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Assessment of Integrated Pest Management Approaches in Chickpea against Pod Borer, *Helicoverpa armigera* (Hübner), through Frontline Demonstrations in Muzaffarpur, Bihar, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author BCA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author MLM edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Chickpea pod borer infestation significantly limits yields in Muzaffarpur, Bihar, India. This study evaluated the effectiveness of Integrated Pest Management (IPM) for pod borer control through Front Line Demonstrations (FLD) involving 65 farmers during the 2022-23 and 2023-24 rabi seasons.

The present study was carried out by Krishi Vigyan Kendra, Muzaffarpur, Bihar, on farmers' fields during the rabi seasons of 2022-23 and 2023-24 as part of the FLD program. Each demonstration covered an area of 0.4 ha, with a neighbouring check plot of the same size maintained for comparison using farmers' practices. The demonstrations were conducted in various villages, including Tepri and Patsara, Kerma and Chhajan, Sakri Faridpur of Bandra, Kurhani, and Sakra blocks of Muzaffarpur district respectively. The Pusa 3043 variety was used in the demonstration plots, while local varieties were planted in the check plots.

The IPM practices included the installation of pheromone traps (@10/ha with *Helicoverpa armigera* lures), the placement of bird perches (@15-20 per acre), spraying Azadirachtin 1500 ppm (2 ml/L), *Helicoverpa armigera* nuclear polyhedrosis virus (HaNPV) @250 LE/ha, Emamectin Benzoate 5% SG (@0.4 g/L), and Indoxacarb (@0.3 ml/L). Data on the number of larvae per meter row was recorded at 10 randomly selected locations in both demonstration and check plots. Data on production costs, inputs used, and monetary returns were collected to assess the economic feasibility of the recommended technology under experimental conditions.

FLDs exhibited significantly lower larval counts (2.62 larvae/meter row) and pod damage (6.34%) compared to control plots. The average technology gap, extension gap, and technology index were 3.31 q/ha, 3.54 q/ha, and 27.48%, respectively. FLDs achieved the highest chickpea yield (11.19 q/ha), resulting in a net profit of Rs 67,472.50/ha and a B:C ratio of 2.69.

These findings demonstrate the efficacy of IPM in enhancing chickpea production and profitability in the region.

Keywords: Azadirachtin; chickpea; emamectin benzoate; front line demonstration; HaNPV; Helicoverpa armigera; IPM.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a vital pulse crop cultivated globally. The leading chickpea-producing countries are India, Turkey, Pakistan, Myanmar and Ethiopia. India is the largest producer of chickpeas with 70% of global production (FAO, 2020). In India, chickpea is cultivated over an area of 9.7 million hectares, producing 13.12 million tonnes with an average productivity of 1142 kg/ha during the year 2021-22 (Anonymous, 2023). It is grown in six major states viz., Maharashtra, Madhya Pradesh, Rajasthan, Gujarat, Uttar Pradesh, Andhra Pradesh, Karnataka and Chhattisgarh altogether contribute 97.15 per cent of the production and 96.95 per cent of the area (Singh et al., 2023). There is still a gap between the requirement and production of pulses in the country (DES, 2021–2022). However, its low productivity is attributed to several factors, including the availability of quality seeds, cultivation methods, and adoption of effective plant protection measures. Surveys, farmer interactions, and field diagnostics have identified pod borer (*Helicoverpa armigera* Hübner) infestation as a significant contributor to low productivity, causing both quantitative and qualitative losses. Amongst the insect pests, *H. armigera*, pod borer has been reported to cause maximum damage (Ojha et al., 2017). Chickpea suffers losses to the tune of 25 to 75% due to the attack of the pod borer (Taggar & Singh, 2011). The pest feeds on tender shoots and young pods (Lal, 1996), boring holes into the pods and inserting half its body to consume developing seeds (Kadam & Patel, 1960). It is considered a serious pest, having attained the status of a national pest in India, with grain yield losses ranging from 10-30% (Quadeer & Singh, 1989) or even up to 60% under favourable conditions.

Chemical pesticides have traditionally been the primary method for managing this pest in India and other developing countries. Chemical control offers rapid and effective results, enabling farmers to achieve substantial pest reduction in a short time. However, excessive and indiscriminate pesticide use over prolonged periods has led to numerous issues, including environmental contamination, biodiversity loss, development of insecticide-resistant *H. armigera* populations, pest resurgence, secondary pest outbreaks, destruction of natural enemies, increased input costs, and toxic hazards due to pesticide residues. The preference for insecticides is driven by their availability and ease of application, but their overuse has contributed to insecticide resistance and environmental pollution (Phokela et al., 1990). Recent studies indicate that *H. armigera* has developed resistance to many commonly used insecticides. High levels of these insecticide residues have also been found in the environment and in the plant's edible portions (Kapoor et al., 2000).

Growing environmental concerns regarding pesticide hazards have spurred global interest in alternative pest management approaches. Considering these challenges, it is essential to explore integrated methods to reduce dependency on chemical pesticides. Integrated Pest Management (IPM) strategies provide a sustainable approach to chickpea production. IPM combines multiple pest control techniques, including pheromone traps, biopesticides, botanical pesticides, and need-based insecticide applications. In light of these considerations, efforts have been made to evaluate IPM packages for their effectiveness against chickpea pod borer.

2. MATERIALS AND METHODS

The present study was carried out by Krishi Vigyan Kendra, Muzaffarpur, Bihar, on farmers' fields during the rabi seasons of 2022-23 and 2023-24 as part of the Front Line Demonstration (FLD) program. Each demonstration covered an area of 0.4 ha, with a neighbouring check plot of the same size maintained for comparison using farmers' practices.

The demonstrations were conducted under irrigated conditions on medium sandy loam soils in various villages, including Tepri and Patsara, Kerma and Chhajan, Sakri Faridpur (Bandra block), Kurhani, and Sakra blocks of Muzaffarpur district. The Pusa 3043 variety was used in the demonstration plots, while local varieties were planted in the check plots. A total of 65 demonstrations were conducted across 65 farmers' fields, covering an area of 26 ha. Interested farmers were selected, and specific issues were identified using a questionnaire.

Before the implementation of the demonstrations each year, all selected farmers received training on IPM practices at Krishi Vigyan Kendra, Turki, Muzaffarpur. Essential critical inputs were provided to the participants. The Integrated Pest Management (IPM) practices included the installation of pheromone traps (@10/ha with *Helicoverpa armigera* pheromone lures from Kendriya Bhandar, Faridabad), mixing 200 g of sorghum seeds with chickpea seeds, the placement of bird perches (@15-20 per acre), spraying Azadirachtin 1500 ppm (2 ml/L), *Ha*NPV (250 LE/ha), Emamectin Benzoate 5% SG (@0.4 g/L), and Indoxacarb (@0.3 ml/L).

Data on the number of larvae per meter row was recorded at 10 randomly selected locations in both the demonstration and check plots. The observations on the larval population counts were taken (Amogha et al., 2023). At maturity, pods were collected from 25 randomly selected plants in each plot and examined.

The damaged (bored) and total numbers of pods were counted and the percent pod damage was determined using the following formula:

$$\text{Pod damage (\%)} = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \text{ x } 100$$

Data on production costs, inputs used, and monetary returns were collected to assess the economic feasibility of the recommended technology under experimental conditions. This information was used to calculate the technology gap, extension gap, and technology index. These parameters were determined using the formulas (Samui et al., 2000).

$$\text{increase yield (\%)} = \frac{\text{Demonstration yield} - \text{farmers yield}}{\text{Farmers Yield}} \text{ x } 100$$

Technology gap (q/ha) = Potential yield - Demonstration yield

Extension gap (q/ha) = Demonstration yield-yield under existing practice

$$\text{Technology index (\%)} = \frac{\text{Potential yield} - \text{Demonstration yield}}{\text{Potential yield}} \text{ x } 100$$

3. RESULTS AND DISCUSSION

3.1 Growth Parameters in Chickpea

The efficacy of Integrated Pest Management for chickpea pod borer control was evaluated against farmers' practices using Front Line Demonstrations. Growth parameters, including germination percentage, plant height, number of pods per plant, pod length, and pod filling percentage, were assessed.

Germination percentage in the demonstration plots was consistently higher (98.35% and 97.14% in 2022-23 and 2023-24, respectively) compared to the check plots (96.64% and 93.26%, respectively). The two-year average germination percentage was 97.75% for IPM and 94.95% for farmers' practices. Similarly, plant height was greater in the IPM plots (41.28 cm and 40.20 cm) than in the check plots (37.48 cm and 38.82 cm) across both seasons. The average plant height over the two years was 40.74 cm in the IPM plots and 38.15 cm in the check plots.

The number of pods per plant was also marginally higher in the IPM plots (68.52 and 70.31) compared to the check plots in both years. While pod length showed minimal differences between the two treatments, pod filling percentage was notably higher in the IPM plots (85.38% and 84.13%) compared to the check plots (80.58% and 81.54%) during both 2022-23 and 2023-24. The overall mean pod filling percentage was also higher under IPM. These findings suggest that the IPM strategy positively influenced chickpea growth and development, potentially contributing to improved yields. A summary of these results is presented in Table 1. Further discussion analysing these results in the context of existing literature and explaining the observed differences would strengthen this section.

3.2 Incidence of Pod Borer, *Helicoverpa armigera*

Observations on larval populations and pod damage revealed a significant difference between the IPM and farmer practice plots. Larval counts were substantially lower in the demonstration plots (3.20 and 2.62 larvae per meter row in 2022-23 and 2023-24, respectively) compared to the check plots (9.40 and 8.55 larvae per meter row, respectively). These findings on larval counts are in parity with the findings of 2024 (Singh et al., 2024). This reduced larval density in the IPM plots likely contributed to the lower pod damage percentages observed. The implementation of pheromone traps, coupled with timely insecticide applications, may have played a crucial role in reducing pod borer populations. These findings are consistent with previous research about the effectiveness of pheromone traps and timely biopesticide applications in reducing pod borer incidence in pigeon pea (Agrawal et al., 2002; Tripathi et al., 2015). Furthermore, the use of insecticides like Emamectin benzoate and Indoxacarb in the IPM strategy likely provided effective control against both early and late-stage borer infestations, contributing to enhanced pod protection. This aligns with the findings of Suganthy & Kumar (2000), who reported the superiority of IPM modules over untreated controls. Table 2 presents the pod damage percentages and the reduction in damage achieved through the IPM strategy. Further analysis and discussion relating these results to the broader context of IPM in chickpea production would enhance this section.

The two-year average data further confirmed the effectiveness of the IPM strategy. Mean larval counts were significantly lower in the demonstration plots, resulting in considerably less pod damage compared to the check plots. The average pod damage percentage in the IPM plots was only 6.82%, compared to 24.58% in the check plots. The IPM technology achieved substantial pod borer damage reductions of 72.59% and 71.84% in 2022-23 and 2023-24, respectively. These results highlight the potential of IPM in minimizing pod borer damage and improving chickpea yields.

Table 1. Observation on Growth parameters in chickpea under FLD

Year	Germination (%)		Plant height (cm)		No. of pods per plant		Pod length (cm)		Pod filling (%)	
	Demo	Check	Demo	Check	Demo	Check	Demo	Check	Demo	Check
2022-23	98.35	96.64	41.28	37.48	68.52	62.15	2.60	1.60	85.38	80.38
2023-24	97.24	93.26	40.20	38.82	70.31	63.35	2.20	1.58	84.13	81.54
Average	97.79	94.95	40.74	38.15	69.42	62.75	2.40	1.59	84.76	80.96

Demo= Demonstration

Table 2. Impact of IPM technology on incidence of pod borer, *Helicoverpa armigera* and pod damage

Year	No. of larvae/meter row [a]		Total No. of pods observed		No. of damaged pods		Pod damage (%) [b]		Damage reduction over check (%)
	Demo	Check	Demo	Check	Demo	Check	Demo	Check	
2022-23	3.20 (2.28)	9.40 (3.56)	100	100	7.30	26.64	7.30 (15.68)	26.64 (31.08)	72.59
2023-24	2.62 (2.12)	8.55 (3.42)	100	100	6.34	22.52	6.34 (14.59)	22.52 (28.33)	71.84
Average	2.91 (2.20)	8.96 (3.49)	100	100	6.82	24.58	6.82 (15.14)	24.58 (29.72)	72.21

a Figures in parenthesis are transformed values of $\sqrt{x+0.5}$

b Figures in parenthesis are transformed angular values;

Table 3. Impact of Integrated Pest Management practices on yield, technology gap, extension gap and technology index of chickpea grown under FLD

Year	Area (ha)	No. of Demo	Yield (q/ha) Demo	Farmers practice (FP) (q/ha)	% increase in yield over FP	Technology gap (q/ha)	Extension gap (q/ha)	Technology index (%)
2022-23	12	30	10.45	7.30	43.15	4.05	3.15	27.93
2023-24	14	35	11.93	8.01	48.94	2.57	3.92	27.03
Average			11.19	7.66	46.05	3.31	3.54	27.48

Demo= Demonstration, FP= Farmers Practice

3.3 Yield Analysis, Technology Gap, Extension Gap and Technology Index of Chickpea

The impact of IPM on chickpea yield was assessed, along with the technology gap, extension gap, and technology index. The highest yield (11.93 q/ha) was observed in the IPM demonstration plots during 2023-24, significantly exceeding the yield in the check plots (8.01 q/ha). The pooled mean yield across both years was also higher in the IPM plots (11.19 q/ha) compared to the farmer practice plots (7.66 q/ha). This substantial yield increase of 46.05% associated with the adoption of IPM practices aligns with previous findings (Dubey et al., 2010; Meena, 2010).

The average technology gap of 3.31 q/ha likely reflects variations in soil fertility, agricultural practices, and local climatic conditions. The average extension gap of 3.54 q/ha underscores the need for effective knowledge dissemination and farmer education through extension approaches such as FLDs, training programs, and method demonstrations. The technology index, which indicates the feasibility of the demonstrated technology, decreased from 27.93% in 2022-23 to 27.03% in 2023-24. This reduction suggests increasing practicality and adoption potential of the IPM technology. Table 3 summarizes the yield data, technology gap, extension gap, and technology index for both years.

3.4 Economic Analysis

The economic benefits of IPM were evaluated by comparing net profits between the demonstration and check plots. The IPM plots consistently generated higher net profits (Rs. 65570 and Rs. 69375 in 2022-23 and 2023-24, respectively) compared to the check plots. These findings are consistent with previous findings of 2003, the highest grain yield and returns per rupee invested with an IPM module that included hand collection of larvae, bird perches, and three sprays of *Bacillus thuringiensis*, *Helicoverpa armigera* nucleo polyhedron virus, and neem seed kernel extract (Chavan et al., 2003). The FLD program effectively demonstrated the productivity and profitability potential of IPM under real-world farm conditions. These results align with the observations of 2005 (Kirar et al., 2005).

Table 4. Impact of IPM Technology on Economics of chickpea under FLD

Year	Gross returns (Rs./ha)		Cost of cultivation (Rs./ha)		Net returns (Rs./ha)		BC ratio	
	Demo	Check	Demo	Check	Demo	Check	Demo	Check
2022-23	91370	68300	25800	26350	65570	41950	2.54	1.59
2023-24	93800	73950	24425	27600	69375	47350	2.84	1.72
Average	92585	71125	25112.50	26,975	67472.50	44,650	2.69	1.66

4. CONCLUSION

This study demonstrated the effectiveness of Integrated Pest Management technology for enhancing chickpea production. The IPM approach significantly improved key growth parameters, along with managing the incidence of pod borer larvae in the IPM plots, which attributed to the strategic use of pheromone traps and timely insecticide applications, resulted in substantially reduced pod damage. Along with increasing the chickpea yield, the potential of IPM for improving chickpea productivity and profitability under real-world farm conditions was effectively highlighted. The FLD program proved to be a valuable platform for showcasing the benefits of IPM to farmers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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