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Efficacy and Economic Evaluation of Various Biopesticides against *Helicoverpa armigera* in Chickpea

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Abstract: The field experiment conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar evaluated the efficacy of various biopesticides, including *Beauveria bassiana*, *Bacillus thuringiensis*, neem seed kernel extract (NSKE), and neem leaves extract, alongside the chemical insecticide chlorantraniliprole 18.5% SC against *Helicoverpa armigera* in chickpea during the *Rabi* 2024-25 season. Chlorantraniliprole consistently suppressed larval populations most effectively, achieving the lowest larval density (1.07 larvae/plant at 3 days after first spray) and maintaining superior control through subsequent observations. Among biopesticides, *B. bassiana* and NSKE recorded moderate larval control. In terms of pod damage and yield, chlorantraniliprole recorded the lowest pod damage (14.8%) and highest grain yield (789.67 kg/ha), while *B. bassiana* and neem seed kernel extract showed moderate pod damage (23.75% and 32.06%) with significant yield increase (718.31 kg/ha and 632.45 kg/ha). Biopesticide *B. bassiana* showed the highest incremental cost-benefit ratio (6.98), indicating greater economic efficiency compared to chlorantraniliprole (ICBR 5.57).

Keywords: *Beauveria bassiana*, Biorational, Chickpea, Incremental cost-benefit ratio, Management

Chickpea (*Cicer arietinum* L.), commonly known as Bengal gram is one of the most vital grain legumes worldwide, especially in underprivileged regions due to its significant nutritional value (Kumara Charyulu and Deb, 2014). Globally, chickpea ranks third among pulse crops, following peas and soybeans, representing about 15% of the global pulse production (Noreen et al., 2024). In addition to its dietary importance, chickpea supports sustainable agriculture by improving soil fertility when included in cereal-based crop rotation systems. India is a leading chickpea producer, with production reaching 13.75 million tonnes over 10.91 million hectares in 2021-22, yielding 12.6 q/ha (DES 2023, MOAF&W, GoI). Chickpea contributes nearly half of India's total pulse production with Maharashtra, Madhya Pradesh, Rajasthan, Gujarat, and Uttar Pradesh as the principal cultivating states. Rajasthan, in particular, cultivates chickpea on 2.25 million hectares, producing 2.66 million tonnes at 1177 kg/hectare productivity (E&S Division, DA&FW, 2022).

However, chickpea yields face threats from various biotic and abiotic stresses, including diseases such as *Ascochyta* blight, *Botrytis* gray mold, fusarium wilt, root rot, and stunt, along with insect pests like *Helicoverpa armigera*, aphids, black cutworm, bruchids, semiloopers, and leaf miners (Gurjar et al., 2011). Among these, *H. armigera* (Hübner), the gram pod borer, stands out as the most destructive pest, causing 30–40% pod damage on average, which can escalate to 80–90% in severe infestations, leading to yield reductions exceeding 75% (Patil SB et al., 2017). Over the past decade, several outbreak events have resulted in yield losses of 10–80%, translating into approximately US$328 million in economic losses annually in semi-arid tropics chickpea production (Patil et al., 2017). On a global scale, *Helicoverpa* damage to cotton, legumes, vegetables, and grains exceeds US$2 billion yearly, with over US$1 billion spent on control measures (Mahmood et al., 2021). The larvae damage tender leaves, flower buds, and pods, causing crop defoliation and yield losses of up to 400 kg/ha. Field surveys consistently identify *Helicoverpa* infestation as a primary constraint to chickpea productivity and quality, where one larva can destroy up to 40 pods during its lifecycle (Taggar and Singh, 2011, Ojha et al., 2017).

Insecticides remain the predominant method for controlling *H. armigera* globally; however, persistent challenges such as widespread resistance development have led to the pest's classification as a national threat in India (Golla et al., 2018). The repeated use of conventional insecticides has resulted in resistance to multiple chemical classes and disrupting natural crop ecosystem making pest management increasingly difficult and unsustainable. Consequently, there is an urgent need for insecticides that leave minimal residues and pose lower environmental risks. This study aims to evaluate and compare the efficacy of selected biopesticides against recommended insecticides through cost-benefit analysis to identify effective and environmentally safer management options for controlling gram pod borer, *H. armigera*, in chickpea.

MATERIAL AND METHODS

Field experiments on chickpea were conducted at G.B.

Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India, during the *Rabi* season of 2024-25. The chickpea variety PG-186 was sown in the first week of November with a row-to-row spacing of 30 cm and a plant-to-plant spacing of 10 cm. Seeds were planted in uniformly sized plots measuring 5 meters by 4 meters, and the crop was managed following recommended agronomic practices. Randomized block design with three replications was used for the trials to ensure statistical accuracy. Six treatments, including a control, were tested: *Beauveria bassiana* (400 g/ha), neem seed kernel extract (NSKE) at 5% (25 kg/ha), neem leaf extract (prepared fresh from 200 g leaves steeped overnight and diluted to 4 liters to achieve a 5% concentration), *Bacillus thuringiensis* (1 l/ha), Chlorantraniliprole 18.5% SC (30 g active ingredient/ha or 0.3 ml/l, the recommended insecticide), and an untreated control. All formulated treatments were sourced commercially from the market except for the neem leaf extract, which was freshly prepared. For neem leaf extract, 200 grams of neem leaves were weighed and mixed with distilled water, steeped overnight, and filtered through muslin cloth, followed by dilution to 4 liters with distilled water to achieve a 5% concentration.

Two foliar sprays were applied, the first at the economic threshold level of (one larva/meter row) and the second 15 days later. Larval populations of *H. armigera* were recorded 24 hours before spraying and again at 3, 7, and 10 days after each spray from five randomly selected plants per plot. Pod damage was assessed by calculating the percentage of damaged pods out of the total pods, and yield increases were calculated as a percentage increase over the control yield (El Fakhouri et al., 2022). The collected data were statistically analyzed using R softwere and SPSS version 16 to ensure the reliability of the results.

RESULTS AND DISCUSSION

The pre-treatment data revealed that the mean larval population of *H. armigera* per plant did not differ significantly among the various treatments and the untreated control, one day prior to the first spray during *Rabi* 2024–25 season, indicating a uniform pest distribution across the experimental plots. There were significant differences in larval populations among the treatments, beginning from 3 days after the first spray (3 DAFS) (Table 1). At 3 DAFS, chlorantraniliprole 18.5% SC recorded the lowest mean larval population (1.07 larvae/ plant), followed by *B. bassiana*, *B. thuringiensis* NSKE) and Neem leaves extract. The untreated control recorded the maximum larval population (2.27 larvae/plant). At 7 DAFS, chlorantraniliprole 18.5% SC continued to maintain the lowest larval population (0.93 larvae/plant) At 10 DAFS, chlorantraniliprole 18.5% SC again recorded the minimum larval density (1.33 larvae/plant), followed by *B. bassiana*, NSKE, *B. thuringiensis* and neem leaves extract. All treatments were significantly superior to the untreated control (5.13 larvae/plant).

The second spray was done after 15 DAFS, and the larval population of *H. armigera* was recorded 24 hours before the second spray, the larval population ranged from 3.20 to 5.53 larvae/plant, At 3 days after second spray, chlorantraniliprole 18.5% SC was significantly more effective than all other treatments, recording the lowest larval population, followed by *B. bassiana*, NSKE, *B. thuringiensis*, and neem leaves extract. In contrast, the maximum larval density was recorded in the untreated control (6.80 larvae/plant). At 7

Table 1. Efficacy of biopesticides and chlorantraniliprole against *H. armigera* in chickpea during 2024-25

Treatments	1^{st} Spray				2^{nd} Spray				Pod damage (%)**	Pod damage reduction over control (%)
	Mean population of *H. armigera/* Plant*				Mean population of *H. armigera/* Plant*					
	Pre Count	3 DAS	7 DAS	10 DAS	Pre Count	3 DAS	7 DAS	10 DAS		
Beuveria bassiana	0.33	1.27 (1.13)	2.20 (1.48)	2.40 (1.55)	3.20 (1.79)	3.73 (1.93)	3.53 (1.88)	2.73 (1.65)	23.75 (29.13)	70.85
Neem seed kernel extract	0.40	1.87 (1.37)	2.80 (1.67)	3.20 (1.79)	4.27 (2.07)	3.93 (1.98)	4.00 (2.00)	4.20 (2.05)	35.80 (36.75)	56.04
Neem leaves	0.33 (0.58)	1.60 (1.26)	3.67 (1.91)	3.80 (1.95)	4.60 (2.14)	4.27 (2.07)	5.67 (2.38)	5.87 (2.42)	57.56 (49.33)	29.33
Bacillus thuringiensis	0.27	1.80 (1.34)	3.13 (1.77)	3.53 (1.88)	4.00 (2.00)	4.13 (2.03)	4.27 (2.07)	4.80 (2.19)	38.26 (38.19)	53.03
Chlorantraniliprole 18.5% SC	0.33	1.07 (1.03)	0.93 (0.97)	1.33 (1.15)	3.47 (1.86)	2.33 (1.53)	1.53 (1.24)	2.40 (1.55)	14.80 (22.61)	81.83
Control	0.40	2.27 (1.51)	4.80 (2.19)	5.13 (2.27)	5.53 (2.35)	6.80 (2.61)	7.90 (2.81)	8.00 (2.83)	81.45 (64.50)	--
CD (p=0.05)	NS	(0.08)	(0.08)	(0.12	(0.18)	0.075	0.106	0.125	2.72	--

Values in parenthesis are *$\sqrt{x+0.5}$ transformed, and **angular transformed values;
Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

DAS, reduction in larval population was observed in chlorantraniliprole 18.5% SC-treated plots (1.53 larvae/plant), was statistically superior to all other treatments. The next best performance was *B. bassiana* (3.53 larvae/plant), followed by NSKE, *B. thuringiensis*, and neem leaves. At 10 DAS, a slight increase in the larval population was recorded across treatments. Chlorantraniliprole 18.5% SC maintained the lowest larval density (2.40 larvae/plant), followed by *B. bassiana* and NSKE. *B. thuringiensis* (4.80 larvae/plant) and neem leaves extract were statistically comparable and significantly superior to the untreated control .

In terms of pod damage and yield chlorantraniliprole 18.5% SC recorded the lowest pod damage percentage (14.80%) and the highest pod damage reduction over control (81.83%) (Table 1, 2) and recorded the maximum average grain yield (789.67 kg/ha), representing a 139.22% yield increase over control, indicating efficacy in protecting the crop and enhancing productivity. Among the biocontrol and botanical treatments, *B. bassiana* and NSKE were statistically at par, resulting in moderate pod damage (23.75% and 32.06%) and yield increases of 117.60% and 91.59% over control, respectively. *B. thuringiensis* showed similar effectiveness to NSKE. Neem leaves were less effective, showing higher pod damage (57.56%) and a lower yield (479.23 kg/ha). The control showed the highest pod damage (81.45%) and lowest grain yield (330.10 kg/ha).

In terms of ICBR value, *B. bassiana* recorded the highest ICBR value of 6.98 and a net gain of Rs. 19,183 over the control. Although the chemical insecticide chlorantraniliprole 18.5% SC resulted in the maximum grain yield of 789.67 kg/ha and the highest net gain of Rs. 22,015.33, its ICBR was lower at 5.57 due to the greater input cost involved. Among the other biopesticides, *B. thuringiensis* and NSKE achieved similar ICBR and the neem leaves treatment lowest ICBR. These findings showed that bio-pesticides, particularly *B. bassiana*, provided a higher return per unit cost compared to the chemical option, emphasizing their efficiency and economic advantage in pest management strategies and are much safer for the pollinators and natural enemies.

In the management of *H. armigera*, several studies have highlighted the potential of entomopathogenic fungi and biopesticides as effective and sustainable alternatives to chemical insecticides. Kalvnadi et al. (2018) reported that *B. bassiana* strain DC2 significantly reduced populations of second-instar larvae. This efficacy was further supported by Petlamul et al. (2019), who observed 100% mortality of *H. armigera* larvae at a spore concentration of 10^{10} conidia/ml. Similarly, Fite et al. (2020) confirmed that three *B. bassiana* strains at 10^{8} conidia/ml effectively controlled third-instar larvae. Laboratory bioassays align with these findings, showing 84-91% mortality for various *B. bassiana* formulations at 1×10^{7} times conidia/ml against third-instar larvae (Malinga and Laing, 2024). Field trials demonstrated efficacy of 50-60% within 7-10 days of foliar spray application (Malinga & Laing 2024). The efficacy of *B. bassiana* in chickpea was further supported by Deepthi and Yadav (2022). In addition to biopesticides, synthetic insecticides such as chlorantraniliprole have demonstrated sub-lethal effects on *H. armigera* populations (Depalo et al., 2017) but remain the most economically advantageous control tool for gram pod borer in chickpea, with superior benefit-cost ratios reported by Reddy and Kumar (2022). Akhtar et al. (2022) corroborated the superior yield and economic efficiency of chlorantraniliprole 18.5% SC in green gram, while neem oil (5%) and neem seed kernel extract efficacy were supported by Reza et al. (2016).

Table 2. Economic evaluation of biopesticides and chlorantraniliprole application for the management of *H. armigera* in chickpea during *rabi* 2024-25

Treatments	Dose (g/l or ml/l)	Cost of insecticide (Rs/ha)	Labour	Total cost (Insecticide + labour) (A)	Grain yield	Additional yield over control	MSP	Cost of grains (Rs)	Value of increased yield (Rs/ha) (B)	Net gain over control (C) (Rs.) (B-A)	ICBR (C/A)
Beuveria bassiana	5 ml/l	750	2000	2750	718.313	388.21	56.5	40584.70	21933.87	19183.87	6.98
Neem seed kernel extract	100 ml/l	1000	2000	3000	632.45	302.35	56.5	35733.61	17082.78	14082.78	4.69
Neem leaves	50 g/l	500	2000	2500	479.22	149.12	56.5	27076.31	8425.47	5925.47	2.37
Bacillus thuringiensis	2 ml/l	650	2000	2650	597.33	267.23	56.5	33749.15	15098.31	12448.31	4.70
Chlorantraniliprole 18.5% SC	0.15 ml/l	1950	2000	3950	789.66	459.56	56.5	44616.17	25965.33	22015.33	5.57
Control	--	--	--	--	330.10	--	56.5	18650.84	--	--	--

ICBR: Incremental Cost Benefit Ratio; MSP of whole pigeon pea: ₹.56.50/kg; Total spray solution used per treatment-: 6.0 liters; Number of applications: 02; Labourers required (02 per spray) : 4; Labour cost @ ₹.500/day.

Cost of biopesticides: *Beuveria bassiana:* ₹ 300/kg, *Bacillus thuringiensis:* ₹ 650/kg, Neem seed kernel extract: ₹ 1000, Neem leaves: ₹ 500; Cost of Chlorantraniliprole *:* ₹ 13000/l

Younas et al. (2023) demonstrated that both *B. bassiana* (at 3.21×10^6 conidia/ml) and chlorantraniliprole significantly reduced larval populations and pod infection in chickpea fields over successive years, contributing to increased crop yield. Moreover, *B. thuringiensis* based biopesticides, combined with *B. bassiana*, achieved high larval mortality rates in laboratory conditions and acceptable efficacy in the field (Malinga and Laing 2024). Collectively, these studies affirm the effective role of biopesticides like *B. bassiana*, *B. thuringiensis*, and botanicals such as neem leaf and seed extracts, alongside selected insecticides like chlorantraniliprole, in integrated pest management strategies for sustainable and economically viable control of *H. armigera*.

CONCLUSION

The study showed the effectiveness of biorational pesticides, particularly *B. bassiana*, in managing *H. armigera* in chickpea. Although chemical insecticides like chlorantraniliprole 18.5% SC achieved the highest yield, pod damage reduction, and larval suppression, *B. bassiana* provided effective pest control and recorded the highest ICBR among all the treatments. This indicates greater economic efficiency despite a slight reduction in yield when compared to chemical control. The superior ICBR of *B. bassiana* highlights its potential as a safer, environmentally sustainable alternative that conserves natural enemies and reduces chemical residue risks. Thus, integrating biorational options like *B. bassiana* into pest management programs can enhance both the economic and ecological sustainability of chickpea production systems.

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