garg and Surendra Kumar, 2000) [6]. The larvae feed on leaves, flower buds, flowers and developing pods, causing severe quantitative and qualitative losses. Under severe infestation, yield losses may range from 25–30 per cent and may exceed 75 per cent under favourable conditions (Sarwar *et al.*, 2009; Jeyarani *et al.*, 2010) [16, 7]. A single larva is capable of damaging up to 40 pods in a single feeding cycle, making the pest one of the major constraints to profitable chickpea cultivation (Khan *et al.*, 2009) [8].

The management of *H. armigera* has largely relied on repeated applications of synthetic insecticides. Although these insecticides provide rapid suppression of the pest, their indiscriminate use has resulted in the development of insecticide resistance, pest resurgence, pesticide residues and adverse effects on beneficial organisms and the environment (Ningthoujam *et al.*, 2015;

Mesnage and Seralini, 2018) [13, 12]. Consequently, emphasis has shifted towards environmentally safer pest management practices that are compatible with integrated pest management (IPM) programmes.

Bio-pesticides have emerged as promising alternatives because of their target specificity, environmental safety and compatibility with natural enemies. Several studies have demonstrated the effectiveness of *Bacillus thuringiensis* (Bt), *Helicoverpa armigera* nucleopolyhedrovirus (HaNPV), *Beauveria bassiana*, *Metarhizium anisopliae* and neem-based formulations in suppressing *H. armigera* infestation under field conditions (Rachna and Kaushik, 2018; Gaffar *et al.*, 2024; Patel *et al.*, 2025) [15, 14]. However, comparative information on the field performance of the PDKV-developed Bt formulation (PDKV SY-4 25% WP) in relation to commercially available Bt and other bio-pesticides under the agro-climatic conditions of Vidarbha is limited.

Therefore, the present investigation was undertaken to evaluate the field efficacy of selected bio-pesticides against *H. armigera* on chickpea with respect to larval suppression, reduction in pod damage and improvement in grain yield under field conditions.

Materials and Methods

Experimental site

The field experiment was conducted during the Rabi season of 2025–26 at the Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. The experimental farm is located at 20°42' N latitude, 77°02' E longitude and an altitude of 307.42 m above mean sea level. The chickpea crop was raised by following the recommended agronomic practices of the university.

Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) comprising eight treatments with three replications using chickpea variety JAKI-9218. The experiment comprised the following treatments, HaNPV (1×10^9 POBs ml⁻¹) @ 10 ml/10 L of water, Bt commercial (Delfin) @ 10 g/10 L of water, (PDKV Bt strain) PDKV SY-4 25% WP (1.7×10^8 spores g⁻¹) @ 10 g/10 L of water, neem oil 2% @ 7–8 ml/10 L of water, neem seed extract (NSE) 5%, *Beauveria bassiana* (1×10^9 CFU ml⁻¹) @ 50 ml/10 L of water, *Metarhizium anisopliae* (1×10^9 CFU ml⁻¹) @ 50 ml/10 L of water, and an untreated control (water spray). Two foliar sprays were applied using a knapsack sprayer with a spray volume of 500 L ha⁻¹. The first spray was applied at the 50% flowering stage of the crop, while the second spray was imposed 15 days after the first application.

Observations

Five plants were selected randomly and tagged in each plot for recording observations. The larval population of *H. armigera* was recorded one day before spraying and at 3, 7 and 14 days after each spray. The cumulative mean larval population was calculated using observations recorded after both sprays.

Per cent pod damage was recorded at harvest by counting healthy and damaged pods from the selected plants and was calculated using the following formula:

$$\text{Pod damage (\%)} = (\text{Number of damaged pods} / \text{Total number of pods}) \times 100$$

Grain yield from each net plot was recorded after harvest and converted into quintals per hectare (q ha⁻¹).

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design (RBD). Larval population and per cent pod damage data were subjected to square root transformation $[\sqrt{x + 0.5}]$ prior to statistical analysis, whereas grain yield data were analysed on the original scale. Treatment means were compared using the Critical Difference (CD) test at the 5% level of significance.

Results and Discussion

Field efficacy of selected bio-pesticides against *Helicoverpa armigera* (Hübner)

The data presented in Table 1 revealed that the pre-treatment larval population recorded one day before the first spray did not differ significantly among the treatments, indicating a uniform distribution of *H. armigera* before the imposition of treatments. However, significant differences among the treatments were observed at all post-treatment observations following both the first and second sprays.

Following the first spray, all the bio-pesticidal treatments significantly reduced the larval population of *H. armigera* compared with the untreated control. Based on the mean larval population, Bt commercial (Delfin) proved to be the most effective treatment by recording the lowest mean larval population of 0.33 larva plant⁻¹ and was significantly superior to all the remaining treatments. (PDKV Bt strain) PDKV SY-4 25% WP recorded the next lowest mean larval population (0.68 larva plant⁻¹) and was statistically at par with HaNPV (0.86 larva plant⁻¹). Neem oil 2%, NSE 5% and *Beauveria bassiana* recorded mean larval populations of 1.28, 1.28 and 1.33 larvae plant⁻¹, respectively, and were statistically at par with each other. *Metarhizium anisopliae* recorded a comparatively higher mean larval population (1.42 larvae plant⁻¹) and was significantly inferior to the above treatments. The untreated control (water spray) recorded the highest mean larval population (2.13 larvae plant⁻¹).

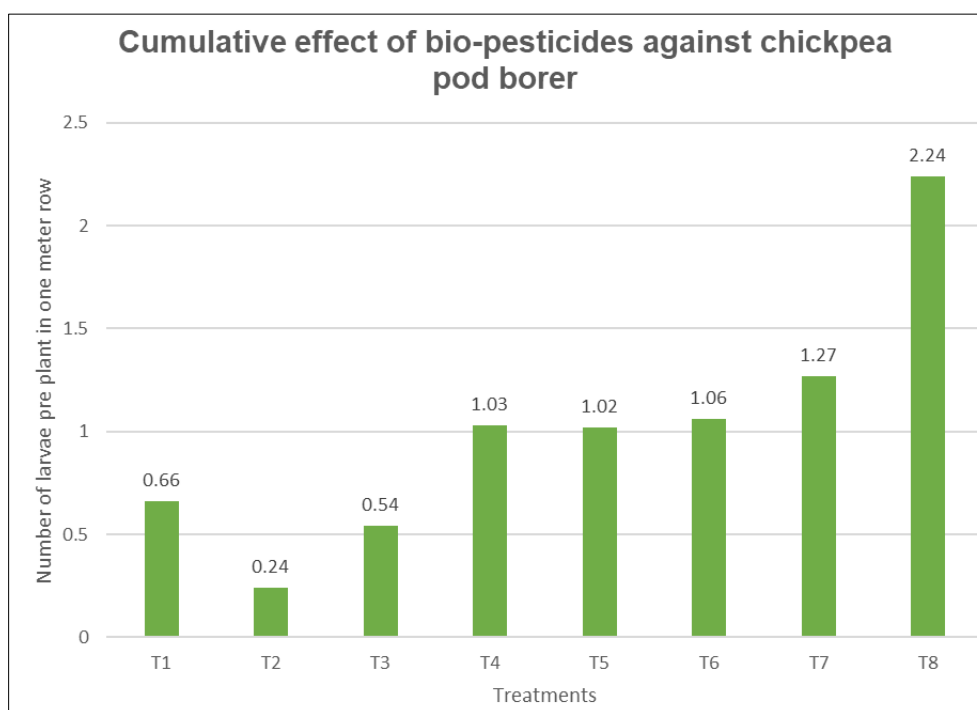
The results obtained after the second spray also revealed significant differences among the treatments. Bt commercial (Delfin) again recorded the lowest mean larval population (0.15 larva plant⁻¹) and proved significantly superior over all the remaining treatments. (PDKV Bt strain) PDKV SY-4 25% WP recorded a mean larval population of 0.40 larva plant⁻¹ and was statistically at par with HaNPV (0.47 larva plant⁻¹). Neem oil 2%, NSE 5% and *Beauveria bassiana* recorded mean larval populations of 0.77, 0.75 and 0.80 larva plant⁻¹, respectively, and were statistically at par with one another. *Metarhizium anisopliae* recorded a comparatively higher mean larval population (1.13 larvae plant⁻¹), whereas the untreated control recorded the highest mean larval population (2.36 larvae plant⁻¹).

The cumulative effect of two consecutive sprays clearly demonstrated the superiority of Bt-based treatments over the other bio-pesticides. The cumulative mean larval population differed significantly among the treatments. Bt commercial (Delfin) recorded the lowest cumulative mean larval population (0.24 larva plant⁻¹) and was significantly superior over all the other treatments. (PDKV Bt strain) PDKV SY-4 25% WP (0.54 larva plant⁻¹) was the next most effective treatment and was statistically at par with HaNPV (0.66 larva plant⁻¹). Neem oil 2%, NSE 5% and *Beauveria bassiana* recorded cumulative mean larval populations of 1.03, 1.02 and 1.06 larvae plant⁻¹, respectively, and were statistically at par with each other. *Metarhizium anisopliae* recorded a comparatively higher cumulative mean larval population (1.27 larvae plant⁻¹) and was significantly inferior to the above treatments but superior to the untreated control, which recorded the highest cumulative mean larval population (2.24 larvae plant⁻¹).

Table 1: Field efficacy of selected bio-pesticides against *Helicoverpa armigera* (Hübner) on chickpea during first and second sprays and cumulative mean larval population

Sr. No.	Treatments	Dose	1 st Spray					2 nd Spray				Cumulative Mean
			<i>H. armigera</i> larvae per plant				Mean	<i>H. armigera</i> larvae per plant			Mean	
			1 DBS	3 DAS	7 DAS	14 DAS		3 DAS	7 DAS	14 DAS		
1	<i>HaNPV</i> (1 × 10 ⁹ POB's/ml)	10 ml/10 l	1.33 (1.34)	1.40 (1.37)	0.66 (1.07)	0.53 (1.01)	0.86 (1.16)	0.66 (1.07)	0.40 (0.94)	0.33 (0.91)	0.47 (0.98)	0.66 (1.08)
2	Commercial <i>Bt</i> (Delfin)	20 g/10 l	1.60 (1.44)	0.46 (0.98)	0.33 (0.91)	0.20 (0.83)	0.33 (0.91)	0.20 (0.83)	0.13 (0.79)	0.13 (0.79)	0.15 (0.80)	0.24 (0.86)
3	PDKV– SY – 4 25% WP (1.7 × 10 ⁸ spores/g)	20 g/10 l	1.26 (1.32)	0.80 (1.13)	0.66 (1.07)	0.60 (1.04)	0.68 (1.09)	0.53 (1.01)	0.33 (0.91)	0.33 (0.91)	0.40 (0.94)	0.54 (1.02)
4	Neem oil 2%	7-8 ml/10 l	1.60 (1.44)	1.46 (1.40)	1.26 (1.32)	1.13 (1.27)	1.28 (1.33)	0.93 (1.19)	0.73 (1.10)	0.66 (1.07)	0.77 (1.13)	1.03 (1.23)
5	NSE	5%	1.73 (1.49)	1.53 (1.42)	1.20 (1.30)	1.13 (1.27)	1.28 (1.33)	1.00 (1.22)	0.67 (1.07)	0.60 (1.04)	0.75 (1.12)	1.02 (1.23)
6	<i>Beauveria bassiana</i> (1 × 10 ⁹ CFU/ml)	50 ml/10 l	1.80 (1.51)	1.66 (1.47)	1.33 (1.35)	1.00 (1.22)	1.33 (1.35)	1.00 (1.22)	0.73 (1.10)	0.66 (1.07)	0.80 (1.14)	1.06 (1.25)
7	<i>Metarhizium anisopliae</i> (1 × 10 ⁹ CFU/ml)	50 ml/10 l	1.73 (1.49)	1.53 (1.42)	1.40 (1.37)	1.33 (1.35)	1.42 (1.38)	1.33 (1.35)	1.07 (1.24)	1.00 (1.22)	1.13 (1.27)	1.27 (1.33)
8	Control (water spray)	-	1.46 (1.39)	1.93 (1.55)	2.20 (1.64)	2.26 (1.65)	2.13 (1.62)	2.26 (1.66)	2.33 (1.68)	2.47 (1.71)	2.36 (1.68)	2.24 (1.65)
	F test		NS	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
	SE(m)±		0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.04
	CD @5%		NS	0.18	0.16	0.15	0.16	0.15	0.13	0.13	0.13	0.12
	CV%		8.37	7.73	7.41	7.32	7.49	7.29	6.83	6.89	7.00	5.97

Figures in parentheses are square root transformed values $\sqrt{(x+0.5)}$

**Graph 1:** Cumulative effect of bio-pesticides against chickpea pod borer

The superior efficacy of *Bt* commercial (Delfin) observed in the present investigation may be attributed to the insecticidal Cry proteins produced by *Bacillus thuringiensis*, which disrupt the midgut epithelium of susceptible larvae, resulting in rapid cessation of feeding followed by larval mortality. The promising performance of (PDKV *Bt* strain) PDKV SY-4 25% WP indicates that this indigenous *Bt* formulation possesses comparable insecticidal potential under field conditions. *HaNPV* also provided satisfactory suppression of *H. armigera*, although its comparatively slower action may be associated with the time required for viral infection, multiplication and eventual mortality of the host larvae. The comparatively lower efficacy of neem-based products and entomopathogenic fungi may be attributed to

their slower mode of action and greater dependence on favourable environmental conditions for successful infection and persistence.

Effect of selected bio-pesticides on pod damage and grain yield of chickpea

The data presented in Table 2 revealed that the different bio-pesticidal treatments significantly influenced both pod damage caused by *Helicoverpa armigera* and grain yield of chickpea. The extent of pod damage varied significantly among the treatments and was closely associated with their efficacy in suppressing the larval population throughout the crop growth period.

Among the evaluated treatments, *Bt* commercial (Delfin) recorded the lowest pod damage (1.81%) and proved to be the most effective treatment. It was followed by (PDKV *Bt* strain)

PDKV SY-4 25% WP (2.73%) and *HaNPV* (2.96%), both of which also recorded significantly lower pod damage than the remaining treatments. NSE 5% (4.37%) performed better than neem oil 2% (5.19%), whereas *Beauveria bassiana* (5.35%) and

Metarhizium anisopliae (7.13%) were comparatively less effective in reducing pod damage. The untreated control (water spray) recorded the highest pod damage (11.97%), indicating severe infestation in the absence of effective plant protection.

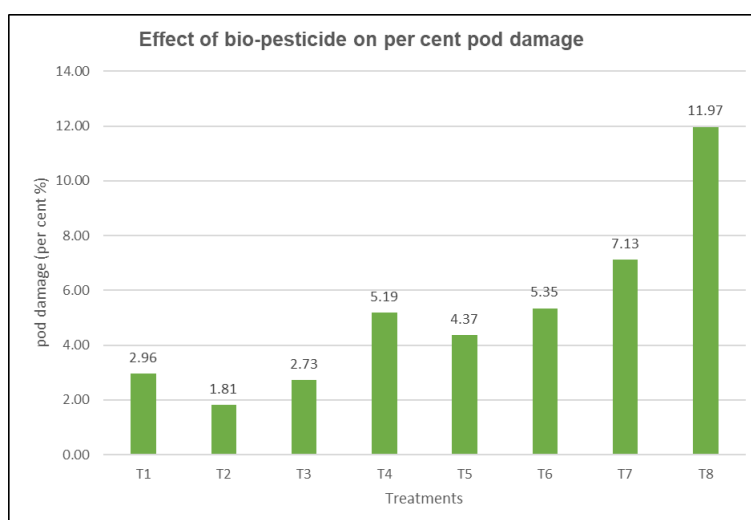
Table 2: Effect of selected bio-pesticides on pod damage and grain yield of chickpea

Sr. No.	Treatments	Pod Damage (%)	Yield (q/ha)
1	<i>HaNPV</i> (1×10^9 POB's/ml)	2.96 (1.85)	16.31
2	Commercial <i>Bt</i> (Delfin)	1.81 (1.52)	18.20
3	PDKV– SY – 4 25% WP (1.7×10^8 spores/g)	2.73 (1.78)	16.72
4	Neem oil 2%	5.19 (2.38)	14.20
5	NSE 5%	4.37 (2.20)	16.30
6	<i>Beauveria bassiana</i> (1×10^9 CFU/ml)	5.35 (2.41)	13.89
7	<i>Metarhizium anisopliae</i> (1×10^9 CFU/ml)	7.13 (2.76)	12.72
8	Control (water spray)	11.97 (3.52)	9.69
	F test	SIG	SIG
	SE(m)±	0.07	0.61
	CD @5%	0.22	1.86
	CV%	5.80	7.20

Figures in parentheses are square root transformed values $\sqrt{(x+0.5)}$.

A similar trend was observed with respect to grain yield. *Bt* commercial (Delfin) recorded the highest grain yield (18.20 q ha⁻¹) and was significantly superior to all other treatments. The next highest grain yield was recorded in (PDKV *Bt* strain) PDKV SY-4 25% WP (16.72 q ha⁻¹), followed by *HaNPV* (16.31 q ha⁻¹) and NSE 5% (16.30 q ha⁻¹). These three treatments were statistically at par with one another. Neem oil 2% produced a grain yield of 14.20 q ha⁻¹, followed by *Beauveria bassiana* (13.89 q ha⁻¹) and *Metarhizium anisopliae* (12.72 q ha⁻¹). The untreated control recorded the lowest grain yield (9.69 q ha⁻¹).

The reduction in pod damage and the corresponding increase in grain yield observed under *Bt* commercial (Delfin), (PDKV *Bt* strain) PDKV SY-4 25% WP and *HaNPV* may be attributed to their superior suppression of *H. armigera* larvae during the reproductive stage of the crop. Effective management of the larval population protected developing pods from feeding injury, resulting in lower pod damage and improved grain yield. In contrast, higher larval infestation in the untreated control resulted in greater pod damage and consequently lower grain yield.



Graph 2: Effect of bio-pesticide on per cent pod damage

The present findings are in close agreement with those of Cherry *et al.* (2000) [5], who reported effective suppression of *Helicoverpa armigera* by *HaNPV* under field conditions. Singh and Yadav (2007) [18] also observed that *Bacillus thuringiensis* was more effective than neem-based treatments in reducing the larval population of gram pod borer. Khanna *et al.* (2009) [9]

further reported that *Bt* application significantly reduced larval infestation and pod damage, resulting in higher grain yield in chickpea. Similarly, Sharma and Rajnikant (2023) [17] found that *Bacillus thuringiensis* recorded lower larval population and performed better than *Beauveria bassiana*, neem oil and NSKE in suppressing *H. armigera*. Gaffar *et al.* (2024) also reported that

Bt-based treatments were superior to botanical bio-pesticides in reducing larval population, minimizing pod damage and producing higher marketable yield under field conditions. Likewise, Biradar *et al.* (2024) ^[4] observed that *Bacillus thuringiensis* recorded lower larval population than NSKE and *Beauveria bassiana*, indicating its greater effectiveness against gram pod borer. Patel *et al.* (2025) ^[14] reported that *Bt* formulations and *HaNPV* significantly reduced larval population and pod damage while improving grain yield compared with the untreated control, whereas Kumar *et al.* (2026) ^[10] found that *Bacillus thuringiensis* consistently recorded lower larval population, higher grain yield and better economic returns than neem-based treatments and entomopathogenic fungi. The results of the present investigation, therefore, substantiate earlier findings that *Bt*-based bio-pesticides, particularly *Bt* commercial (Delfin), followed by PDKV SY-4 25% WP and *HaNPV*, are highly effective in suppressing *H. armigera*, reducing pod damage and improving grain yield under field conditions.

Conclusion

The present investigation demonstrated that the tested bio-pesticides differed significantly in their effectiveness against *Helicoverpa armigera* under field conditions. Among the evaluated treatments, *Bt* commercial (Delfin) consistently proved to be the most effective by recording the lowest larval population, minimum pod damage and the highest grain yield. (PDKV *Bt* strain) PDKV SY-4 25% WP emerged as the next most effective treatment and exhibited performance comparable to *HaNPV* in suppressing gram pod borer infestation. Neem-based products and entomopathogenic fungi also reduced pest infestation compared with the untreated control, although their efficacy was comparatively lower than *Bt*-based treatments. The findings of the present study indicate that *Bt* commercial (Delfin), followed by PDKV SY-4 25% WP and *HaNPV*, can be effectively incorporated into integrated pest management programmes for sustainable management of *H. armigera* in chickpea under the agro-climatic conditions of Vidarbha.

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