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EVALUATION OF CERTAIN BIOPESTICIDES AGAINST *Helicoverpa armigera* AND *Maruca vitrata* IN PIGEONPEA

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ABSTRACT

Field trials were conducted to evaluate the efficacy of various biopesticides against the pod borer complex, specifically *Helicoverpa armigera* and *Maruca vitrata*, in pigeonpea at the Regional Agricultural Research Station, Warangal, over three consecutive *kharif* seasons from 2019 to 2021. The study assessed seven treatments, including both chemical options and an untreated control, for their effectiveness in suppressing the pod borer complex. The findings indicated that *Bacillus thuringiensis* var. *kurstaki* (Bt. kurstaki) at 1 g L^{-1}, Azadirachtin at 1500 ppm (administered at 5 mL L^{-1}), and *Beauveria bassiana* at 5 g L^{-1} were significantly superior and comparable to each other in controlling both the gram pod borer (*Helicoverpa armigera*) and the spotted pod borer (*Maruca vitrata*). These treatments achieved the highest mean percentage of larval reduction and the lowest cumulative percentage of pod damage compared to the control. Moreover, the best incremental cost-benefit ratio (ICBR) of 1:4.73 was recorded in plots treated with Bt. kurstaki at 1 g L^{-1}, which was comparable to the chemical control plot with an ICBR of 1:3.90. Thus, all three biopesticides represent viable, eco-friendly alternatives for managing pod borers in pigeonpea.

Keywords: Biopesticide, Ecofriendly, Pigeonpea, Pod borers

Pigeonpea (*Cajanus cajan* (L.) Millsp.), also known as *tur* or redgram, is a significant pulse crop in India, ranking just after chickpea in importance. This versatile grain legume is valued for its nutritional content, providing approximately 22% protein, 1.2% fat, and 65% carbohydrate, making it a vital component of the vegetarian diet (FAO, 2005). Pigeonpea is consumed both as green peas and dry seeds, commonly prepared as *dal*. Beyond its dietary benefits, pigeonpea plays a crucial role in soil health. Its ability to fix atmospheric nitrogen, extract water and nutrients from deeper soil layers, and contribute organic matter through leaf litter enhances soil fertility.

In India, pigeonpea is cultivated over 4.5 million hectares, with an annual production of 3.66 million tons and a productivity rate of 824 kg/ha (Anonymous, 2022). It constitutes approximately 15% of the total pulse production in the country. Major pigeonpea-producing states include Karnataka, Telangana, Maharashtra, Madhya Pradesh, Uttar Pradesh, and Jharkhand. In Telangana, pigeonpea is grown on 2,28,000 hectares, yielding 2,06,000 tons annually with a productivity rate of 904 kg/ha. The primary pigeonpea-growing districts in Telangana are Vikarabad, Sangareddy, Adilabad, Komaram Bheem Asifabad, Jogulamba Gadwal, and Narayanapet (Anonymous, 2022).

Currently, the acreage and production of pigeonpea in the Telangana region are experiencing a decline, largely due to biotic stresses affecting the crop, particularly at the reproductive stage. Among these biotic stresses, insect pests represent a significant barrier to achieving optimal yields. The crop is vulnerable to various insect pests throughout different growth stages, but the pod borer complex is particularly detrimental. This complex includes the gram pod borer (*Helicoverpa armigera* Hübner), the legume pod borer (*Maruca vitrata* Fabricius), which attack the crop during the flowering and pod formation stages, and the pod fly (*Melanagromyza obtusa* Malloch), which affects the crop during pod maturation. Collectively, these pests are responsible for approximately 60 to 90 percent of yield losses in pigeonpea (Wadasker *et al.*, 2013). Among these pests, *H. armigera* is the most severe, accounting for 80-90% of the total damage caused by the pod borer complex. The economic impact of *H. armigera* is substantial, leading to an annual loss of approximately 250,000 tons of grains, valued at over 3,750 million rupees (Banu *et al.*, 2005).

In the management of pod borer complexes in pigeonpea, farmers often resort to conventional insecticides due to their widespread availability, immediate effectiveness, and notable pest control

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capabilities. However, the persistent and indiscriminate use of these conventional insecticides poses several risks, including the development of insecticide resistance, outbreaks of secondary pests, resurgence of target pests, environmental pollution, residual toxicity, loss of biodiversity, and potential human health hazards. The high levels of resistance observed in pod borers to conventional insecticides have prompted a renewed focus on alternative pest management strategies, particularly the exploration of biopesticides.

Biopesticides, including botanicals such as neem seed kernel extract (NSKE), entomopathogenic bacteria like *Bacillus thuringiensis* (Berliner) (Bt), and entomopathogenic fungi such as *Beauveria bassiana*, *Lecanicillium lecanii*, and *Metarhizium anisopliae*, offer promising and environmentally friendly alternatives for controlling these insect pests (Jeyarani and Karuppuchamy, 2010). The use of these biopesticides, as part of an integrated pest management approach, can provide effective pest control while minimizing ecological and socio-economic impacts. In light of these considerations, the present study was conducted to evaluate the bio-efficacy of selected biopesticides against the pod borer complex in pigeonpea.

MATERIALS AND METHODS

The experiments were conducted at the Regional Agricultural Research Station, Warangal, PJ Telangana State Agricultural University, Telangana, India, over a three-year period from *kharif* 2019 to *kharif* 2021. The study utilized the medium-duration pigeonpea variety Rudreshwara (WRG 65), which was a popular variety in Telangana during this time. The experimental site was situated at 18°00'37"N latitude and 79°35'45"E longitude, with an elevation of 873 feet above mean sea level. The experimental design was a randomized complete block design (RCBD) with three replications. The design included six treatments and an untreated control, with each plot measuring 30 square meters (comprising 5 rows, each 5 meters in length, spaced 120 cm apart with a row width of 20 cm). The crop was managed according to recommended agronomic practices. Two spray applications were made during the crop growth period: the first application was at the 50% flowering stage, and the second application was administered 15 days after the first. Observations were made on the total number of webs per plant for *Maruca* and the number of larvae per plant for *Helicoverpa*. These observations were recorded from three randomly tagged plants per replication before treatment and at 7 and 10 days after each spray application.

The data on the percent reduction of larval populations in the test treatments were calculated based on the reduction in larval numbers for each treatment relative to the untreated control. This involved comparing the larval populations observed in the test treatments with those in the control to determine the efficacy of each treatment in reducing the pest populations.

The data on the number of pods damaged by *M. vitrata* and *H. armigera* were recorded as the percentage of pods damaged, based on observations from 5 randomly selected plants per plot. The percentage of pod damage was calculated using the following formula:

$$\text{Percent pod damage} = \frac{\text{Number of damage pods}}{\text{Total number of pods}} \times 100$$

Yield data were recorded separately from each treatment plot. After harvesting, all pods from each plot were threshed, and the grain yield per plot was recorded and extrapolated to yield per hectare. To normalize the data for statistical analysis, mean pod borer populations in pigeonpea were transformed using a square root transformation, while percentage pod damage values were transformed to arc sine values. Following these transformations, the data were subjected to statistical analysis. Additionally, the Incremental Cost-Benefit Ratio (ICBR) was calculated for each treatment to assess the economic efficiency of the different pest management strategies.

RESULTS AND DISCUSSION

Efficacy of biopesticides against larval population of gram pod borer, *Helicoverpa armigera*

The cumulative mean population of *Helicoverpa armigera* per plant before spraying, across different biopesticide-treated plots, ranged from 1.89 to 2.92 from *kharif* 2019 to *kharif* 2021. This range indicated a relatively uniform distribution of the pest across the experimental field, with no significant differences among the treatments before application. However, post-treatment results demonstrated significant differences in the mean larval populations among the treatments. Significant reductions in the larval populations were observed seven and ten days after both spray applications. The cumulative mean percent reduction of *H. armigera* larvae at these intervals showed that all treatments were more effective compared to the untreated control. According to the pooled data after the first spray (Table 1), the highest mean percent reduction in *H. armigera* larval population was achieved with the chemical control using Chlorantraniliprole 18.5 SC at 0.3 mL L^{-1}, which resulted in a 65% reduction. This was followed by Azadirachtin at 1500 ppm (5 mL L^{-1}), which achieved a 38% reduction, *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L^{-1} with a 36% reduction, and *Beauveria* *bassiana* at 5 g L⁻¹, which resulted in a 33% reduction compared to the untreated control.

Similarly, the pooled data following the second spray (Table 1) demonstrated that the highest mean percent reduction in *H. armigera* larval population was achieved with Flubendamide 480 SC at 0.2 mL L⁻¹, which resulted in an 85% reduction in larval populations. This was followed by Azadirachtin at 1500 ppm (5 mL L⁻¹), which achieved a 47% reduction, *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L⁻¹ with a 41% reduction, and *Beauveria bassiana* at 5 g L⁻¹, which led to a 39% reduction compared to the untreated control. While these biopesticide treatments were comparable to each other in their effectiveness, they were significantly more effective than the other treatments and controls.

Efficacy of biopesticides against legume/ spotted pod borer, *Maruca vitrata*

The cumulative mean population of *Maruca vitrata* in different biopesticide-treated plots before spraying ranged from 1.44 to 2.25 live webs per plant across the *kharif* seasons from 2019 to 2021. This range indicated a relatively uniform distribution of *M. vitrata* across the experimental field, with no significant differences among the treatments prior to application. However, post-treatment results revealed significant differences in the mean number of live webs of *M. vitrata* among the treatments seven and ten days after both spray applications. The cumulative mean percent reduction in *M. vitrata* populations at these intervals showed that all treatments were significantly more effective than the untreated control. According to the pooled data after the first spray (Table 2), the highest mean percent reduction in *M. vitrata* was achieved with the chemical control using Chlorantraniliprole 18.5 SC at 0.3 mL L⁻¹, resulting in a 60% reduction in live webs. This was followed by *Beauveria bassiana* at 5 g L⁻¹ with a 38% reduction, Azadirachtin at 1500 ppm (5 mL L⁻¹) with a 36% reduction, and *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L⁻¹ with a 32% reduction compared to the untreated control.

Similarly, the pooled data after the second spray (Table 2) indicated that the highest mean percent reduction in *M. vitrata* was achieved with Flubendamide 480 SC at 0.2 mL L⁻¹, which resulted in an 82% reduction in live webs. This was followed by *Beauveria bassiana* at 5 g L⁻¹, which achieved a 44% reduction, Azadirachtin at 1500 ppm (5 mL L⁻¹) with a 41% reduction, and *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L⁻¹ with a 37% reduction compared to the untreated control. While these biopesticide treatments showed comparable effectiveness to each other, they were significantly more effective than the other treatments and the untreated control.

Effect of various treatments on pod damage

The cumulative pod damage caused by the pod borer complex, comprising *Helicoverpa armigera* and *Maruca vitrata*, from *kharif* 2019 to 2021 across different treatments is illustrated in Figure 1. All treatments significantly reduced cumulative mean pod damage compared to the untreated control, with damage ranging from 14.4% to 35.77%. Among the treatments, *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L⁻¹ proved to be the most effective, resulting in the lowest percent pod damage at 19.5%. This was closely followed by Azadirachtin at 1500 ppm (5 mL L⁻¹) and *Beauveria bassiana* at 5 g L⁻¹, which recorded pod damage rates of 21.69% and 21.77%, respectively. These treatments were statistically similar to each other. In contrast, Chlorantraniliprole 18.5 SC at 0.3 mL L⁻¹ and Flubendamide 480 SC at 0.2 mL L⁻¹ achieved the lowest percent pod damage at 14.4%. This level of damage was significantly lower compared to the other treatments and the untreated control.

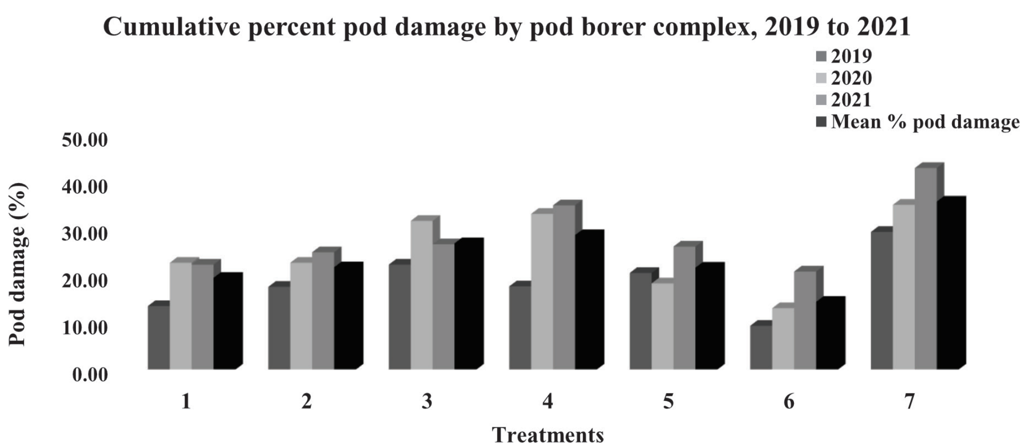

Fig. 1. Cumulative per cent pod damage by pod borers complex from 2019 to 2021

Table 1. Pooled data of *Helicoverpa armigera* population from *Vanakalam*, 2019 to 2021

Treatments	Dosage	Mean *Helicoverpa armigera* larvae/ plant							
		1st spray				2nd spray			
		Pre count	7 DAS	10 DAS	Percent reduction over control	Pre count	7 DAS	10 DAS	Percent reduction over control
Bt. *kurstaki*	1.0 g/l	2.04 (1.60)	0.96 (1.21)	0.93 (1.19)	36	1.59 (1.45)	0.97 (1.21)	0.88 (1.17)	41
Beauveria bassiana	5.0 g/l	2.02 (1.59)	1.16 (1.29)	0.96 (1.21)	33	1.47 (1.40)	1.02 (1.10)	0.91 (1.19)	39
Metarhizium anisopliae	5.0 g/l	2.05 (1.60)	1.23 (1.31)	1.13 (1.27)	22	1.66 (1.47)	1.10 (1.26)	1.09 (1.26)	27
Lecanicillium lecanii	5.0 g/l	2.28 (1.67)	1.39 (1.37)	1.19 (1.30)	17	1.95 (1.57)	1.25 (1.32)	1.20 (1.30)	20
Azadirachtin 1500 ppm	5.0 ml /l	1.89 (1.55)	1.16 (1.29)	0.89 (1.18)	38	1.46 (1.40)	0.84 (1.16)	0.79 (1.14)	47
Chlorantraniliprole 18.5 SC fb Flubendiamide 480 SC	0.3 ml/l & 0.2 ml/l	2.32 (1.68)	0.74 (1.11)	0.50 (1.0)	65	1.57 (1.44)	0.41 (0.96)	0.22 (0.85)	85
Untreated control	-	2.92 (1.85)	1.61 (1.45)	1.44 (1.39)	-	2.03 (1.59)	1.54 (1.43)	1.49 (1.41)	-
CD (p≤0.05)	-	NS	0.45	0.27	-	NS	0.27	0.2	-
CV (%)	-	13.78	15.4	11.67	-	6.5	15.1	10.9	-

Values in parentheses are square root transformed values; DAS: Days after spray

Table 2. Pooled data of *Maruca vitrata* population from *Vanakalam*, 2019 to 2021

Treatments	Dosage	Mean number of *Maruca vitrata* webs per plant							
		1st spray				2nd spray			
		Pre count	7 DAS	10 DAS	Percent reduction over control	Pre count	7 DAS	10 DAS	Percent reduction over control
Bt. k*urstaki*	1.0 g/l	1.56 (1.43)	0.96 (1.21)	0.83 (1.15)	32	0.86 (1.16)	0.59 (1.04)	0.53 (1.03)	37
Beauveria bassiana	5.0 g/l	1.47 (1.40)	0.91 (1.19)	0.77 (1.13)	38	0.78 (1.13)	0.51 (1.0)	0.48 (0.98)	44
Metarhizium anisopliae	5.0 g/l	1.50 (1.42)	1.09 (1.26)	0.99 (1.22)	19	0.93 (1.20)	0.6 (1.05)	0.62 (1.06)	27
Lecanicillium lecanii	5.0 g/l	1.79 (1.51)	1.13 (1.28)	1.07 (1.25)	13	0.82 (1.15)	0.71 (1.10)	0.71 (1.10)	16
Azadirachtin 1500 ppm	5.0 ml /l	1.44 (1.39)	0.81 (1.14)	0.79 (1.14)	36	0.64 (1.07)	0.57 (1.03)	0.50 (1.0)	41
Chlorantraniliprole 18.5 SC fb Flubendiamide 480 SC	0.3 ml/l & 0.2 ml/l	1.96 (1.57)	0.44 (0.97)	0.49 (0.99)	60	0.42 (0.96)	0.18 (0.82)	0.15 (0.81)	82
Untreated control	-	2.25 (1.66)	2.13 (1.62)	1.23 (1.31)	-	1.32 (1.35)	1.12 (1.27)	0.85 (1.16)	-
CD ($p \leq 0.05$)	-	NS	0.18	0.16	-	NS	0.09	0.07	-
CV (%)	-	6.9	10.8	9.3	-	12.7	15.4	11.7	-

Values in parentheses are square root transformed values; DAS: Days after spray

Effect of various treatments on grain yield and economics

The results regarding cumulative grain yield demonstrated that all treatments yielded significantly higher grain outputs compared to the untreated control. The mean grain yield per hectare for all treatments ranged from 1,174 kg ha^{-1} to 1,492 kg ha^{-1}, whereas the untreated control yielded 1,091 kg ha^{-1}. This indicates that all treatments, particularly the chemical controls, were more effective in enhancing grain yield compared to the untreated control. The highest grain yield was recorded with Chlorantraniliprole 18.5 SC at 0.3 mL L^{-1}, which produced 1,492 kg ha^{-1}, representing a substantial increase of 401 kg ha^{-1} over the untreated control. Flubendamide 480 SC at 0.2 mL L^{-1} also performed well, though with slightly lower yield. Among the biopesticides, Azadirachtin at 1500 ppm (5 mL L^{-1}) achieved the highest grain yield of 1,281 kg ha^{-1}, followed by *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L^{-1} with 1,256 kg ha^{-1}, and *Beauveria bassiana* at 5 g L^{-1} with 1,242 kg ha^{-1}. These biopesticide treatments were statistically comparable to each other but significantly differed from the chemical controls and the untreated control (Table 3).

The comparative economic analysis of various biopesticide treatments against the pod borer complex over a three-year period revealed that the Incremental Cost-Benefit Ratio (ICBR) ranged from 1:1.07 to 1:4.73. The highest ICBR of 1:4.73 was achieved with *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L^{-1}, which was comparable to the chemical control using Chlorantraniliprole 18.5 SC at 0.3 mL L^{-1}, which had an ICBR of 1:3.90. Flubendamide 480 SC at 0.2 mL L^{-1} also demonstrated a favorable ICBR of 1:3.90. In terms of net returns over the control, biopesticide treatments yielded between Rs. 2,828 and Rs. 8,990 per hectare. The highest net return of Rs. 8,990 per hectare was recorded with *Bt. kurstaki* at 1 g L^{-1}, followed by Azadirachtin at 1500 ppm (5 mL L^{-1}) with Rs. 8,640 per hectare and *Beauveria bassiana* at 5 g L^{-1} with Rs. 7,316 per hectare. The chemical control plot, however, achieved the highest net return of Rs. 21,066 per hectare. The lower net returns from biopesticide-treated plots, compared to the chemical control, can be attributed to the relatively lower yields observed in the biopesticide treatments.

The cumulative efficacy of biopesticides in controlling the pod borer complex in pigeonpea, as assessed after two spray applications, indicated that *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L^{-1}, Azadirachtin at 1500 ppm (5 mL L^{-1}), and *Beauveria bassiana* at 5 g L^{-1} were the most effective treatments for managing *Helicoverpa armigera* and *Maruca vitrata*. These treatments achieved the highest grain yields and

Table 3. Economics of certain biopesticides against pod borer complex in pigeonpea

	Treatments	Dosage	Yield (Kg/ha)				Additional yield over control	Income from additional yield	Cost of plant protection (Treatment + Labour)	Net returns over control	ICBR
			2019	2020	2021	Mean yield					
T_1	*Bt. kurstaki*	1.0 g/l	1323	1150	1296	1256	165	10890	1900	8990	1:4.73
T_2	Beauveria bassiana	5.0 g/l	1389	1160	1178	1242	151	9966	2650	7316	1:2.76
T_3	Metarhizium anisopliae	5.0 g/l	1314	1086	1158	1186	95	6270	2900	3370	1:1.16
T_4	Lecanicillium lecanii	5.0 g/l	1304	1082	1136	1174	83	5478	2650	2828	1:1.07
T_5	Azadirachtin 1500 ppm	5.0 ml /l	1379	1233	1232	1281	190	12540	3900	8640	1:2.2
T_6	Chlorantraniliprole 18.5 SC fb Flubendiamide 480 SC	0.3 ml/l & 0.2 ml/l	1500	1383	1592	1492	401	26466	5400	21066	1:3.90
T_7	Untreated control	-	1106	1056	1111	1091					
CD ($p \leq 0.05$)						99.6					
CV (%)						4.05					

*Market price of pigeonpea: Rs. 6600/q; Labour charge per day: Rs.450/-
*Cost per unit of each treatment: *Bt. kurstaki* (Rs.500/-); *Beauveria bassiana* (Rs.875/-); *Metarhizium anisopliae* (Rs.1000/-); *Lecanicillium lecanii* (Rs.875); Azadirachtin 1500 ppm (1900); Chlorantraniliprole 18.5 SC (Rs.1150/-); Flubendiamide 480 SC (Rs.1100/-)

were statistically comparable in their efficacy against the pod borers. These findings align with previous research by Thilagam *et al*. (2007), who reported that a *Bt. kurstaki*-based product (Spic-Bio) at 2.5 L/ha was highly effective, recording the lowest *H. armigera* larval populations. Similar results were reported by Sreekanth and Seshamahalakshmi (2012), who found that pod damage due to *M. vitrata* was lowest with Spinosad (17.38%), followed by *Bt.* (27.57%) and *Beauveria bassiana* SC formulation at 300 mg acre^{-1} (33.82%), compared to a control with 45.84% damage, representing reductions of 62.1%, 39.9%, and 26.2%, respectively. Additionally, earlier studies by Sreekanth and Seshamahalakshmi (2010) noted that inflorescence damage from *M. vitrata* was lowest with Spinosad 45% SC at 73 g a.i. ha^{-1} (4.7%), followed by *Bt.* at 1.5 kg ha^{-1} (10.5%) and *Beauveria bassiana* SC formulation at 300 mg L^{-1} (14.1%), with reductions of 80.9%, 57.6%, and 42.9% over control, respectively as against 24.7% damage in control.

A similar study on biopesticides reported that the first spray application resulted in the lowest number of *Maruca* webs (32.00 per 25 shoots) with neem seed kernel extract (NSKE) at 5% concentration and 50 g acre^{-1}. Ten days after spraying, the lowest larval populations were observed with neem fruit powder (0.57 larvae per 7 plants), followed by Spinosad 45 SC (0.62 larvae per 7 plants) and *Streptomyces* spp. (0.90 larvae per 7 plants) (Jagdish *et al.,* 2014). These findings are consistent with the results of Pandey and Das (2016), who found that *Beauveria bassiana* at 1 kg ha^{-1} was highly effective, recording the lowest grain damage at 6.71%. This was followed by *Verticillium lecanii* at 1 kg ha^{-1} with 7.03% damage, *Bacillus thuringiensis* (PDBC-BT-1) at 1.5 L ha^{-1} with 7.55% damage, and neem soap at 1 kg ha^{-1} (10 g L^{-1}) with 7.70% damage. All these treatments were statistically comparable to each other.

This study highlights the effectiveness of biopesticides in managing the major pigeonpea pod borer complex, specifically *Helicoverpa armigera* and *Maruca vitrata*. Based on the results, *Bacillus thuringiensis* (Bt. kurstaki) at 1 g L^{-1}, Azadirachtin at 1500 ppm (5 mL L^{-1}), and *Beauveria bassiana* at 5 g L^{-1} are recommended for the effective and economical control of the pod borer complex in pigeonpea. These biopesticides demonstrated comparable efficacy in controlling larval populations and achieving optimal grain yields. Therefore, they present viable alternatives to conventional chemical insecticides for managing pod borers in pigeonpea cultivation.

Achieving higher grain yields in pigeonpea while effectively managing the major pod borer complex using biopesticides alone presents a significant challenge under field conditions. Therefore, integrating biopesticides with chemical pesticides in a comprehensive Integrated Pest Management (IPM) program for pod borers is recommended. This approach ensures more consistent and effective control of the pest complex, thereby enhancing overall crop productivity and sustainability.

Authors' contribution

Conceptualization and designing of research work (DV, TF, PJM); Execution of field/lab experiments and data collection (DV, TF, GP); Data analysis and interpretation (DV, NSK, MM); Preparation of manuscript (DV, RVR).

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