Evaluation of Selected Insecticides against Pod Borer, *Helicoverpa armigera* and Productivity, Profitability Analysis in Bengal Gram

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ABSTRACT

Background: Chickpea (*Cicer arietinum* L.) is an important pulse crop in India but suffers severe yield losses due to the pod borer *Helicoverpa armigera*. Chemical control remains common, yet indiscriminate use affects natural enemies and profitability. Hence, field-based evaluation of eco-compatible insecticidal options under integrated pest management (IPM) is essential for sustainable productivity.

Methods: Frontline demonstrations (FLDs) were conducted for three consecutive rabi seasons (2020-21, 2021-22 and 2022-23) on farmers' fields in Ananthapuramu district Andhra Pradesh. The IPM module consisted of Spinosad 45 SC (0.3 mL L^{-1}) and Profenophos 40% + Cypermethrin 4% EC (2 mL L^{-1}), evaluated against an untreated control across 10 farmer-participatory plots. Larval populations of *H. armigera* and natural enemies were recorded before and after spraying and the data were analysed using randomized block design (RBD) with Duncan's multiple range test (DMRT). Economic indicators, adoption and yield gap indices and phytotoxicity effects were assessed following standard protocols.

Result: The trials revealed that Spinosad 45 SC (0.3 mL L^{-1}) was significantly more effective than Profenophos 40% + Cypermethrin 4% EC (2 mL L^{-1}) in suppressing *H. armigera* populations, recording 70.84%-84.03% reduction compared to 19.00%-21.88% under the latter treatment. Both insecticides were found to be safe for the key natural predators *Cheilomenes sexmaculata* and *Coccinella septempunctata*. Demonstration plots under IPM recorded higher grain yields (23.75-24.23 q ha^{-1}) and net returns (` 79,026-` 1,05,646 ha^{-1}) compared to farmer practices (19.95-21.18 q ha^{-1}; ` 52,033$^{-1}$ ` 70,691 ha^{-1}). The benefit-cost ratio also improved markedly from 0.89-1.07 under traditional practices to 1.74-1.75 under IPM. These results clearly demonstrate the superiority of Spinosad-based IPM modules in enhancing productivity, profitability and ecological safety in Bengal gram cultivation.

Key words: Bengal gram, Frontline demonstration, *Helicoverpa armigera*, Insecticide efficacy, Integrated pest management, Profitability analysis.

INTRODUCTION

Bengal gram (*Cicer arietinum* L.) is one of the most important pulse crops cultivated worldwide and constitutes nearly 20% of global pulse production, serving as a major source of dietary protein, carbohydrates, vitamins and minerals in developing countries (Jukanti *et al.,* 2012). India is the largest producer and consumer of chickpea, contributing about 70% of global production, where the crop plays a crucial role in nutritional security, soil fertility improvement and sustainable cropping systems (FAOSTAT, 2023). Despite its importance, the productivity of Bengal gram remains constrained by several biotic stresses, among which insect pests are the most destructive. Gram pod borer, *Helicoverpa armigera* (Hübner), is a highly polyphagous and economically important pest causing severe yield losses in chickpea-growing regions. The pest initially feeds as a defoliator during early crop growth stages and later damages flowers and developing pods, resulting in yield losses ranging from 30% to 80% depending on pest severity and environmental conditions (Ahmad *et al.,* 2015). Excessive and indiscriminate use of conventional insecticides by farmers has led to problems

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such as pest resistance, resurgence, higher production costs and ecological imbalance. Hence, adoption of Integrated Pest Management (IPM) strategies involving need-based application of safer, new-generation insecticides has become essential for sustainable pod borer management (Nitharwal *et al.,* 2017).

Ananthapuramu district of Andhra Pradesh, located in the Scarce Rainfall Zone (SRZ), represents a major Bengal gram growing region under rainfed conditions. However, studies indicate that farmers in this region have limited awareness and adoption of improved crop protection technologies, including seed treatment, pest monitoring tools and timely application of selective insecticides (Jyothi *et al*., 2019). The continued dependence on traditional pest management practices has resulted in a considerable technology gap and extension gap, ultimately affecting crop productivity and profitability (Prasad *et al.,* 2022). Frontline demonstrations (FLDs), implemented through krishi vigyan kendras (KVKs), serve as an effective extension approach for demonstrating validated agricultural technologies under real farming situations. Unlike controlled research experiments, FLDs aim to enhance farmer confidence, facilitate technology dissemination and promote adoption of scientifically proven practices leading to higher productivity and economic returns (Reddy *et al*., 2024; Demonstration-based validation of IPM practices under farmers' conditions is therefore critical for bridging the gap between research recommendations and field-level adoption.

In the scarce rainfall zone of Andhra Pradesh, limited systematic demonstrations have been conducted to evaluate modern pest management technologies in Bengal gram under farmers' field conditions. Therefore, the present study was undertaken through frontline demonstrations to demonstrate and validate recommended integrated pest management practices for gram pod borer management across different locations of Ananthapuramu district, with the objective of improving productivity, profitability and farmer adoption under real farming situations.

MATERIALS AND METHODS

Frontline demonstrations (FLDs) were conducted on farmers' fields under the jurisdiction of Krishi Vigyan Kendra (KVK), Reddipalli, during the *rabi* seasons of 2020-21, 2021-22 and 2022-23. The demonstrations were undertaken to validate recommended integrated pest management (IPM) practices for managing major insect pests of Bengal gram under farmers' field conditions. The study also assessed the impact of the demonstrated IPM module on natural enemy populations and field safety of the treatments. A package of recommended Integrated Pest Management (IPM) practices (Table 1) was demonstrated across 10 farmer-participatory fields for three consecutive years. The IPM module demonstrated included seed treatment, installation of *Helicoverpa armigera* pheromone traps, application of bio-pesticides and need-based spraying of recommended insecticides. However, for impact assessment under farmers' field conditions, yield performance and pest reduction were primarily evaluated by comparing the Spinosad-based IPM intervention with the prevailing farmer insecticide practice. The total number of *Helicoverpa armigera* larvae was recorded from five randomly selected plants per treatment one day before insecticide application and at 3, 7 and 14 days after each of the two sprays, with a 15-day interval between applications. Natural enemies, namely *Cheilomenes sexmaculata* (Fabricius) and *Coccinella septempunctata* (Linnaeus), common generalist predators feeding mainly on aphids and other soft-bodied insects in Bengal gram ecosystem, were recorded at the same observation intervals to assess the ecological safety of the treatments. The percentage reduction of *H. armigera* population over the untreated control was calculated following Reddy *et al*. (2024). A separate field experiment was laid out in RBD with seven replications and a plot size of 100 m^2 to evaluate the phytotoxic effects of the tested insecticides. Phytotoxicity observations were recorded following CIBRC guidelines to confirm field safety of the recommended insecticides under farmers' field conditions. No phytotoxic symptoms were observed during the observation period. Yield data were collected using a random crop-cutting method from both demonstration plots and farmer-practice plots. Adoption gaps were categorised as full adoption (no gap), partial adoption (partial gap) and no adoption (full gap). The adoption gap index was calculated as per Rajasekhar *et al.* (2022). Technology gap, extension gap, yield gap and technology index were computed using the standard procedures of Samui *et al.* (2000) and Rajasekhar *et al.* (2022).

Statistical analysis

Population data of *H. armigera* and natural enemies were arc sine transformed before analysis. Experimental data were analysed using randomized block design (RBD) as

Table 1: Difference between technological intervention and farmer practice through front line demonstration (FLD) in Bengal gram.

Technology intervention	Farmers practice	Gap
Seed treatment with carbendazim 12% + mancozeb 63% WP @ 2 g kg^{-1} seed.	Not Followed	Full gap
Installation of *H. armigera* pheromone traps	No Pheromone traps used	Full gap
Azadirachtin 10000 ppm spray 35-45 DAS to kill eggs of leaf feeders	Followed rarely	Partial gap
Use of bio-formulation *Baeuevaria Bassiana* @ 5 g L^{-1}	Followed rarely	Partial gap
Use of CIBRC registered and recommended insecticide Spinosad @ 0.3 mL L^{-1}	Indiscriminate use of insecticides with similar mode of action	Partial gap

Table 2: Evaluation of insecticides against *Helicoverpa armigera* in Bengal gram.

	2020 season					2021 season					2022 season				
Treatments	PTC	3 DAT	7 DAT'	14 DAT	PRC	PTC	3 DAT	7 DAT'	14 DAT	PRC	PTC	3 DAT	7 DAT'	14 DAT	PRC
Spinosad	3.00	1.29	0.57	0.86	71.33	3.57	1.14	0.43	0.57	84.03	3.43	0.71	0.53	1.00	70.84
	(9.24)^{b}	(6.42)^{c}	(3.40)^{c}	(4.08)^{c}		(10.86)^{b}	(5.64)^{b}	(2.62)^{c}	(3.41)^{c}		(10.64)^{b}	(4.18)^{a}	(3.26)^{c}	(3.31)^{c}	
Profenophos	3.00	2.14	1.57	2.43	19.00	4.57	3.14	2.71	3.57	21.88	4.71	2.86	2.29	2.86	21.52
+cypermethrin	(8.02)^{b}	(8.39)^{b}	(7.10)^{b}	(8.92)^{b}		(12.32)^{a}	(10.07)^{a}	(9.44)^{b}	(10.84)^{b}		(12.52)^{a}	(9.67)^{b}	(8.67)^{b}	(9.63)^{b}	
Control	3.43	4.00	4.43	4.57	-	4.71	4.43	4.57	5.29	-	4.71	4.57	5.14	5.00	-
	(10.51)^{a}	(11.51)^{a}	(12.13)^{a}	(12.28)^{a}		(12.52)^{a}	(12.13)^{a}	(12.32)^{a}	(13.28)^{a}		(12.52)^{a}	(12.32)^{c}	(13.06)^{a}	(12.88)^{a}	
S.Em±	0.03	0.72	0.04	0.03	-	0.02	0.73	0.05	0.81	-	0.03	0.04	0.02	0.09	-
CD at 0.05	0.812	1.026	2.279	2.379	-	0.780	2.219	2.092	2.195	-	0.833	2.032	2.398	2.728	-

PTC: Pre-treatment count; DAT: Days after treatment; PRC: Per cent reduction over control; Values in parentheses are arc sine transformed values in a column means followed by a common letter are not significantly different by DMRT (P=0.05). Spinosad treatment represents the IPM technology demonstrated under frontline demonstrations (FLDs), whereas Profenophos + Cypermethrin represents prevailing farmer practice.

Table 3: Evaluation of insecticides against natural enemies in Bengal gram.

	2020 season				2021 season				2022 season			
	Cheilomenes sexamaculata		*Coccinella septempunctata*		*Cheilomenes sexamaculata*		*Coccinella septempunctata*		*Cheilomenes sexamaculata*		*Coccinella septempunctata*	
Treatments	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT
Spinosad	1.4	2.6	1.6	2.2	2.0	3.2	1.4	2.2	2	2.4	1.6	2.2
	(1.12)	(1.73)	(1.22)	(1.41)	(1.37)	(2.47)	(1.14)	(1.47)	(1.56)	(1.54)	(1.40)	(1.63)
Profenophos	1.5	1.9	1.8	2.1	1.6	2.7	1.8	2.4	1.8	2.2	2.2	2.4
+cypermethrin	(1.18)	(1.31)	(1.33)	(1.39)	(1.73)	(1.79)	(1.33)	(1.54)	(1.44)	(1.47)	(1.61)	(1.69)
Control	1.4	2.3	2	2.2	2	2.2	2.2	2.6	1.6	2.2	2.2	2.6
	(1.12)	(1.46)	(1.39)	(1.41)	(1.39)	(1.47)	(1.45)	(1.60)	(1.43)	(1.48)	(1.63)	(1.75)
S.Em±	0.03	0.04	0.02	0.06	0.03	0.72	0.04	0.086	0.02	0.73	0.05	0.81
CD at 0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PTC: Pre-treatment count; DAT: Days after treatment; PRC: Per cent reduction over control; Values in parentheses are square root transformed values in a column means followed by a common letter are not significantly different by DMRT (P=0.05).

described by Gomez and Gomez (1984). Treatment means were separated using duncan's multiple range test (DMRT) (Duncan, 1951).

RESULTS AND DISCUSSION

Spinosad 45 SC at 0.3 mL L^{-1} and Profenophos 40% + Cypermethrin 4% EC at 2 mL L^{-1} were demonstrated against *H. armigera* in Bengal gram over a three-year period from 2020 to 2022. Spinosad 45 SC at 0.3 mL L^{-1} showed effective control of the larval population (mean population across all observations: 0.90, 0.71, 0.74/plant), with percentage reductions over control of 71.33%, 84.03% and 70.84% in 2020, 2021 and 2022, respectively (Table 2) followed by Profenophos 40% + Cypermethrin 4% EC (mean population across all observations: 2.04, 3.14, 2.67/plant) resulted in percentage reductions of 19.00%, 21.88% and 21.52% during the years 2020-2022. The tested insecticides were comparatively safe to the natural enemies *Cheilomenes sexmaculata* and *Coccinella septempunctata*, as their populations were maintained or slightly increased after spraying (Table 3), indicating the selective action of the treatments and availability of alternative prey such as aphids and other soft-bodied insects in the crop ecosystem.

Table 4-6 present the cost-economic analysis of IPM strategies for managing *H. armigera* in Bengal gram during the years 2020-21, 2021-22 and 2022-23. The cost of insecticide usage played a significant role in the total cost of cultivation under farmer practices. The average total cost for IPM-based Bengal gram was Rs. 45,440, 52,729 and 60,302 for the years 2020-21, 2021-22 and 2022-23, respectively (Tables 4-6), which was lower than the cost for traditional farmer practices (Rs. 58,950, 59,944 and 65,953). The yield obtained from the demonstration practice was higher (23.75, 22.55, 24.23 q/ha), showing an increase of 12.47%, 18.49% and 21.73% compared to the farmer practice (21.18, 19.05, 19.95 q/ha) in the years 2020-21, 2021-22 and 2022-23, respectively. The net returns for the demonstration practice were recorded as 79,026, 69,041 and 105,646, which were greater than those from the

Table 4: Bengal gram economic analysis for the year 2020.

Farmer name	Yield (q/ha)		% Increase	Total returns (Rs ha^{-1})		Input cost (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional returns (Rs ha^{-1})	B:C ratio	
	Demo	FP		Demo	FP	Demo	FP	Demo	FP		Demo	FP
K. Dileep	24.58	23.5	4.60	128799	123140	46250	61250	82549	61890	20659	1.78	1.01
M. Srikanth Reddy	24.5	22.4	9.38	128380	117376	46025	58750	82355	58626	23729	1.79	1.00
K. Pavan Kumar	23	21.9	5.02	120520	114756	43900	60250	76620	54506	22114	1.75	0.90
P. Vinay Kumar	22.75	19.4	17.27	119210	101656	48300	64000	70910	37656	33254	1.47	0.59
U. Siva Kumar	24.5	22.1	10.86	128380	115804	47375	51625	81005	64179	16826	1.71	1.24
M. Prabhu	24.95	22.5	10.89	130738	117900	49500	56450	81238	61450	19788	1.64	1.09
N. Narayana Reddy	23.5	19.4	21.13	123140	101656	42250	61250	80890	40406	40484	1.91	0.66
A. Soma Sekhar	23	20.5	12.20	120520	107420	43750	59750	76770	47670	29100	1.75	0.80
A. Phani Kumar	22	18.6	18.28	115280	97464	43550	61575	71730	35889	35841	1.65	0.58
A. Surappa	24.75	21.5	15.12	129690	112660	43500	54600	86190	58060	28130	1.98	1.06
Average	23.75	21.18	12.47	124466	110983	45440	58950	79026	52033	26993	1.74	0.89

Table 5: Bengal gram economic analysis for the year 2021.

Farmer name	Yield (q/ha)		% Increase	Total returns (Rs ha^{-1})		Input cost (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional returns (Rs ha^{-1})	B:C ratio	
	Demo	FP		Demo	FP	Demo	FP	Demo	FP		Demo	FP
A. Nagappa	23.5	20.5	14.63	126900	110700	53500	62500	73400	48200	25200	1.37	0.77
P. Suryanarayana	23.9	19.8	20.71	129060	106920	51520	59400	77540	47520	30020	1.51	0.80
M. Manikanta	22.7	19.1	18.85	122580	103140	55850	57850	66730	45290	21440	1.19	0.78
K. Pavan Kumar	20.5	18.1	13.26	110700	97740	54250	59620	56450	38120	18330	1.04	0.64
K. Jayarami Reddy	24.6	19.8	24.24	132840	106920	53850	62500	78990	44420	34570	1.47	0.71
M. Ashok	23.8	21.5	10.70	128520	116100	56400	63410	72120	52690	19430	1.28	0.83
A. Muthyal Rao	20.4	17.6	15.91	110160	95040	49850	58400	60310	36640	23670	1.21	0.63
P. Janaradhan Naidu	21.9	18.5	18.38	118260	99900	52150	57620	66110	42280	23830	1.27	0.73
M. Sukumar	22.7	18.1	25.41	122580	97740	50410	58500	72170	39240	32930	1.43	0.67
P. Ranjith	21.5	17.5	22.86	116100	94500	49510	59640	66590	34860	31730	1.34	0.58
Average	22.55	19.05	18.49	121770	102870	52729	59944	69041	42926	26115	1.31	0.72

farmer practice (52,033, 42,926 and 70,691) over the three years. The benefit-cost ratio was determined, indicating that the IPM practice for Bengal gram generated higher profits (1.74, 1.31, 1.75) compared to the farmer practice (0.89, 0.72, 1.07) in the respective years. The technology gap in the demonstration varied from 0.15 to 4.61 q/ha compared to the potential yields (Fig 1). The technology gap was at its minimum (0.77) during the year 2022-23, as higher rainfall during the 2022 *Kharif* season contributed to increased yields (Supplementary material). This was also reflected in the additional net returns achieved in 2022, which were 34,955 rupees, higher than those in 2020 (26,993 rupees) and 2021 (26,115 rupees). During the three years, the extension gap ranged between 1.08 and 5.67, whereas the yield gap fluctuated from 4.60 to 30.08. The overall impact of Spinosad-based IPM demonstrations on pest reduction, productivity enhancement, economic returns and ecological safety across the three years is summarized in Fig 2.

The use of the bio-pesticide Spinosad for managing pod borer during the early crop growth stages (before 40 DAS) likely contributed to yield improvement by minimizing flower and pod damage caused by larval feeding during the reproductive stage. Spinosad was highly effective in reducing *Helicoverpa armigera* populations below the economic threshold level. Its effectiveness may be attributed to its rapid knock-down action and prolonged residual toxicity against actively feeding larval stages. Spinosad acts primarily through contact and ingestion activity with translaminar movement within leaf tissues, ensuring effective control of exposed larvae while remaining comparatively safe to natural enemies. Similar results were reported by Sreekanth *et al.* (2014); Suneel and Sarada, (2015); Chandra *et al.* (2016); Nitharwal *et al.* (2017) and Gafar *et al.* (2024), who found that spinosad 45 SC effectively reduced the larval population of pod borer. This efficacy is due to spinosad unique mode of action, which

Table 6: Ground nut economic analysis for the year 2022.

Farmer name	Yield (q/ha)		% Increase	Total returns (Rs ha^{-1})		Input cost (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional returns (Rs ha^{-1})	B:C ratio	
	Demo	FP		Demo	FP	Demo	FP	Demo	FP		Demo	FP
V. Srinivas reddy	23.5	21.52	9.20	160975	147412	58500	64850	102475	82562	19913	1.75	1.27
A. Lokanatha reddy	24.5	21.85	12.13	167825	149673	59450	65380	108375	84293	24083	1.82	1.29
K. Eswaraiah	24.85	19.85	25.19	170223	135973	57450	64850	112773	71123	41650	1.96	1.10
H. Sreeramulu	23.85	19.85	20.15	163373	135973	61520	64500	101853	71473	30380	1.66	1.11
M. Manikanta	22.75	18.45	23.31	155838	126383	62850	67850	92988	58533	34455	1.48	0.86
C. Narasimhulu	23.85	18.56	28.50	163373	127136	60450	65850	102923	61286	41637	1.70	0.93
I. Venkatesh	24.52	18.85	30.08	167962	129123	60850	66450	107112	62673	44440	1.76	0.94
A. Nagaraju	24.74	19.85	24.63	169469	135973	60950	67850	108519	68123	40397	1.78	1.00
A. Sasidhar	23.85	19.85	20.15	163373	135973	61250	66500	102123	69473	32650	1.67	1.04
M. Nallappa	25.85	20.85	23.98	177073	142823	59750	65450	117323	77373	39950	1.96	1.18
Average	24.23	19.95	21.73	165948	136644	60302	65953	105646	70691	34955	1.75	1.07

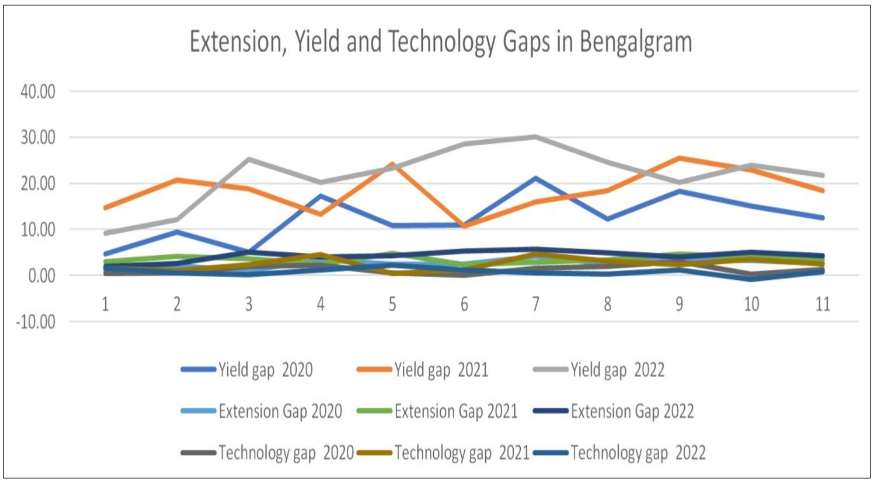

Fig 1: Comparative analysis of yield gap, extension gap and technology gap in Bengal gram across frontline demonstrations during 2020-2022.

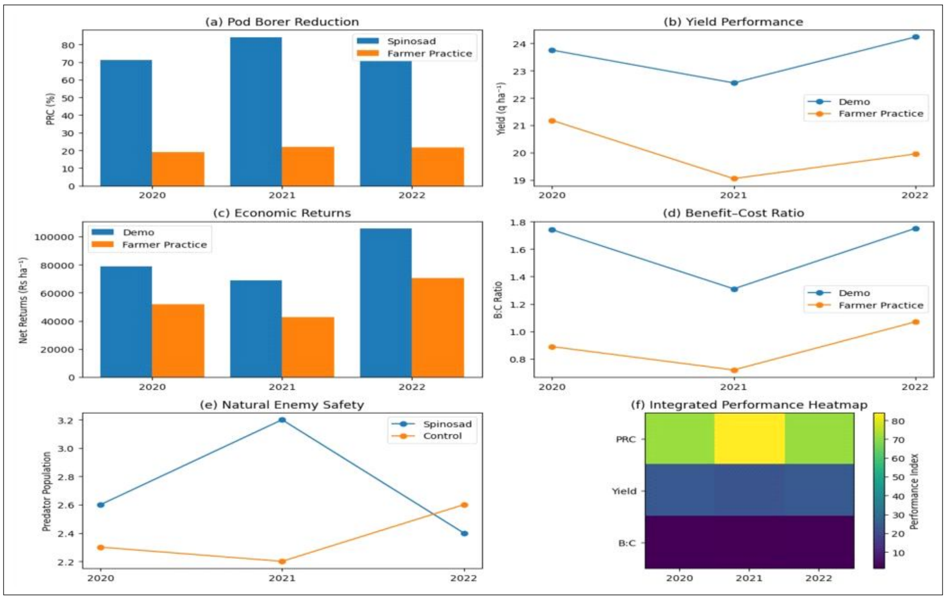

Fig 2: Integrated evaluation of Spinosad-based IPM demonstration for management of *Helicoverpa armigera* in Bengal gram showing pest reduction, yield improvement, economic benefits and ecological safety during 2020-2022.

involves binding to nicotinic acetylcholine receptors in the insect nervous system, leading to hyperactivity, paralysis and ultimately the death of the larvae as well as it provides long-term control for up to 15 days after spraying.

The current economics of bengalgram align with findings from studies conducted in various states of India by Kantwa *et al.* (2024); Ramesh *et al.* (2023); Singh *et al.* (2023); Yadav *et al.* (2024) and Yaligar *et al.* (2024). The technology gap, with an average range of 0.77 to 2.45 across all demonstrations over three years, suggests that timely cooperation from farmers in implementing critical IPM interventions could significantly impact the productivity of Bengal gram. The extension gap, varying from 1.1 to 5.67 q/ha, emphasizes the efforts of scientists in educating farmers about the significance of key IPM interventions during the crop growth phase. The relatively low technology index (3.09% to 9.80%) indicates the practicality of our technology in terms of net returns and individual farmer yields. A lower technology index indicates that the technology is more feasible. The average technology gap and extension gap highlight the necessity for further enhancement of extension efforts to close the gap and increase the adoption of improved technologies reported by Prasad *et al.* (2022).

Based on the above findings, it can be concluded that the use of appropriate scientific cultivation methods, particularly the timely application of insecticides before pest levels reaches the economic threshold level (ETL) during critical stages, as demonstrated in the frontline demonstration program, significantly reduced the technology gap and contributed to increased productivity.

CONCLUSION

The three-year field result demonstration of Spinosad 45 SC at 0.3 mL L^{-1} with farmers practice Profenophos 40% + Cypermethrin 4% EC clearly demonstated that spinosad was highly effective in managing *Helicoverpa armigera*, achieving 71.33%-84.03% reduction in larval population, compared with only 19. 00%-21.88% reduction under Profe-nophos 40% + Cypermethrin 4% EC. Further the spinosad treatment recorded higher bengalgram yields (23.75-24.23 q ha^{-1}) than farmer practices (19.05-21.18 q ha^{-1}), along with increased net returns (` 79,026- `1,05,646 ha^{-1}) and improved benefit-cost ratios (1.31-1.75). The lower technology index (3.09%-9.80%) and reduced technology gap (0.77-4.61 q ha^{-1}) highlight the feasibility and adoptability of the demonstrated IPM strategy under real farm conditions. The observed extension gap (1.08-5.67 q ha^{-1}) highlights the need for strengthened extension activities and effective dissemination of recommended technologies to enhance farmer adoption. The absence of phytotoxic effects and the maintenance of predator populations indicate the ecological safety and compatibility of the recommended insecticides under field conditions. Overall, Spinosad-based IPM can be recommended as a sustainable, economically viable and environmentally compatible strategy for effective pod borer management in Bengal gram.

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Author contribution statement

B.K. Kishore Reddy conducted designed the experiment and conducted all the field experiments and manuscript

drafting. SNM, MJ, G. Narayana Swamy, GRR corrected the manuscript. G.T. Madhavi, KSR, G. Sashikala, B. Chandhana, M. Ravi Kishore and KM assisted in conducting field experiment. GRR assisted in statistical analysis. All authors have seen and approved the manuscript and its contents.

Disclaimers

The opinions and conclusion outlined in this article reflect those of the author and should not be considered as representing the perspectives of their affiliated institutions. While the authors have ensured the accuracy and completeness of the information presented, they disclaim any responsibility for direct or indirect damages that may result from the application of this content.

Ethical statement

This study did not involve human participants or vertebrate animals. Field experiments were conducted in accordance with institutional and national agricultural research guidelines.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

Ahmad, S., Shafiq-Ansari, M. and Muslim, M. (2015). Toxic effects of neem-based insecticides on the fitness of *Helicoverpa armigera* Hubner. *Crop Protection.* **68:** 72-78.

Chandra, S.G.V., Ashwani, K., Lavanya, V. and Rehaman, S.K. (2016). Efficacy of certain chemicals and neem products against *Helicoverpa armigera* (Hubner) on chickpea (*Cicer arietinum* L.). *Journal of Entomology and Zoology Studies.* **5(2):** 1-4.

Duncan, D.B. and Perry, J.E. (1951). The transmutation of N14 by protons. *Physical Review.* **82(6):** 809.

Food and Agriculture Organization of the United Nations. (2023). *FAOSTAT Statistical Database*. https://www.fao.org/faostat/.

Gafar, B.B., Yadav, U., Mushinamwar, D.R. and Chavan, S.R.V. (2024). Efficacy of certain biopesticides and chemicals against gram pod borer *Helicoverpa armigera* (Hubner) on chickpea (*Cicer arietinum* L.). *International Journal of Advanced Biochemistry Researc.* **8(5):** 339-342.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. John Wiley and Sons.

Jukanti, A.K., Gaur, P.M., Gowda, C.L. and Chibbar, R.N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. *British Journal of Nutrition.* **108:** 11-26.

Jyothi, V.S., Lahari, K. and Lakshmi, R.P. (2019). Upscaling of bengalgram yield by cluster frontline demonstrations in rain shadow Anantapuramu district. *International Journal of Agriculture Sciences.* **11(5):** 7979-7981.

Kantwa, C.R., Tripathy, S., Bhadauria, R.S., Sharma, B., Jakhar, S.R., Kumar, S. and Singh, S.R.K. (2024). Front line demonstration on performance of chickpea in Malwa region of Madhya Pradesh. *Legume Research.* **47(1):** 74-77. doi: 10.18805/LR-4890.

Nitharwal, R.S., Kumar, A., Jat, S.L. and Chula, M. (2017). Efficacy of newer molecules against gram pod borer, *Helicoverpa armigera* (Hub.) on chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry.* **6(4):** 1224-1227.

Prasad, D., Prakash, V., Meena, R.S. and Bairwa, S.K. (2022). Performance of chickpea (*Cicer arietinum*) frontline demonstrations in Rajasthan. *Indian Journal of Agricultural Sciences.* **92(2):** 254-257.

Rajashekhar, M., Prabhakar Reddy, T., Chandrashekara, K.M., Rajashekar, B., Jagan, M.R.M., Ramakrishna, K., Satyanarayana, E., Shankar, A., Jahan, A., Kumar, P. and Shravika, L. (2022). Evaluation of integrated pest management module for pink bollworm, *Pectinophora gossypiella* (Saunders) and its economic analysis under farmer's field conditions. *International Journal of Pest Management.* **29:** 1-9.

Ramesh, G., Durgaprasad, N.V.V.S., Jahnavi, M. and Chowdary, L.R. (2023). Impact of cluster frontline demonstrations on yield of chickpea (*Cicer arietinum* L.) in Prakasam district of Andhra Pradesh, India. *International Journal of Plant and Soil Science.* **35(9):** 65-70.

Reddy, K.K.B., Sadhineni, M., Johnson, M., Reddy, K.K.K., Kishore, R.M., Rani Sudha, K. and Madhavi, G.T. (2024). Evaluation of integrated pest management module against pests of groundnut and productivity, profitability analysis under open field conditions. *Legume Research.* **47(4):** 628-636. doi: 10.18805/LR-5278.

Samui, S.K., Maitra, S., Roy, D.K., Mandal, A.K. and Saha, D. (2000). Evaluation of front-line demonstration on bengalgram. *Journal of the Indian Society of Coastal Agricultural Research.* **18(2):** 180-183.

Singh, M.K., Kumar, N., Mandal, B.S. and Singh, F. (2023). Impact of front-line demonstration of chickpea (*Cicer arietinum* L.) grown under irrigated semi-arid condition of Haryana. *Environment and Ecology*. **41(4):** 2381-2384.

Sreekanth, M., Lakshmi, M.S.M. and Rao, Y.K. (2014). Bio-efficacy and economics of certain new insecticides against gram pod borer, *Helicoverpa armigera* (Hubner) infesting pigeonpea (*Cajanus cajan* L.). *International Journal of Plant, Animal and Environmental Sciences.* **4(1):** 11-15.

Suneel, G.V. and Sarada, O. (2015). Field efficacy and economics of some new insecticide molecules against lepidopteran caterpillars in chickpea. *Current Biotica.* **9(2):** 153-158.

Yadav, B.L., Khan, I. and Singh, T.P. (2024). Enhancing productivity of chickpea through cluster front line demonstration in Jaipur district of Rajasthan. *Legume Research*. **47(11):** 1986-1989. doi: 10.18805/LR-5364.

Yaligar, R., Jyothi, R., Narappa, G., Radha, J., Arabhanvi, F., Revathi, R.M. and Shruthi, N. (2024). Productivity, profitability and yield gap analysis in chickpea under front line demonstration in Tungabhadra command area of Koppal district. *Legume Research*. **48(3):** 437-443. doi:10.18805/LR-5303.