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PERFORMANCE OF DIFFERENT INTEGRATED PEST MANAGEMENT PACKAGES FOR THE SUPPRESSION OF CHICKPEA POD BORER

M. A. SARKAR[1], M. M. RAHMAN[2], N. K. DUTTA[3]
M. H. RASHID[4] AND A. K. M. R. H. FERDOUS[5]

Abstract

Chickpea (*Cicer arietinum* L.) is a major pulse crop in Bangladesh, but its productivity is severely constrained by the pod borer, *Helicoverpa armigera* (Hubner). This study evaluated the efficacy of four integrated pest management (IPM) packages combining pheromone-based mass trapping, microbial and plant-derived biorational insecticides, and selective chemical sprays, compared with conventional farmer practice (Cypermethrin plus Chlorpyriphos: Nitro®) and untreated control, across two Rabi seasons (2020–21 and 2021–22). Sex pheromone traps were installed to monitor and partially suppress adult *H. armigera* populations, and foliar applications of IPM components were performed during the pod formation stage, when chickpea pods are most vulnerable. All IPM packages significantly reduced pod damage relative to untreated control and conventional practices. The lowest pod infestation (2.83-3.01%) and highest yields (1.48-1.58 t ha^{-1}) were achieved in IPM packages integrating pheromone trapping with *Bacillus thuringiensis* var. *kurstaki* plus Spinosad (Spinomax®) or plant-derived *Celastrus angulatus* extract (Bio-Chamak®), outperforming the conventional farmer practice (pod damage 4.53-5.97%; yield 1.34-1.39 t ha^{-1}). Peak moth captures occurred 60-80 days after sowing, and abiotic factors, particularly temperature and relative humidity, were positively associated with moth activity. Economic analysis indicated that, despite the highest marginal benefit-cost ratio (MBCR) for farmer practice (1.87) due to lower input costs, IPM packages achieved substantial yield improvements with MBCRs up to 1.39. These results demonstrate that biorational-based IPM strategies integrated with pheromone mass trapping effectively suppress *H. armigera*, and enhance chickpea productivity.

Keywords: *Cicer arietinum, Helicoverpa armigera*, pod borer, pheromone trap, biopesticides.

Introduction

Chickpea (*Cicer arietinum* L.) is a major pulse crop in Bangladesh, ranking seventh in area and production. The crop currently occupies 3,946 ha, producing

[1,3&5]Entomology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, [2]Department of Entomology, Faculty of Agriculture, Gazipur Agricultural University (GAU), Gazipur-1706, and [4]Regional Agricultural Research Station, BARI, Burirhat, Rangpur-5410, Bangladesh.

5,048 tons at a national average yield of 1.28 t ha^{-1} (BBS, 2025). According to the FAO, in 2023, chickpea is cultivated globally on 14.1 million hecters, with an average yield of 1171 kg ha^{-1}, resulting an annual production of 16.5 million tons (FAOSTAT, 2025). Eleven species of insect pests of chickpea have been recorded in Bangladesh of which nine species attack in field and two species attack in storage. Among these, the field insect pests pod borer, *Helicoverpa armigera* (Hubner) is the most destructive and very notorious insect pests, bear polyphagous nature and serious in most of the chickpea growing areas in Bangladesh (Hossain *et al*., 2016). In the chickpea growing area pod borer (*H. armigera* Hubner) (Lepidoptera: Noctuidae), is the most common and critical challenge for successful chickpea production around the world (Ujjan *et al*., 2019; Kumar *et al*., 2019; Jai *et al*., 2020). Bajia and Bairwa (2015) reported that it causes about 75 to 90 % losses in seed yield, and it was pointed out that gram pod borer damage leaves, tender shoots, apical tips, floral buds and pods. In case of outbreaks, yield losses caused by chickpea pod borer range from 10-90% and 50-60% pod damage in the crop depending upon the insect population and susceptibility of genotypes (Sharma *et al*., 2012; Kambrekar, 2012; Iqbal *et al*., 2014; Ahmed and Awan, 2013). Single larva can damage 40 pods and it feeds on floral buds, flowers and young pods of the growing crop (Khan *et al*., 2009; Bajia and Bairwa, 2015). *H. armigera* is widely dispersed throughout the African, Asian, European and Mediterranean regions (EPPO, 2006; Zohary *et al*., 2012).

The wider host range, multiple generation, migratory behavior and high fecundity of gram pod borer made it difficult to manage. The chemical control options are still regarded as the last resort for its management due to their quick known effects (Sreekanth *et al*., 2014). In Bangladesh, synthetic insecticides are generally used to control the pest. However, continuous and indiscriminate use of synthetic pesticides has resulted in residues, development of insecticide resistance, adverse effects on non-target organisms, humans and the environment (Boulamtat *et al*., 2020; Patil *et al.*, 2017; Hossain *et al.*, 2010; Kumar and Sarada, 2015). Integrated pest management (IPM) offers an effective, environmentally compatible approach by combining multiple control tactics, including mechanical removal, biological and botanical insecticides, pheromone-based monitoring and mass trapping, and selective use of low-risk chemical molecules.

Recent advancements in biorational insecticides have demonstrated significant potential for pod borer management. Plant-derived compounds, such as *Celastrus angulatus* extract (Bio-chamak®), and microbial products, including *Bacillus thuringiensis* formulations (Spinomax® – a combination of Bt var. *kurstaki* and spinosad), exhibit high insecticidal activity while preserving ecological safety (Rahman *et al*., 2023, 2025; Rashid *et al*., 2003). These bioactive agents act through specific physiological and behavioral mechanisms, including feeding inhibition, disruption of digestion, and neuro-modulation, with minimal potential for resistance development (Wang *et al*., 2001; Wei *et al*., 2009). Nevertheless, their integration with pheromone-based technologies in field-level chickpea IPM has been poorly documented under Bangladesh agro-ecological conditions.

Pheromone traps are valuable tools for monitoring and management of *H. armigera*, enabling early detection, forecasting, and targeted control measures (Ahmed and Khalique, 2002). Compatibility of microbial and biorational insecticides with chemical sprays has also been demonstrated, reducing pest populations while minimizing environmental hazards (Khalique and Ahmed, 2003; Ahmed *et al*., 2012).

Considering the need for environmentally safe and sustainable pest management, the present study was designed to evaluate the efficacy of IPM packages incorporating biorational and microbial insecticides, pheromone-based mass trapping, and selective chemical sprays against chickpea pod borer. This approach aims to optimize yield protection while reducing reliance on conventional insecticides.

Materials and Methods

Experimental site and duration: Field experiments were conducted in two consecutive winter (*Rabi*) seasons during 2020–2021 and 2021–22 at the Entomology Research field, Bangladesh Agricultural Research Institute (BARI), Gazipur (24°00′N, 90°25′E; elevation 8.4 m above sea level). The area is characterized by a subtropical climate with distinct dry and cool winters, moderate rainfall, and an average temperature range of 15-30°C. The soil of the experimental site was silty clay loam with pH 6.8 and moderate organic matter content. The experiments were performed under irrigated conditions following standard agronomic practices recommended for chickpea cultivation in central Bangladesh.

Experimental design and crop establishment: The experiment was laid out in a randomized complete block design (RCBD) with six treatments and three replications (dispersed). Each plot measured 10.0 m × 5.0 m with 1.0 m spacing between plots and 1.5 m between blocks to prevent cross-interference of treatments. The treatments were randomly allotted in each block. The seeds of BARI Chola-9 were sown in rows with spacing of 50 cm and plant to plant distance was maintained 10 cm. The seeds were sown during the last week of November in both years. Standard agronomic practices were done as recommended. The recommended fertilizer doses were applied at 5 t ha^{-1} cow dung, 20-25-25-10-2-1.5 kg ha^{-1} of N-P_2O_5-K_2O-S-Zn-B at the time of final land preparation. Standard irrigation, weeding, and mulching operations were performed as required to maintain uniform crop growth across all treatments.

Treatments and Integrated Pest Management (IPM) Packages: Four IPM packages were formulated based on previous research findings and were evaluated alongside the farmer's practice (chemical pesticides only) and an untreated control. Each package incorporated different combinations of mechanical, biological, biorational, and insecticidal components (Table 1). Application schedules, dosages, and input materials were standardized across treatments to ensure valid and comparable assessment of efficacy.

Table 1. Details of Multi-component IPM packages applied in the experiment

Description of IPM Packages

IPM package 1: Sex pheromone trap + Spinosad (Success® 2.5 SC @ 1.2 ml L^{-1} water)

IPM package 2: Sex pheromone trap + *Bacillus thuringiensis* var. *kurstaki* (Btk) + Spinosad (Spinomax® @ 2 ml L^{-1} water)

IPM package 3: Sex pheromone trap + *Celastrus angulatus* extract (Bio-Chamak® 1% EW @ 2.5 ml L^{-1} water)

IPM package 4: Sex pheromone trap + Chlorantraniliprole (Coragen® 18.5 SC @ 0.5 ml L^{-1} water)

Farmer's practice: Weekly spraying of Cypermethrin + Chlorpyriphos (Nitro® 505EC @ 2ml L^{-1} water)

Untreated control (no pest management interventions)

Treatment application procedure: Sex pheromone traps were installed prior to foliar treatments to monitor and partially suppress adult *H. armigera* populations. Traps were deployed at a density of 40 per hectare, 45 days after sowing (DAS) with a 25 m spacing to prevent overlapping pheromone plumes and ensure representative sampling of the experimental field. BARI-developed water traps were equipped with species-specific pheromone lures and positioned slightly above the crop canopy using bamboo supports. Traps remained in the field throughout the cropping season, and captured male moths were counted weekly to track adult population dynamics, peak activity periods, and the efficacy of the integrated pest management (IPM) packages in suppressing adult moths.

Foliar applications of the pesticidal components of each IPM package were performed during the pod formation stage, the period of highest susceptibility to *H. armigera* infestation. Treatments, as specified in Table 1, were applied three times at 7-day intervals using a calibrated hand-operated knapsack sprayer to ensure uniform coverage across the entire crop canopy. This standardized application guaranteed that all plants within each plot received consistent exposure to the assigned IPM interventions, enabling accurate assessment of treatment efficacy. By integrating precise pest monitoring with strategically timed applications, this approach minimized off-target effects, preserved natural enemy populations, and maximized the effectiveness of biological and biorational control measures within the chickpea cropping system.

Assessment of pod infestation by pod borer: At maturity, all the pods were collected from randomly placed 1m^2 quadrants in each plot and examined. The damaged (bored) and total numbers of pods were counted and the per cent pod damage was determined using the following formula:

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

The per cent reduction of pod damage compared to the untreated control was calculated using the following formula:

$$\text{Percent reduction over control} = \frac{\text{Mean population in control} - \text{Mean population in treatment}}{\text{Men population in control}} \times 100$$

Yield production and economic analysis: Crops of the central four rows were harvested and then threshed. The grains were cleaned and dried in the bright sunshine. The grain yield obtained from each plot was converted into per hectare (t ha^{-1}). A detailed record of labor, pesticide, biopesticide, and pheromone trap costs was maintained for each treatment. The untreated control served as a reference for gross and net benefit estimation. Gross return was calculated with the marketable yield of chickpea and farm gate price. The marginal benefit-cost ratio (MBCR) was computed following the method of Ali *et al*. (1996): MBCR= Additional benefit over control/ Additional cost over control.

Adjusted net return = Net return from the treated plant – Net return from the control plant

Net return = Gross return – Cost of treatment

Statistical analysis: All data were subjected to analysis of variance (ANOVA) using R statistical software (version 4.3.1). Treatment means were separated by the least significant difference (LSD) test at a 5% probability level ($p \leq 0.05$). Data expressed in percentages were arcsine-transformed before analysis to ensure homogeneity of variance.

Results and Discussion

Effect of IPM packages on pod damage infestation and moth trapping week^{-1}trap^{-1}: The chickpea pod borer, *H. armigera*, remained the dominant pest throughout both cropping seasons (2020–2021 and 2021–2022), and pod infestation differed significantly among treatments ($p \leq 0.05$). During the 2021–2022 season, pod damage ranged from 2.83% to 8.27% (Table 2). The lowest pod damage (2.83%) was recorded in IPM package 2, which combined sex pheromone mass trapping with spraying of *Bacillus thuringiensis* var. *kurstaki* + Spinosad (Spinomax®), and statistically comparable to other IPM packages. Slightly higher pod damage (2.91%) was observed in IPM package 3 (sex pheromone trap + Bio-Chamak®), followed by IPM package 4 (sex pheromone trap + Coragen®) and IPM package 1 (sex pheromone trap + Success®), which recorded 2.95% and 3.01% pod damage, respectively. The conventional farmer's practice (weekly spraying of Nitro®) resulted in 4.53% pod damage, while untreated control plots suffered the highest infestation (8.27%).

In the 2020–21 season, pod damage ranged from 3.01% to 9.03%, with IPM package 2 again providing the lowest damage (3.01%) (Table 2). Other IPM treatments consistently resulted in significantly lower infestation than the farmer's practice, which recorded 5.97%, whereas untreated plots exhibited 9.03% damage. These findings corroborate previous studies indicating that integration of pheromone traps with bio-insecticides or biorational agents significantly reduces pod borer infestation (Madhu, 2014; Sreekanth *et al*., 2014; Tushar *et al*., 2020; Singh *et al*., 2013). The efficacy of Chlorantraniliprole, Spinosad, and Bt-based treatments aligns with reports by Balikai *et al*., 2001; Hossain *et al*., 2010; and Tiwari *et al*., 2007 confirming the superior performance of IPM strategies over conventional chemical applications. Integrated approaches combining biocontrol, biorational, and minimal-risk chemicals have been shown to reduce larval population and pod damage while maintaining compatibility with natural enemies (Jerusha and Thakur, 2018; Sarkar *et al*., 2006).

Table 2. Effect of different IPM packages on mean pod borer infestation of chickpea during two cropping seasons and moth trapped week^{-1} trap^{-1}

Cropping season	Management packages	Pod damage (%)	Pod damage reduction over control (%)	Moth trapped/ trap/week (Avg. of 16 weeks)
2021–22	IPM package-1	3.01 c	63.60	0.33
	IPM package-2	2.83 c	65.78	0.25
	IPM package-3	2.91 c	64.81	0.25
	IPM package-4	2.95 c	64.33	0.33
	Farmer's practice	4.53 b	44.37	-
	Untreated Control	8.27 a	-	-
2020–21	IPM package-1	3.99 c	55.81	1.08
	IPM package-2	3.01 d	66.67	1.25
	IPM package-3	3.82 c	57.70	1.16
	IPM package-4	3.54 c	60.79	1.12
	Farmer's practice	5.97 b	33.89	-
	Untreated Control	9.03 a	-	-

Means having same letter(s) in a column are not significantly different at $P \leq 0.05$ followed by LSD

Notes: IPM package 1: Sex pheromone trap + Success®; IPM package 2: Sex pheromone trap + Spinomax®; IPM package 3: Sex pheromone trap + Bio-Chamak®; IPM package 4: Sex pheromone trap + Coragen®; Farmer's practice: Weekly spraying of Nitro® and an Untreated Control.

Pheromone trap catches: Weekly monitoring of sex pheromone traps revealed that peak male *H. armigera* activity occurred between 60-80 days after sowing, coinciding with the chickpea podding period. IPM package integrating both pheromone traps and bio-insecticides (Package 1- Package 4) captured 0.25-0.33 moths per trap per week in 2021–2022, compared to 1.08-1.25 moths per trap per week in 2020–2021 (Table 2). Mass trapping reduced mating success, contributing to lower larval infestation and pod damage, highlighting the importance of pheromone traps as a key component of multi-tactic IPM strategies. One of the most successful applications of pheromones in pest management is mating disruption. By releasing synthetic pheromones into the environment, pest populations can be confused or overwhelmed, preventing males from locating females and reducing reproduction rates. This technique has been particularly effective against moth pests (Witzgall *et al*., 2010).

To clarify the mechanistic basis of the IPM interventions evaluated in this study, all insecticidal, biorational, and semi chemical-based components incorporated into the management packages. A semi chemical-based tool used which is highly species-specific for partial suppression of *H. armigera* populations. Captured moths provide real-time information on adult emergence, flight peaks, and infestation risk, enabling precise timing of control measures. Pheromone trapping has emerged as a promising approach in pest management technologies, offering advancements and innovations that hold great potential for effective pest control. Advancements in pheromone trapping have enabled targeted monitoring and control of specific pest populations (Awanindra *et al*., 2024). Ahmed and Khalique (2002) did experimentation and reported forecasting adult populations of *H. armigera* on chickpea through pheromone traps and its role in management of this insect. Mahmudunnabi *et al.* (2013) observed that biocontrol agent release along with installation of sex pheromone traps and spraying of HNPV an effective management of pod borer attacking chickpea. *Bacillus thuringiensis* var. *kurstaki,* a microbial bioinsecticide producing Cry δ-endotoxins that acts selectively on lepidopteran larvae. *Bt* is highly selective, environmentally benign, and compatible with most natural enemies, making it ideal for bio-intensive IPM. Extensive studies were reported by Khalique and Ahmed (2003) and found the retarded effect of spore-δ-delta endotoxin complex of *Bt* subsp. *kurstaki* Berliner strains on the development of *H. armigera* (Hubner) and reported significant retarded development in the larvae of *H. armigera* as well as impact of *Bt* on biology of *H. armigera*. Khalique and Ahmed (2001a,b) studied synergistic interaction between

Bt and pyrethroid-insecticide, they have also conducted studies evaluation of toxicity of *Bt* and its sub-lethal effect on the development of *H. armigera*. *Bt* field test results indicated that microbial insecticides can be used (with and without adjuvants) for management of *H. armigera* populations infesting chickpea and their use would reduce reliance on toxic chemicals (Ahmed *et al.,* 2006, 2012). Spinosad (Success®), a fermentation-derived bioinsecticide from *Saccharopolyspora spinosa,* is effective against borers and has minimal adverse effects on predators and parasitoids. Singh and Amit (2012) studied the efficacy of certain new molecules insecticides against gram pod borer, *H. armigera* and reported that Spinosad 45 SC was the best among all the treatments in larval population over control. *Celastrus angulatus* extract (Bio-Chamak), a botanically derived biorational insecticide containing sesquiterpenes, triterpenoids, and flavonoids. These compounds function primarily as antifeedants and stomach poisons, impairing digestive physiology and inducing starvation-mediated mortality. Rashid *et al.* (2021) did experimentation on tomato fruit worm, *H. armigera* and obtained the lowest fruit infestation, highest yield and net income from sex pheromone mass trapping + *Celastrus angulatus* (Bio Chamak®) + Matrine. Spinomax® (*Bt* + Spinosad®), a synergistic biopesticide combining *Bt* endotoxins with spinosad's neurotoxic activity. This dual-action formulation enhances larval mortality, extends residual efficacy, and reduces resistance development. It is particularly suitable for sustainable management of Fall army worm (*S. frugiperda*) of maize and other lepidopteran caterpillar pests of different crops. Bhandari *et al.* (2025) who observed that *Bacillus thuringiensis* var. *kurstaki* + *Saccharopolyspora spinosa* 15 % SC significantly increased larval mortality and effectively controlled the damage caused by *S. frugiperda*. Dutta *et al.* (2021) who reported that *Bt* + Spinosad (Spinomax®) showed higher effectiveness in reducing plant and cob infestation compared to other biopesticides against fall armyworm, *S. frugiperda*. Sarkar *et al.* (2021) observed that, *Bt* + Spinosad (Spinomax®) a new generation biopesticide was effective against the major pest brinjal shoot and fruit borer followed by *Celastrus angulatus* (Bio-Chamak®). Chlorantraniliprole (Coragen®), a diamide insecticide acting as a selective ryanodine receptor modulator. Chlorantraniliprole is widely used and highly effective against *H. armigera*, with low mammalian toxicity and reduced ecological footprint. The advent of synthetic organic insecticides enabled to gain an upper hand in struggle against insects to protect the crops, domesticated animals and ourselves from their pestiferous attack. Pagidala and Kumar (2024) did experimentation and reported that Chlorantraniliprole 18.5 SC was more effective and economical treatment in controlling larval population of *H. armigera* followed by Spinosad 45 SC. Anuradha (2023) reported that two foliar applications of Chlorantraniliprole at ten days interval period reduced significantly the larval populations of *H. armigera, S.*

litura without any phytotoxic symptoms in cotton. Chlorantraniliprole application in open field condition was found to be harmless to natural enemy (Coccinellids and Spiders). Chlorantraniliprole was found to be comparatively safer to natural enemies.

The above facts are formulating to introduce the IPM packages. The present study revealed that integration of all the components was successfully suppressed the *H. armigera* population resulted the lower pod damage (%) and significant pod damage reduction over control (%) as well as good marketable seed yield. All the IPM packages were performed better than that of farmer's conventional practice i.e., weekly spraying of toxic broad-spectrum insecticide mixture combines Cypermethrin + Chlorpyriphos (Nitro® 505EC @ 2ml L^{-1} water), a pyrethroid that disrupts voltage-gated sodium channels and causes rapid knockdown, with chlorpyriphos, an organophosphate that inhibits acetylcholinesterase and induces neuromuscular dysfunction. Although widely used in conventional chickpea cultivation, this combination poses significant environmental hazards, adversely affects non-target organisms, and contributes to the rapid development of insecticide resistance in pest populations.

Effect of IPM packages on yield: Significant differences in marketable chickpea yield were observed among the IPM packages ($p \leq 0.05$). All IPM packages produced higher yields compared with the untreated control, which yielded 1.01-1.02 t ha^{-1}. In the *Rabi* 2021–22 season, the highest yield was obtained from IPM Package 2 (1.58 t ha^{-1}), followed closely by IPM Package 3 (1.56 t ha^{-1}), IPM Package 4 (1.54 t ha^{-1}), and IPM Package 1 (1.51 t ha^{-1}), whereas the conventional chemical-based farmer practice produced 1.39 t ha^{-1} (Table 3). Similarly, in the *Rabi* 2020–21 season, the highest yield was recorded in IPM Package 2 (1.48 t ha^{-1}), followed by IPM Package 4 (1.41 t ha^{-1}), IPM Package 3 (1.39 t ha^{-1}), and IPM Package 1 (1.36 t ha^{-1}).

The enhanced yields under IPM treatments can be attributed to the integration of biorational and biological control tactics, which effectively reduced pod borer infestation and minimized crop losses. These findings are consistent with earlier reports where the use of *Helicoverpa* nuclear polyhedrosis virus (HNPV) followed by cypermethrin application significantly increased chickpea yield (Hossain *et al*., 2010; Sarkar *et al*., 2006). Similarly, Jerusha and Thakur (2018) observed that weeding, hand picking, and application of Indoxacarb improved grain yield by reducing pest pressure. Insecticide treatments combined with *B. thuringiensis* var. *kurstaki* were also reported to enhance yield while suppressing larval populations and pod damage (Tiwari and Sehgal, 2007). Furthermore, Visalakshmi *et al*. (2005) highlighted that the strategic combination of IPM components, either individually or in packages, offers a sustainable alternative to conventional chemical control of chickpea pod borer. The present study is the first to evaluate the efficacy of new generation biopesticides, biorationals, and low-toxic, environmentally safe chemical pesticides in an integrated management approach against chickpea pod borer. The results demonstrate that these IPM packages are effective in reducing pest damage and enhancing yield, providing a viable and sustainable alternative to conventional chemical-intensive practices.

Table 3. Effect of different IPM packages on seed yield of chickpea in two cropping seasons

Cropping season	Management packages	Yield (t/ha)	Yield increase over control (%)
2021–22	IPM package-1	1.51 a	32.45
	IPM package-2	1.58 a	35.44
	IPM package-3	1.56a	34.61
	IPM package-4	1.54a	33.77
	Farmers practice	1.39b	26.62
	Untreated Control	1.02c	-
2020–21	IPM package-1	1.36 b	34.65
	IPM package-2	1.48 a	46.53
	IPM package-3	1.39 b	37.63
	IPM package-4	1.41 b	39.60
	Farmer's practice	1.28 c	26.73
	Untreated Control	1.01 d	-

Means having same letter(s) in a column are not significantly different at $P \leq 0.05$ followed by LSD.

Benefit-cost analysis: Economic assessment indicated that all IPM packages achieved lower marginal benefit-cost ratios (MBCR) compared with the conventional farmer's practice (Table 4). The highest MBCR (1.87) was recorded for the farmer's practice, which involved weekly spraying of Nitro®, followed by IPM Package 1 (MBCR 1.39). Across the two-year study period, the average marketable yields of the IPM packages ranged from 1.44 to 1.53 t ha^{-1}, whereas the farmer's practice yielded 1.34 t ha^{-1}, achieving the highest MBCR primarily due to lower input costs. Although IPM Package 2 produced the highest gross and net returns as a result of maximum marketable yield, its slightly higher input costs led to a marginally lower MBCR relative to the farmer's practice.

These results demonstrate that while IPM packages may require higher initial investment, they provide substantially higher productivity and long-term sustainability benefits by reducing pest pressure through environmentally safe, bio-intensive methods. Previous studies have reported similar trends, where IPM components such as neem seed kernel extract, *Beauveria bassiana*, *B. thuringiensis*, and HNPV virus effectively reduced larval populations and pod damage, resulting in favorable cost-benefit ratios (Visalakshmi *et al*., 2005). This emphasizes that strategically integrated pest management not only enhances yield and crop protection but also provides an economically viable alternative to conventional chemical-intensive practices.

Table 4. Economic evaluation of different IPM packages for management of pod borer in chickpea

IPM packages	Average two years marketable yield (t/ha)	[1] Gross return (Tk./ha)	[2] Cost of Treatment (Tk./ha)	Net return (Tk./ha)	Adjusted net return (Tk./ha)	Marginal Benefit Cost Ratio (MBCR)
Package 1	1.44	72000	8580	63420	11920	1.39
Package 2	1.53	76500	12900	63600	12100	0.98
Package 3	1.48	74000	15150	58850	7350	0.49
Package 4	1.48	74000	17025	56975	5475	0.32
Farmer's practice	1.34	67000	5400	61600	10100	1.87
Untreated Control	1.02	51000	0	51500	-	

Cost of relevant materials/activities:

[1]Farmgate price of chickpea @ Tk. 50.00 per kg.

[2][Cost of Success 2.5SC: @ Tk. 3000/L; Cost of Bio-chamak 1% EW: @ Tk. 3000/L; Cost of Spinomax: @ Tk. 3000/L; Cost of Coragen 18.5 SC: @Tk. 17500/L; Cost of Nitro 505EC: @Tk. 900/L; Cost of *Helicoverpa* pheromone: @ 75 Tk./trap with installation (BARI developed); Cost of spray: Two laborers/spray/ha @ Tk. 450.00/labour/day; Spray volume required: 500L/ha.]

Conclusion

The study demonstrates that integrated pest management packages combining sex pheromone-based mass trapping with biorational insecticides, including *Bacillus thuringiensis* var. *kurstaki* and *Celastrus angulatus* extract, effectively suppress chickpea pod borer and enhance marketable yields. Although conventional chemical sprays showed slightly higher marginal benefit-cost ratios due to lower input costs, IPM packages provided superior yield benefits and ecological sustainability. These findings confirm that integrating biorational insecticides with pheromone-based strategies offers an efficient and practical method for sustainable chickpea production in Bangladesh.

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