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Efficacy of Biorational and Insecticides against *Helicoverpa armigera* (Hübner) in Pigeonpea

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***Abstract*:** The field experiment conducted at Norman E. Borlaug Crop Research Centre (N.E.B.C.R.C.), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during *Kharif* 2024–25 evaluated the efficacy of six biorational insecticides against the gram pod borer, *Helicoverpa armigera*, infesting pigeonpea. All treatments significantly reduced the larval population compared to the untreated control. Chlorantraniliprole 18.5% SC was most effective in reducing larval population, recording as low as 0.33 larvae/5 plants at 10 days after second spray, with pod damage reduction of 77.44% and a substantial grain yield of 797 kg/ha, representing a 97.11% increase over the untreated control. Spinetoram and azadirachtin also provided significant larval suppression and pod damage control, achieving pod damage reductions of 71.43% and 40.60%, and grain yields of 745.67 kg/ha and 652.50 kg/ha, respectively. *Bacillus thuringiensis* var. kurstaki demonstrated effective pest suppression with 45.86% pod damage reduction, a 72.51% yield increase to 697.50 kg/ha, and the highest incremental cost-benefit ratio (ICBR) of 8.20, underscoring superior economic efficiency. *Metarhizium anisopliae* displayed moderate efficacy with 29.32% pod damage reduction and a 42.70% yield increase. These findings highlight the potential of *Bt* as a highly effective and economically viable component of integrated pest management strategies, capable of reducing chemical pesticide reliance while sustaining pigeonpea productivity and profitability.

***Keywords*:** Biorational, Management, Insect pests, Insecticides, Pigeonpea

Pigeonpea (*Cajanus cajan* L.) is a vital grain legume crop in India, ranking second in cultivated area among pulse crops. It serves as a staple food, consumed both as green peas and dry seeds (Kumar et al., 2016, Agale et al., 2021). Predominantly grown in marginal lands or as part of mixed cropping systems with cotton, sorghum, and soybean, pigeonpea often receives limited farmer attention (Sharma et al., 2011). The crop's yield has stagnated over the last three decades, primarily due to damage caused by diverse insect pests (Basandrai et al., 2011). During reproductive phase, pigeonpea is vulnerable to biotic stresses, with pests attacking flowers, pods, and developing grains. In recent years, there has been a notable shift in pest dynamics on pigeonpea. Among the multiple insect pests infesting pigeonpea, the pod borer complex comprising the gram pod borer (*Helicoverpa armigera* Hübner), the legume pod borer (*Maruca vitrata* Geyer) which attacks during flowering and pod formation stages, and the pod fly (*Melanagromyza obtusa* Malloch) at the pod maturation stage pose the major biotic constraints to achieving higher productivity in the crop (Veeranna et al. 2023). *Helicoverpa armigera* larvae cause significant yield losses in pigeonpea by feeding aggressively on leaves during the early instar stages and later attacking developing pods and seeds, leading to an estimated annual grain loss of up to 250,000 tonnes and economic losses exceeding 3750 million rupees (Sardar et al., 2018). Damage to pigeonpea pods caused by the pod borer complex has been reported in range of 20 to 72 per cent (Priyadarshini et al., 2013). Besides the pod borers, other pests such as the leaf webber *Grapholita critica (*Meyr.) and several sucking pests including *Clavigralla gibbosa* Spinola, *Reptortus dentipes* Fabricius, *Anoplocnemis curvipis* (Fabricius), *Nezara virudula* (Linnaeus), and the green leafhopper *Empoasca kerri* (Pruthi), have emerged as significant threats, causing substantial economic losses (Rachappa et al., 2018). While chemical insecticides have been effective in controlling this pod pest complex, their indiscriminate application has led to adverse consequences including pest resurgence, development of insecticide resistance, disruption of natural enemy populations, health risks to humans and animals, and environmental contamination. Given these challenges, there is an urgent need to adopt eco-friendly and sustainable pest management strategies (Sahoo, 2002, Kumar & Muthukrishnan, 2017, Dokekar et al., 2025). The use of insecticides that are selective, target-specific, biodegradable, and safe for beneficial organisms is imperative. In this context, biorational insecticides, microbial pesticides, and botanical extracts have gained prominence owing to their efficacy in pest suppression and their role in maintaining ecological and economic balance (Chethan et al. 2024). The present study was undertaken to evaluate the efficacy of various insecticides and biorational insecticides against pod borer, particularly *Helicoverpa armigera*, within the pigeonpea agro-ecosystem.

MATERIAL AND METHODS

The field experiment was carried out at the N.E.B.C.R.C., Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, during the *Kharif* season of 2024-25. The study was in a randomized block design comprising six treatments, including an untreated control, each replicated three times. The pigeonpea variety PA 291 was cultivated using standard agronomic practices with a spacing of 70 × 20 cm in plots measuring 4 × 5 m². The treatments included foliar application of liquid formulations of *Bacillus thuringiensis* var. *kurstaki* (0.5% WP) @2.5 g/L, *Metarhizium anisopliae* (2 × 10^8 CFU/ml) @5 ml/l, azadirachtin (1500 ppm) @5 ml/l, spinetoram 11.7% SC @54 g a.i/ha (0.9 ml/l), chlorantraniliprole 18.5% SC @30 g a.i/ha (0.3 ml/l) (recommended insecticide), along with an untreated control were evaluated against *H. armigera.* The first foliar spray was applied at the 50% flowering stage, followed by a second application 10 days later. Insecticide treatments were applied using a manually operated foot sprayer equipped with a hollow cone nozzle. For recording observations on the larval population of *H. armigera*, five plants were randomly selected from each plot. The selected plants were carefully examined, and the number of *H. armigera* larvae was counted before the first spray and at 3, 7, and 10 days after each spray (AICRP, 2024). At harvest, 100 pods were randomly collected from each net plot. The percentage of pod damage was calculated based on these counts. The seed yield of pigeonpea from each net plot was recorded and extrapolated to yield per hectare.

Statistical analysis: Statistical analysis was carried out using SPSS software (version 16.0) using Duncan's Multiple Range Test (DMRT), with critical difference values calculated at the 5% level of significance.

RESULTS AND DISCUSSION

Cumulative Impact of biorational insecticide on larval population of *H. armigera:* The pre-treatment observations revealed that the mean larval population of *H. armigera*/5 plants did not differ significantly among the various treatments and the untreated control, one day prior to the first spray during *Kharif* 2024–25, indicating a fairly uniform distribution of the pest across treatments. At three days after the first spray (DAFS), significant differences in mean larval populations were observed among the treatments (Table 1). Chlorantraniliprole 18.5% SC proved to be the most effective, recording the lowest larval population (0.87 larvae/5 plants), followed by Spinetoram 11.7% SC , Azadirachtin 1500 ppm , *Bt.* var. *kurstaki* and *Metarhizium anisopliae* (over untreated control (1.60 larvae/5 plants). At seven DAFS, the lowest larval population (1.03 larvae/5 plants) was in Chlorantraniliprole 18.5% SC, which was statistically at par with Spinetoram 11.7% SC. Similar trends persisted at 10 DAFS, where the lowest larval population (1.10 larvae/5 plants) was observed in Chlorantraniliprole followed by Spinetoram (1.13 larvae/5 plants). Treatments with Azadirachtin 1500 ppm, *Bt* var*. kurstaki,* and *M. anisopliae* also recorded lower larval populations compared to the control (Table 1).

Prior to the second spray, the larval population of *H. armigera* ranged between 1.17 and 1.87 larvae/5 plants. At three days after the second spray (DASS) spray, Chlorantraniliprole 18.5% SC was significantly more effective than the other treatments in reducing larval numbers, with an average of 0.70 larvae/5 plants, and was statistically on par with Spinetoram. Among the biorational control options evaluated for pod borer suppression, Azadirachtin 1500 ppm demonstrated the highest efficacy, recording the lowest *H. armigera* population (1.07 larvae/5 plants) and showing parity with *Bt* var. *kurstaki*. Overall, Azadirachtin 1500 ppm ranked next in effectiveness to the chemical insecticide treatments. At 7 DASS, a marked reduction in larval population was noted, ranging from 0.47 to 2.07 larvae/5 plants across treatments. The minimum population in Chlorantraniliprole 18.5% SC, which was significantly superior to all other treatments and the untreated control. Spinetoram was the next most effective treatment, followed by Azadirachtin 1500 ppm, which was statistically comparable to *Bt* var. *kurstaki*. At 10 DASS, a substantial decline in larval population was observed across all treatments. Chlorantraniliprole 18.5% SC remained the most effective treatment, maintaining the lowest larval density of 0.33 larvae/5 plants. This was statistically at par with Spinetoram, followed by Azadirachtin 1500 ppm. *Bt* var. *kurstaki* and *M. anisopliae* were also found to be statistically comparable (Table 1).

The present findings are consistent with earlier studies emphasizing the effectiveness of Chlorantraniliprole against *H. armigera* in pigeonpea. Patel (2015), identified Chlorantraniliprole 18.5% SC as the most potent treatment for managing pod borer infestations in pigeonpea. Kumar et al. (2016), also reported that the *Bacillus thuringiensis* strain NBAII-*Bt* G4 at 2% was the next most effective treatment after the chemical insecticide spray, recording an average surviving larval population of *H. armigera* (1.01 larvae/plant) and *M. vitrata* (1.10 larvae/inflorescence). Warad et al. (2021) also highlighted Chlorantraniliprole 18.5% SC as the most effective treatment for pod borer management in pigeonpea. Veeranna et al. (2023) observed that Chlorantraniliprole 18.5% SC at 0.3 ml/l, followed by Emamectin benzoate 5% SG at 0.4 g/l, provided superior control of *H. armigera.* These findings collectively reinforce the superior efficacy of Chlorantraniliprole based treatments in reducing larval populations and minimizing pod damage under field conditions, thereby confirming its reliability as a key component in integrated pest management strategies for pigeonpea.

Efficacy of biorationals on pigeonpea pod damage and grain yield and Comparative evaluation of Incremental cost benefit ratio (ICBR): All the treatments significantly reduced pod damage caused by *H. armigera* compared to the untreated control. Among the treatments, Chlorantraniliprole 18.5% SC recorded the lowest pod damage (10.00%), the highest percent reduction in pod damage over control (77.44%), and the maximum grain yield (797.00 kg/ha), representing a 97.11% increase in yield over the untreated control. Spinetoram also performed well, resulting in 71.43% reduction over control, grain yield of 745.67 kg/ha, and an 84.42% yield increase. *Bt.* var. *kurstaki* resulted 45.86% reduction. Azadirachtin and *M. anisopliae* were comparatively less effective. The untreated control had the highest pod damage (44.33%) and lowest grain yield (404.33 kg/ha).

The comparative evaluation of ICBR (Table 2) revealed that although Chlorantraniliprole 18.5% SC achieved the highest grain yield and maximum pod damage reduction incremental cost-benefit ratio (ICBR) was 6.95, which is lower than that of several biorational treatments. *Bt var. kurstaki* recorded an ICBR of 8.20, the highest among all treatments, followed closely by Spinetoram (ICBR 6.91). Although *M. anisopliae* and Azadirachtin resulted in moderate yield increases and pod damage reduction, their ICBR values (4.53 and 5.40, respectively) were lower than *Bt*

Table 1. Efficacy of biorational insecticides against gram pod borer*, H. armigera* infesting pigeonpea

Treatment	Before spray	Mean number of *H. armigera* larvae/5 plants (days after spray)							Pod damage (%)	Pod damage reduction over control (%)
		1st Spray			Before spray	2nd Spray				
		3	7	10 DAF		3	7	10		
Bt. var. *kurstaki*	1.57^{a}	1.20^{bc}	1.27^{ab} (1.13)	1.33^{ab} (1.15)	1.50^{a} (1.22)	1.13^{bc} (1.06)	1.00^{bc} (1.00)	0.90^{c} (0.95)	24.00^{b}	36.09
Metarhizium anisopliae	1.67^{a}	1.33^{c} (1.15)	1.37^{b} (1.17)	1.43^{b} (1.20)	1.48^{a} (1.22)	1.20^{c} (1.10)	1.10^{c} (1.05)	0.97^{c} (0.98)	31.33^{b}	29.32
Azadirachtin 1500 ppm	1.60^{a}	1.13^{abc} (1.06)	1.20^{ab} (1.10)	1.30^{ab} (1.14)	1.37^{a} (1.17)	1.07^{bc} (1.03)	0.93^{bc} (0.97)	0.67^{b} (0.82)	26.33^{b}	48.87
Spinetoram 11.7% SC	1.70^{a} (1.30)	0.93^{ab} (0.97)	1.17^{ab} (1.08)	1.13^{a} (1.06)	1.23^{a} (1.11)	0.90^{ab} (0.95)	0.73^{ab} (0.86)	0.53^{ab} (0.73)	12.67^{a}	67.67
Chlorantraniliprole 18.5% SC	1.67^{a} (1.29)	0.87^{a} (0.93)	1.03^{a} (1.02)	1.10^{a} (1.05)	1.17^{a} (1.08)	0.70^{a} (0.84)	0.47^{a} (0.68)	0.33^{a} (0.58)	10.00^{a}	80.45
Control	1.53^{a} (1.24)	1.60^{d} (1.26)	1.73^{c} (1.32)	1.87^{c} (1.37)	1.87^{a} (1.37)	1.97^{d} (1.40)	2.07^{d} (1.44)	2.13^{d} (1.46)	44.33^{c}	

Means in the same column followed by the same letter are not significantly different from each other at the 5% probability level according to the Duncan's Multiple Range Test (DMRT).

Table 2. Comparative economic evaluation of biorational application over untreated control for the management of *H. armigera* in pigeonpea

Treatment	Quantity used (g/l or ml/l) in water	Cost of Insecticide (₹/ha)	Total cost (insecticide+ labour) (A)	Grain yield (kg/ha)	Percent increase in yield over control (%)	Cost of grains (₹)	Additional yield over control	Value of increased yield (₹/ha) (B)	Net gain over control (C) (₹) (B-A)	ICBR (C/A)
Bt. var. *kurstaki*	2.5	550	2550	697.50	72.51	55800	293.17	23453.33	20903.33	8.19
Metarhizium anisopliae	5	496	2496	577.00	42.70	46160	172.67	13813.33	11317.33	4.53
Azadirachtin 1500 ppm	5	1100	3100	652.50	61.38	52200	248.17	19853.33	16753.33	5.40
Spinetoram 11.7% SC	0.9	1450	3450	745.67	84.42	59653.33	341.33	27306.66	23856.66	6.91
Chlorantraniliprole 18.5% SC	0.3	1950	3950	797.00	97.11	63760	392.67	31413.33	27463.33	6.95
Control	-	-	-	404.33	-	32346.7	-	-	-	-
CD (p=0.05)	-	-	-	0.83	-		-	-	-	-

ICBR: Incremental Cost Benefit Ratio; MSP of whole pigeon pea : ₹.80.00/kg. Total spray solution used per treatment-: 6.0 liters; Sprays done-02; Labours required : 02 per spray =4; Labour cost @ ₹.500/day/labour.; Cost of *Bt.* var. *kurstaki* - *₹440/kg,* Cost of *Metarhizium anisopliae* - *₹200/kg,* Cost of *Azadirachtin 1500 ppm* - ₹440/l, Cost of *Spinetoram 11.7% SC* - ₹3235/l, Cost of *Chlorantraniliprole* - ₹13000/l *var. kurstaki* and Spinetoram. Prajapati and Patel, (2025) also reported that at both the green pod stage and harvest, plots treated with Chlorantraniliprole 0.006% exhibited the lowest pod damage (6.60%). Agale et al. (2021) reported that the application of Spinosad 45% SC was significantly effective, recording the lowest pod and seed damage by *H. armigera* . Taggar and Singh (2015) reported that the highest grain yield with Spinosad 45% SC, followed by *Bacillus thuringiensis* formulation at 1.5 kg/ha and a combination of *B. thuringiensis* with *Beauveria bassiana* at 3.0 g/l. Das et al. (2022) identified *B. thuringiensis* and Azadirachtin as effective options for managing the pod borer complex in pigeonpea. Veeranna et al. (2023) observed Chlorantraniliprole 18.5% SC in managed both *H. armigera* and *M. vitrata*.

CONCLUSION

B. thuringiensis var. kurstaki is an effective and economically advantageous option for managing *H. armigera* in pigeonpea, showing substantial pod damage reduction and yield increase with the highest incremental cost-benefit ratio (ICBR) among tested treatments. Although chemical insecticides such as Chlorantraniliprole have showed higher efficacy in reducing pest population and increasing yield, high cost and potential environmental risks make biorational pesticides a more sustainable and cost-effective alternative for long-term pest management. Spinetoram, Azadirachtin, and *Metarhizium anisopliae* also provided moderate control levels and yield improvements, supporting their use as complementary components in integrated pest management (IPM) strategies. The integration of Bt with these biorational and selective chemical options can enhance sustainability, reduce chemical residues, and conserve natural enemies, thus ultimately promote eco-friendly and profitable pigeonpea production systems.

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