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INTEGRATED NON-CHEMICAL PEST MANAGEMENT MODULE FOR THE MANAGEMENT OF POD BORERS IN PIGEONPEA

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ABSTRACT

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is an important pulse crop cultivated under rainfed conditions. Its productivity is greatly influenced by insect pests, particularly the pod borers *Helicoverpa armigera* (Hübner) and *Maruca vitrata* (Geyer). Indiscriminate use of chemical insecticides has resulted in insecticide resistance, pest resurgence, pesticide residues and ecological concerns. Therefore, the present study was undertaken to develop and evaluate an integrated non-chemical pest management module against pod borers in pigeonpea at the Regional Agricultural Research Station (RARS), Warangal (GPS 18°00¢38.5²N 79°35¢45.3²E) for three consecutive years from *Kharif* 2023 to 2025 in the medium maturity pigeon pea cultivar 'Warangal Kandi-2 (WRG 255). The study was laid out with three treatments comprising an integrated non-chemical pest management module (NCPM), integrated pest management (IPM) and farmers practice. The module comprised cultural, ecological, biological and botanical interventions. The performance of the module was compared with University-recommended pest management practices and farmers practices. The cumulative results showed that the non-chemical module reduced *H. armigera* and *M. vitrata* populations by 58.5 and 53.0 per cent, respectively, with pod damage of 12.76 and 8.90 per cent. The module recorded a pigeonpea grain yield of 1001.6 kg ha{ ¹ along with greengram intercrop yield of 329 kg ha{ ¹ and a benefit-cost ratio of 2.18, which was higher than farmers practice (1.95). Although chemical-based recommended practices recorded higher pest suppression and yield, the non-chemical module proved effective, economical and environmentally sustainable. The developed module can serve as a viable option for organic and low-input pigeonpea production systems.

Key Words: Redgram, Chickpea pod borer, Spotted pod borer, Pod borer complex, Organic farming, Integrated pest management, Botanical, Microbial.

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the most important pulse crops cultivated in tropical and subtropical regions. Pigeonpea occupies about 4.5 million hectares in India, with an annual production of 3.66 million tonnes and an average productivity of 824 kg/ha. In Telangana alone, the crop is cultivated on approximately 2.28 lakh hectares, producing 2.06 lakh tonnes annually (Anonymous, 2022). In Telangana, pigeonpea is predominantly grown under rainfed conditions during the *Kharif* season, where productivity is constrained by several biotic and abiotic stresses. Among these, insect pests are one of the major factors responsible for significant yield losses.

More than 250 insect species have been reported to infest pigeonpea, although only a few are economically important. The pod borer complex, comprising the gram pod borer, *Helicoverpa armigera* (Hübner), spotted pod borer, *Maruca vitrata* (Geyer) and pod fly, *Melanagromyza obtusa* (Malloch), is particularly destructive during the flowering and pod development stages. Yield losses due to insect pests have been estimated to range from 27% to 100%, depending on pest intensity and environmental conditions (Srilaxmi and Paul, 2010).Management of the pod borer complex continues to rely largely on applications of chemical insecticides. However, indiscriminate use of these chemicals has resulted in pesticide residues, environmental pollution, destruction of natural enemies, pest resurgence and the development of insecticide resistance. These concerns have intensified the need for sustainable and environmentally safe alternatives. Dependence on pesticides brings significant economic costs and environmental liabilities of off-target drift, chemical residues and resistance. With reports of pesticide resistance in pod borer (Kranthi et al. 2002), the need for development of safe, economic and effective pest management strategies was emphasized.

Organic farming and non-chemical crop protection are increasingly being promoted owing to their environmental, ecological and food safety benefits. However, although organic farming has gained considerable attention across different cropping systems, the development of scientifically validated best management practices remains in its infancy for many crops, including pigeonpea. The absence of

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standardized non-chemical pest management modules has compelled farmers to continue relying on synthetic insecticides for pod borer management.

Integrated non-chemical pest management have shown potential in suppressing pod borer incidence while preserving ecological balance. With the increasing demand for organically produced pigeonpea, there is an urgent need to develop effective, economically viable and scientifically validated non-chemical pest management modules. Therefore, the present investigation was undertaken to evaluate an integrated non-chemical pest management module against the major pod borers of pigeonpea.

MATERIAL AND METHODS

A field experiment on Integrated Non-Chemical Pest Management (NCPM) Module for the Management of pod borers in pigeonpea was conducted for 3 consecutive years from *Kharif* 2023 to 2025 at the Experimental Farm (D Block) of the Regional Agricultural Research Station (RARS)-PJTAU, Warangal, Telangana. The study was laid out with three treatments comprising an integrated non-chemical pest management module, integrated pest management (IPM) and farmers practice as observational trial.

The integrated non-chemical pest management module (T1) included deep summer ploughing, cultivation of pigeonpea variety WRG 255 at a spacing of 120 cm × 20 cm under rainfed *kharif* conditions and intercropping with greengram. Ecological pest management practices such as installation of T-shaped bird perches (@10/acre), trap crops as marigold and border crop, sunnhemp and pheromone traps (@10/acre) were incorporated. Nutrient management included application of FYM @ 5 t/acre as basal manure, followed by application of ghanajeevamrutham @125 kg/acre at 60 DAS and liquid jeevamrutham @200 L/acre applied 2-3 times at 15-day intervals from flowering onwards. Seeds were treated with beejamrutham and *rhizobium* @10 g/kg seed. Weed management was carried out through manual weeding. Pest management was achieved through sequential application of eco-friendly inputs, including neemastra, *Bacillus thuringiensis* var. *kurstaki* (Bt) @2.5 g/L, brahmastra, and agniastra at 10 days interval from flower bud initiation. Disease management involved application of sour buttermilk @10 L/100 L water per acre and application of *Trichoderma viride* @2 kg mixed with 25 kg FYM per acre during ploughing.

The University recommended integrated pest management treatment (T2) followed the recommended package of practices, including deep summer ploughing, cultivation of WRG 255 at 120 cm × 20 cm spacing under rainfed conditions, application of FYM @5 t/acre, and nutrient application of 20 kg nitrogen + 50 kg phosphorus per acre. Weed management was carried out using pendimethalin @7 ml/L as pre-emergence herbicide followed by imazethapyr @1.5 ml/L. Seed treatment was performed with imidacloprid @5 g/kg, metalaxyl @3 g/kg, and *Rhizobium* @10 g/kg seed. Pest management ETL of the pests involved pheromone traps (@10/acre) and sequential insecticide applications comprising chlorpyriphos 50 EC + neem (*Azadirachtin* 1500 ppm), emamectin benzoate 5% SG @0.5 g/L and chlorantraniliprole 18.5 SC @0.3 ml/L.

The farmers practice (T3) represented the conventional pest management followed by farmers. Weed management was performed using pendimethalin @5 ml/L as a pre-emergence herbicide. Pod borer management relied mainly on chemical insecticides, including emamectin benzoate 5% SG @0.5 g/L and chlorantraniliprole 18.5 SC @0.3 ml/L applied during the crop period

The pigeonpea cultivar, Warangal Kandi-2 (WRG 255) medium duration was sown at a spacing of 120 × 20 cm following the recommended agronomic practices for the zone. Each treatment plot consisted 500 sq meter area. Pest management sprays were scheduled at the flower bud initiation stage in non-chemical based pest management and in Integrated pest management at pest reaches ETL and farmer practices at flowering stage. Observations recorded are larval population, number of *Helicoverpa armigera* and *Maruca vitrata* larvae per plant from ten randomly tagged plants per replication recorded before spraying and at 10 days after each spray, pod and seed

Table 1. Comparative efficacy of non-chemical and conventional pest management strategies against *Helicoverpa armigera*) in redgram during 2023-24

Treatments	Mean larval *Helicoverpa armigera* per plant														
	1st spray			2nd spray			3rd spray			4th spray			5th spray		
	Pre count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	0.8	0.6	25	1.5	1.0	33	1.2	0.4	67	0.9	0.3	67	0.8	0.2	75
T2 (University recommended IPM)	-	-	-	3.1	1.2	61	1.2	0.2	83	0.4	0	100	-	-	-
T3 (Farmer Practice)	-	-	-	2.7	0.9	72	1.1	0.2	82	0.9	0.1	89	-	-	-

Table 2. Comparative efficacy of non-chemical and conventional pest management strategies against *Maruca vitrata* in redgram during 2023-24

Treatments	Mean larval *Maruca vitrata* per plant														
	1st spray			2nd spray			3rd spray			4th spray			5th spray		
	Pre count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	1	0.8	**20**	1.8	1.2	**33**	1.4	0.7	**50**	0.8	0.3	**63**	1	0.3	**70**
T2 (University recommended IPM)	-	-	**-**	2.4	1	**58**	1.4	0.5	**64**	0.4	0	**100**	-	-	**-**
T3 (Farmer Practice)	-	-	**-**	1.4	0.6	**57**	1	0.4	**60**	0.7	0.1	**86**	-	-	**-**

Table 3. Comparative efficacy of non-chemical and conventional pest management strategies on pod damage, yield and economics of redgram during 2023-24

Insecticides Dosage	Damage due to *H. armigera* (%)	Damage due to *M. vitrata* (%)	Yield Kg/ha. (Redgram+greengram)	B:C ratio
T1 (Non-chemical)	14.8	12.4	1336+448	2.51
T2 (University recommended IPM)	3.44	5.2	1876	3.18
T3 (Farmer Practice)	5.2	7.6	1702	2.70

Table 4. Comparative efficacy of non-chemical and conventional pest management strategies against *Helicoverpa armigera*) in redgram during 2024-25

Treatments	Mean larval *Helicoverpa armigera* population per plant														
	1st spray			2nd spray			3rd spray			4th spray			5th spray		
	Pre count	10 DAS	Reduction(%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	-	-	-	0.8	0.6	25	1.2	0.8	33	0.8	0.4	50	0.6	0.2	67
T2 (University recommended IPM)	-	-	-	0.8	0.5	38	1.6	0.6	63	1.2	0.1	92	-	-	-
T3 (Farmer Practice)	-	-	-	1.0	0.4	60	1.1	0.2	82	0.8	0.1	88	-	-	-

damage (%) assessed at harvest due to different pod borer pests, grain yield (kg/ha) estimated after harvest and economics i.e., cost: benefit ratio was computed based on treatment wise input costs and yield returns.

RESULTS AND DISCUSSION

Efficacy of non-chemical pest management module against *Helicoverpa armigera*

The efficacy of the integrated non-chemical pest management (NCPM) module against *Helicoverpa armigera* varied across the three cropping seasons (Tables 1, 4, 7 and 10). During *Kharif* 2023, the NCPM module recorded a progressive reduction in larval population from 25% after the first spray to 75% after the fifth spray. In comparison, the integrated pest management (IPM) practice achieved complete (100%) suppression after the fourth spray, whereas the farmer's practice recorded 89% reduction. During *Kharif* 2024, the non-chemical module recorded 67% reduction after five sequential sprays, while the IPM and farmers practice achieved 92% and 88% reduction, respectively. In *Kharif* 2025, only four sprays were required due to comparatively lower pest pressure and the non-chemical module recorded 44% reduction compared with 85% under the IPM and 75% under farmers practice.

Pooled analysis over three years revealed that the non-chemical module reduced *H. armigera* infestation by 58.5%, with a mean larval population of only 0.23 larvae plant^{-1} after the final spray. Although the IPM practice was the most effective (96.0% reduction), the non-chemical module consistently maintained *H. armigera* populations below damaging levels, demonstrating its potential as an eco-friendly alternative for sustainable pigeonpea cultivation.

Efficacy against *Maruca vitrata*

The non-chemical pest management module also effectively suppressed *Maruca vitrata* throughout the study period (Tables 2, 5, 8 and 11). During *Kharif* 2023, sequential application of botanical formulations and *Bacillus thuringiensis* var. *kurstaki* resulted in a gradual increase in control, reaching 70% after the fifth spray. In comparison, the IPM achieved complete suppression (100%), whereas farmers practice recorded 86% reduction after 4th spray.

During *Kharif* 2024, the non-chemical module reduced *M. vitrata* populations by 67% after 5th spray, while the IPM and farmers practice recorded 75% and 80% reduction, respectively. During *Kharif* 2025, the module achieved 50% reduction after four sprays, compared with 83% and 75% under the IPM and farmers practice, respectively.

The pooled data demonstrated that the non-chemical module achieved an average reduction of 53.0% in *M. vitrata* infestation, while the University-recommended IPM and farmers practice recorded 87.5% and 83.0% reduction, respectively. Although chemical management provided greater suppression, the non-chemical module effectively maintained pest populations at manageable levels while avoiding reliance on synthetic insecticides.

Effect on pod damage

The non-chemical module significantly reduced pod damage caused by the major pod borer complex (Tables 3, 6, 9 and 12). Across three years, pod damage due to *H. armigera* and *M. vitrata* was restricted to 12.76% and 8.90%, respectively. Pod fly damage under the non-chemical module remained comparable with the conventional treatments. As expected, the University-recommended IPM practice recorded the lowest pod damage (4.84% for *H. armigera* and 4.50% for *M. vitrata*), whereas farmers practice resulted in 5.83% damage from *H. armigera* and 6.0% damage from *M. vitrata*.

The relatively lower efficacy of the non-chemical module compared with insecticide-based management can be attributed to the slower action of botanicals and microbial biopesticides. However, the integration of intercropping, trap crops, bird perches, pheromone traps, organic nutrient management, and repeated botanical applications substantially suppressed pest populations and minimized crop damage.

Grain yield and economics

Despite relying entirely on non-chemical interventions, the integrated module produced satisfactory grain yields and favourable economic returns. During *Kharif* 2023, pigeonpea grain yield reached 1,336 kg ha{ ^{1} along with an intercrop greengram yield of 448 kg ha{ ^{1}, resulting in a benefit-cost ratio of 2.51. During 2024, pigeonpea and greengram yields were 803 and 239 kg ha^{-1}, respectively, with a B:C ratio of 1.99. In 2025, the module produced 866 kg ha^{-1} pigeonpea and 300 kg ha^{-1} greengram, recording a B:C ratio of 2.05.

Table 5. Comparative efficacy of non-chemical and conventional pest management strategies against *Maruca vitrata* in redgram during 2024-25

Treatments	Mean larval *Maruca vitrata* population per plant														
	1st spray			2nd spray			3rd spray			4th spray			5th spray		
	Pre count	10 DAS	Reduction(%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	-	0.4	-	1.4	1.0	29	1.8	1.0	44	1.4	0.8	43	1.2	0.4	67
T2 (University recommended IPM)	1	0.8	20	1.0	0.6	40	1.2	0.4	67	0.8	0.2	75	-	-	-
T3 (Farmer Practice)	-	-	-	1.8	0.8	56	1.4	0.4	71	1.0	0.2	80	-	-	-

Table 6. Comparative efficacy of non-chemical and conventional pest management strategies on pod damage, yield and economics of redgram during 2024-25

Insecticides Dosage	Damage due to *H. armigera*(%)	Damage due to *M. vitrata*(%)	Yield Kg/ha. (Redgram+greengram)	B:C ratio
T1 (Organic management)	12.8	8.2	803+239	1.99
T2 (University recommendation)	6.6	5.2	1212	2.10
T3 (Farmer Practice)	7.2	6.2	1145	1.64

Table 7. Comparative efficacy of non-chemical and conventional pest management strategies against *Helicoverpa armigera*) in redgram during 2025-26

Treatments	Mean no.of *Helicoverpa armigera* larvae per plant											
	1st spray			2nd spray			3rd spray			4th spray		
	Pre count	10 DAS	Reduction (%)	Pre count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	-	-	-	0.7	0.5	29	1.1	0.7	36	0.9	0.5	44
T2 (University recommended IPM)	-	-	-	0.8	0.5	37	1.5	0.5	67	1.3	0.2	85
T3 (Farmer Practice)	-	-	-	1.1	0.4	63	1.0	0.1	90	0.8	0.2	75

*DAS-Days after spraying

Table 8. Comparative efficacy of non-chemical and conventional pest management strategies against *Maruca vitrata* in redgram during 2025-26

Treatments	Mean no. of *Maruca vitrata* larvae per plant											
	1st spray			2nd spray			3rd spray			4th spray		
	Pre count	10 DAS	Reduction (%)	Pre count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction(%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	-	-	-	1.2	0.8	**33**	1.6	0.8	**50**	1.2	0.6	**50**
T2 (University recommended IPM)	-	-	-	0.8	0.4	**50**	1.0	0.2	**80**	0.6	0.1	**83**
T3 (Farmer Practice)	-	-	-	1.6	0.6	**63**	1.2	0.1	**92**	0.8	0.2	**75**

The pooled analysis indicated an average pigeonpea grain yield of 1,001.6 kg ha^{-1} together with an intercrop greengram yield of 329 kg ha^{-1} under the non-chemical module. The pooled B:C ratio (2.18) was substantially higher than farmer's practice (1.95), although slightly lower than the University-recommended IPM (2.47). The additional income generated from greengram intercropping partly compensated for the comparatively lower pigeonpea yield and improved the overall profitability of the non-chemical production system.

The three-year evaluation clearly demonstrated that the integrated non-chemical pest management module effectively reduced infestations of *Helicoverpa armigera* and *Maruca vitrata* while maintaining acceptable grain yield and profitability. Although the University-recommended chemical schedule provided the highest level of pest suppression and grain yield, the non-chemical module offered distinct advantages by eliminating synthetic insecticide use, conserving natural enemies, reducing pesticide residues, and promoting ecological sustainability. The integration of cultural, ecological, biological, and botanical interventions successfully reduced dependence on chemical pesticides and provides a practical pest management option for organic and low-input pigeonpea production systems.

The present study demonstrated that the integrated non-chemical pest management (NCPM) module effectively suppressed the major pod borers, *Helicoverpa armigera* and *Maruca vitrata* under rainfed condition. Over three consecutive cropping seasons, the module achieved a cumulative reduction of 58.5% in *H. armigera* and 53.0% in *M. vitrata* resulting in lower pod damage, satisfactory grain yield and a promising benefit-cost ratio. Although the University-recommended chemical schedule consistently recorded the highest level of pest suppression, the non-chemical module provided satisfactory control while avoiding the use of synthetic insecticides. The gradual reduction in larval populations observed after successive applications indicates that the combined effect of cultural, ecological, biological and botanical interventions was more effective than any single component alone.

Deep summer ploughing, intercropping with greengram, trap cropping with marigold, border crop with sunnhemp, installation of bird perches and pheromone traps, organic nutrient management and repeated applications of Neemastra, Brahmastra, Agniastra and *Bacillus thuringiensis* var. *kurstaki* collectively contributed to suppressing pod borer populations. These findings are consistent with the Shanower *et al*. (1999) and Volp *et al*. (2025) who emphasized that sustainable management of pigeonpea insect pests requires integration of multiple compatible tactics rather than sole reliance on insecticides.

The comparatively lower efficacy of the non-chemical module than the University-recommended chemical schedule is expected because botanical formulations and microbial biopesticides generally exhibit slower action and shorter persistence than synthetic insecticides. Nevertheless, the present study demonstrated that repeated applications of botanicals and microbial pesticides maintained pest populations below economically damaging levels. Similar observations were reported by Veeranna *et al*. (2024); Sreekanth and Seshamahalakshmi (2012), who found that *B. thuringiensis* formulations and neem-based biopesticides significantly reduced *H. armigera* and *M. vitrata* populations in pigeonpea while remaining safer to natural enemies than conventional insecticides.

The present results also support earlier findings on the role of habitat management in pest suppression. Intercropping, trap cropping, and conservation of natural enemies have been reported to reduce colonization and survival of pod borers while enhancing biological control. Sharma *et al.* (2010) demonstrated that integrated pest management modules combining cultural practices, monitoring, botanicals and need-based interventions significantly reduced pesticide use and improved productivity in major pulse-growing regions.

The lower pod damage and satisfactory grain yield recorded under the non-chemical module further confirm that eco-friendly pest management can maintain acceptable productivity. Although the University-recommended treatment produced the highest grain yield and benefit-cost ratio, the inclusion of greengram as an intercrop increased total system productivity and improved overall profitability under the non-chemical module. Similar observations have been reported from integrated pest management programmes in

Table 9. Comparative efficacy of non-chemical and conventional pest management strategies on pod damage, yield and economics of redgram during 2025-26

Insecticides Dosage	Damage due to *H. armigera* (%)	Damage due to *M. vitrata*(%)	Yield Kg/ha. (Redgram+greengram)	B:C ratio
T1 (Non-chemical)	10.7	6.1	866+300	2.05
T2 (University recommended IPM)	4.5	3.1	1168	2.15
T3 (Farmer Practice)	5.1	4.2	1079	1.53

Table 10. Pooled data on the comparative efficacy of non-chemical and conventional pest management strategies against *Helicoverpa armigera* in redgram during *Kharif* 2023-2025

Treatments	Mean larval *Helicoverpa armigera* population per plant											
	1st spray			2nd spray			3rd spray			4th spray		
	Pre count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction(%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	0.50	0.37	18.00	1.1	0.77	31.33	1.10	0.57	48.00	0.57	0.23	58.5
T2 (University recommended IPM)	0.27	0.17	12.33	1.8	0.73	55.33	1.37	0.33	77.00	0.53	0.03	96.0
T3 (Farmer Practice)	0.37	0.13	21.00	1.6	0.47	74.00	1.00	0.20	79.67	0.57	0.07	88.5

Table 11. Pooled data on the comparative efficacy of non-chemical and conventional pest management strategies against *Maruca vitrata* in redgram during *Kharif* 2023-2025

Treatments	Mean larval *Maruca vitrata* population per plant											
	1st spray			2nd spray			3rd spray			4th spray		
	Pre count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction (%)	Pre Count	10 DAS	Reduction(%)	Pre Count	10 DAS	Reduction (%)
T1 (Non-chemical)	0.73	0.67	26.5	1.60	1.00	37.33	1.47	0.77	48.00	0.73	0.37	53.0
T2 (University recommended IPM)	0.60	0.40	35.0	1.47	0.60	59.33	1.07	0.33	71.33	0.40	0.07	87.5
T3 (Farmer Practice)	0.53	0.20	63.0	1.47	0.50	68.33	1.07	0.33	68.67	0.57	0.10	83.0

Table 12. Pooled data on the comparative efficacy of non-chemical and conventional pest management strategies on pod damage, yield and economics of redgram during *Kharif* 2023-2025

Insecticides Dosage	Damage due to *H. armigera* (%)	Damage due to *M. vitrata*(%)	Yield Kg/ha. (Redgram+greengram)	B:C ratio
T1 (Non-chemical)	12.76	8.9	1001.6	2.18
T2 (University recommended IPM)	4.84	4.5	1418.6	2.47
T3 (Farmer Practice)	5.83	6.0	1308.6	1.95

pigeonpea, where diversified cropping systems and reduced pesticide inputs enhanced economic returns while improving ecosystem stability.

The growing demand for residue-free pulses and increasing concerns over insecticide resistance, environmental contamination and loss of biodiversity have renewed interest in non-chemical pest management. Recent reviews have emphasized that future pigeonpea pest management should integrate cultural practices, biological control, host plant resistance, habitat manipulation, botanicals and decision-based interventions to reduce dependence on synthetic insecticides. The comprehensive review by Volp *et al*. (2025) highlighted that sustainable management of *H. armigera*, *M. vitrata* and other pigeonpea pests will require integrated approaches that conserve natural enemies and improve agroecosystem resilience rather than relying exclusively on chemical control.

Overall, the present findings corroborate earlier reports that integrated non-chemical pest management is capable of maintaining pod borer populations below economically damaging levels while providing acceptable yield and profitability. The developed module offers an environmentally safe, economically feasible and farmer-friendly alternative for organic and low-input pigeonpea cultivation. Further multi-location validation and integration with biological control agents could enhance its robustness and facilitate wider adoption under diverse agro-climatic conditions.

CONCLUSION

The present study demonstrated that the integrated non-chemical pest management module effectively suppressed the major pod borers, *Helicoverpa armigera* and *Maruca vitrata*, in pigeonpea through the integration of cultural, ecological, biological and botanical approaches. Across three years, the module achieved a 58.5% reduction in *H. armigera* and a 53.0% reduction in *M. vitrata*, resulting in reduced pod damage, satisfactory grain yield (1001.6 kg ha{ ^{1}), an additional greengram intercrop yield (329 kg ha{ ^{1}) and a better benefit-cost ratio (2.18), which was higher than the farmers practice. Although the University-recommended chemical management recorded superior pest suppression and yield, the non-chemical module proved to be an effective, eco-friendly and economically viable alternative that reduces dependence on synthetic insecticides, conserves natural enemies and supports sustainable and organic pigeonpea production.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Anonymous, 2022. Annual Report-2022. All India Coordinated Research Project on Pigeonpea.

Kranthi, K.R., Jadhav, D.R., Kranthi, S., Wanjari, R., Ali, S.S. and Russell, D.A., 2002. Insecticide resistance in five major insect pests of cotton in India. Crop Protection, 21(6): 449-460.

Shanower, T.G., Romeis, J. and Minja, E.M., 1999. Insect pests of pigeonpea and their management. Annual Review of Entomology, 44: 77-96.

Sharma, O.P., Gopali, J.B., Yelshetty, S., Bambawale, O.M., Garg, D.K. and Bhosle, B.B., 2010**.** Pests of Pigeonpea and their Management. National Centre for Integrated Pest Management (NCIPM), LBS Building, IARI Campus, New Delhi-110012, India.

Sreekanth, M. and Seshamahalakshmi, M., 2012. Studies on relative toxicity of biopesticides to *Maruca vitrata* (Geyer) on pigeonpea (*Cajanus cajan* L.). Journal of Biopesticides, **7**: 291-295.

Srilaxmi, K. and Paul, R., 2010. Diversity of insect pests of pigeonpea (*Cajanus cajan* L. Millsp.) and their succession in relation to crop phenology in Gulbarga, Karnataka. The Ecoscan, 4: 273-276.

Veeranna, D., Fatima, T., Sandhya Kishore, N., Padmaja, G., Madhu, M., Jagan Mohan Rao, P. and Uma Reddy, R., 2024. Evaluation of certain biopesticides against *Helicoverpa armigera* and *Maruca vitrata* in pigeonpea. Agricultural Research Journal, 61(2): 196-202.

Volp, T.M., Jat, B.L., Jaba, J., Zalucki, M.P. and Furlong, M.J., 2025. Integrated pest management in pigeonpea: Progress and prospects. Journal of Applied Entomology, 149(4): 661-681.