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EFFICACY OF MULTI-COMPONENT INTEGRATED PEST MANAGEMENT STRATEGIES AGAINST KEY INSECT PESTS OF BRINJAL

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ABSTRACT

Brinjal (*Solanum melongena* L.) is one of the most pesticide-intensive vegetable crops in Bangladesh, where excessive insecticides are used to control the brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenée) and sap-sucking pests which poses severe environmental and health risks. To develop an eco-compatible alternative, field experiments were conducted during two consecutive Rabi seasons (2020-2021 and 2021-2022) at the Entomology Research Field, BARI, Gazipur, to evaluate the efficacy of four integrated pest management (IPM) packages combining mechanical, biological, and biorational components. Treatments included combinations of mechanical removal, pheromone trapping, and applications of new-generation bio-insecticides such as *Bacillus thuringiensis*, Spinosad (Success®, Sodium lauryl ether sulphate (Fizimite®), Matrine (Biotrin®), and *Celastrus angulatus* extract (Bio-Chamak®). All IPM packages significantly reduced populations of sucking pests including aphids, jassids, and whiteflies, as well as shoot and fruit infestation by *L. orbonalis*, compared with untreated control and farmers' conventional practices. Among them, IPM Package-2 (Mechanical control+Fizimite®+pheromone trapping+Spinomax®) and Package-3 (Mechanical control+Biotrin®+pheromone trapping+Bio-Chamak®) achieved the greatest pest suppression (≈76-74% reduction in shoot and fruit infestation) and resulted the highest marketable yields (27.0 and 26.7 t ha^{-1}, respectively). These treatments also provided superior marginal benefit-cost ratios (6.48-7.77), confirming their economic feasibility. The integration of mechanical, pheromone, and biorational tools offers a robust, residue-free alternative to pesticide-intensive management. Adoption of such bio-intensive IPM strategies can substantially reduce chemical dependency, conserve natural enemies, and promote safer, more sustainable brinjal production systems in Bangladesh and similar agro-ecological regions.

Keywords: *Leucinodes orbonalis*, jassids, whiteflies, aphids, biopesticides, pheromone trap

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INTRODUCTION

Brinjal (*Solanum melongena* L.), one of the most widely cultivated and consumed vegetable crops in South and Southeast Asia, holds immense nutritional and economic importance in Bangladesh. However, its productivity and quality are severely constrained by a complex of insect pests that infest the crop from the nursery stage to harvest. Among these, the brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenée) is considered to be the most destructive pest, capable of inflicting yield losses exceeding 70-85% in absence of effective control (Alam *et al*. 2004). In addition, several sap-sucking pests such as the aphid (*Aphis gossypii* Glover), jassid (*Amrasca biguttula biguttula* Ishida), whitefly (*Bemisia tabaci* Gennadius), thrips, and mites have gained considerable importance in recent years due to their increasing infestation and damaging potential (Alam *et al*. 2004, Munde *et al*. 2011). These pests not only directly reduce plant vigor by sucking cell sap but also act as vectors of viral diseases, further aggravating yield losses that may exceed 85% under severe infestation in Bangladesh.

The BSFB larvae bore into young shoots and developing fruits, disrupting the translocation of plant nutrients and water, which leads to shoot wilting, flower drop, and deformed fruits. Meanwhile, prolonged outbreaks of sucking pests can stunt plant growth, especially during dry periods. Despite these challenges, farmers in Bangladesh predominantly depend on repeated applications of synthetic insecticides, often exceeding 80-100 sprays per growing season to achieve blemish-free fruits for the local market. Such indiscriminate pesticide use has led to alarming environmental and health concerns, including pesticide residue accumulation, resurgence of secondary pests, development of insecticide resistance, and disruption of beneficial arthropod populations (Korsak and Sato 1977, Rashid *et al*. 2003, Ulrichs *et al*. 2001). Moreover, the excessive use of insecticides in brinjal (approximately 47% of all vegetable insecticide use in Bangladesh) makes it one of the most pesticide-intensive crops, with an estimated application rate of 1.41 kg or L ha^{-1} (Alam *et al*. 2004). Such practices elevate production costs and pose serious threats to human health and export potential due to pesticide residues (Islam *et al*. 1999).

In this context, the paradigm of Integrated Pest Management (IPM) offers a sustainable alternative to sole chemical dependence by integrating multiple eco-compatible components. Effective IPM combines mechanical removal of infested plant parts, biological and botanical insecticides, pheromone-based monitoring and mass trapping, and selective use of low-risk chemical molecules. Among recent advancements, new-generation biorational insecticides including plant-derived compounds such as *Celastrus angulatus* extract (Bio-chamak®), Matrine (Biotrin®), D-limonene (Bio-clean®), Sodium lauryl ether sulphate (Fizimite®) and microbial-based products like *Bacillus thuringiensis* formulations have shown strong insecticidal potential while preserving ecological safety (Rahman *et al*. 2023, 2025, Rashid *et al*. 2022). These bioactive agents act through unique physiological and behavioral mechanisms, such as feeding inhibition, digestive system disruption, and neuro-modulation, with minimal likelihood of resistance development (Wang *et al*. 2001, Wei *et al*. 2009). However, their field-level integration with mechanical control and pheromone-based technologies in brinjal IPM remains poorly documented under Bangladesh agro-ecological conditions.

Therefore, the present study was designed to evaluate and compare the efficacy of four newly developed IPM packages, each combining different mechanical, biological, and biorational components, against the major insect pests of brinjal. The specific objectives were to (i) determine the comparative effectiveness of IPM packages in suppressing both sucking and borers pests, (ii) assess their influence on marketable yield and fruit infestation, and (iii) conduct a benefit-cost analysis to identify the most economically viable and environmentally safe management strategy. The findings of this research are expected to contribute significantly toward developing a bio-intensive IPM framework for sustainable brinjal production and reducing dependency on hazardous chemical pesticides in Bangladesh.

MATERIALS AND METHODS

Experimental site and duration: Field experiments were conducted for two consecutive winter (*Rabi*) seasons during 2020-2021 and 2021-2022 at the Entomology Research Field of the 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 brinjal cultivation in central Bangladesh.

Experimental design and crop establishment: The experiment was laid out in a randomized complete block design (RCBD) with five treatments and an untreated control with three replications. Each plot measured 8.0 m × 2.5 m with 1.0 m spacing between plots and 1.5 m between blocks to prevent cross-interference of treatments. Brinjal variety *BARI Begun-8* was used as the test crop. Thirty-day-old healthy seedlings were transplanted at a spacing of 75 cm × 60 cm during the last week of October in both years. The recommended fertilizer doses were applied at 20 t ha^{-1} cow dung, 120 kg N, 100 kg P_2O_5, 100 kg K_2O, and 15 kg S per hectare. Standard irrigation, weeding, and mulching operations were performed as required to maintain uniform crop growth across all treatments and untreated control.

Treatments and integrated pest management packages: Five pest management regimes were evaluated with an untreated control (Table 1). Each IPM package was composed of different combinations of mechanical, biological, and biorational components.

Mechanical control consisted of regular removal and destruction of infested shoots and fruits at weekly intervals. Sex pheromone traps for BSFB were installed at 4-5 weeks after transplanting (WAT) at a density of 80 traps ha^{-1}, maintaining

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

Treatments	Description of IPM Packages
T_1	**IPM package 1:** Mechanical control + D-limonene (Bio-clean® 5% SL @ 1 ml L^{-1} water) + Sex pheromone trapping + Spinosad (Success® 2.5 SC @ 1.2 ml L^{-1} water)
T_2	**IPM package 2:** Mechanical control + Sodium lauryl ether sulphate (Fizimite® 10% @ 1 ml L^{-1} water) + Sex pheromone trapping + *Bacillus thuringiensis* var. kurstaki (Bt) + Spinosad (Spinomax® @ 2 ml L^{-1} water)
T_3	**IPM package 3:** Mechanical control + Matrine (Biotrin® 0.5% AS @ 1.5 ml L^{-1} water) + Sex pheromone trapping + *Celastrus angulatus* extract (Bio-Chamak® 1% EW @ 2.5 ml L^{-1} water)
T_4	**IPM package 4:** Mechanical control + Afidopyropen (Sefina® 5 DC @ 2 ml L^{-1} water) + Sex pheromone trapping + Spinosad (Success® 2.5 SC @ 1.2 ml L^{-1} water)
T_5	Farmer's practice: Weekly spraying of Chlorantraniliprole + Thiamethoxam (Voliam Flexi® 300 SC @ 0.5 ml L^{-1} water)
	Untreated control (no pest management interventions)

12.5 m spacing between traps. Traps were positioned just above the crop canopy using bamboo stakes and monitored weekly throughout the cropping period. A total of three foliar sprays were applied for each treatment, starting at the initial detection of pest infestation and continued at 7-day intervals. Applications were made using a hand-operated knapsack sprayer calibrated for uniform droplet size.

Description of new-generation biorational insecticides: The novel plant-derived bioactive compounds tested in this study included *Celastrus angulatus* extract (Bio-Chamak® 1% EW) and *Matrine* (Biotrin® 0.5% AS). *C. angulatus*, a traditional medicinal shrub native to East Asia, possesses potent insecticidal properties due to its rich content of sesquiterpenes, triterpenes, and flavonoids (Wei *et al*. 2009). The active compounds disrupt pest digestive systems, inhibit feeding, and induce starvation and mortality without causing cross-resistance (Wang *et al*. 2001). *Matrine*, an alkaloid extracted from *Sophora flavescens*, acts as a neuroactive compound that interferes with insect neurotransmission, offering broad-spectrum activity against both sucking and chewing pests. These products were included to evaluate their compatibility and field efficacy within integrated IPM systems.

Data collection

Sucking pest population: Observations on aphids, jassids, thrips, and whiteflies were recorded from five randomly selected plants per plot. From each plant, five leaves were examined (one from the lower canopy, two from the middle, and two from the upper canopy). The number of live insects per leaf was counted from the abaxial surface using a 10× hand lens. Data were expressed as mean insect population per five leaves.

Shoot and fruit infestation by BSFB: For brinjal shoot and fruit borer, the number of healthy and infested shoots were recorded at 7-day intervals from ten randomly selected plants per plot. During each harvest, the total number of healthy and infested fruits were counted to estimate the percentage of fruit infestation using the formula:

Percent fruit infestation=Number of infested fruits/Total number of fruits×100

The reduction in pest population over the untreated control was calculated using the following formula:

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

Pheromone trap monitoring: Adult male moths of BSFB captured in pheromone traps were counted weekly throughout the cropping season. The data were used to assess pest abundance and evaluate the trapping efficiency of the IPM packages.

Yield and economic analysis: Healthy fruits were harvested periodically from each plot, and total marketable yield (t ha^{-1}) was calculated. 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. 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

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

Seasonal incidence and pest pressure: During both cropping seasons (2020-2021 and 2021-2022), brinjal fields were infested by several insect pests, including the shoot and fruit borer (*Leucinodes orbonalis* Guenée), aphids (*Aphis gossypii* Glover), jassids (*Amrasca biguttula biguttula* Ishida), and whiteflies (*Bemisia tabaci* Gennadius). Pest populations began to increase from 30-40 days after transplanting (DAT), peaked between 65-90 DAT under warm and dry weather conditions, and gradually declined thereafter. This population trend closely followed fluctuations in temperature and relative humidity, corroborating previous findings by Khan *et al*. (2023) and Saikia *et al*. (2020), who highlighted that climatic factors play a critical role in pest proliferation in brinjal ecosystems.

Effect of IPM packages on sucking pest suppression: Integrated pest management (IPM) packages significantly reduced the population densities of major sucking pests such as aphids, jassids, and whiteflies compared to the untreated control ($p \leq 0.05$) during both cropping seasons (2020-2021 and 2021-2022). The populations of thrips and epilachna beetles remained negligible throughout the experiment, while predatory ladybird beetles (Coccinellidae) were frequently observed, indicating the conservation of natural enemies under IPM regimes. In Rabi 2021-22 season; the mean aphid, jassid, and whitefly populations were the lowest in IPM Package 4 (mechanical control + Sefina® 5 DC + sex pheromone trapping + Success® 2.5 SC ®) recording 1.93, 5.84, and 5.47 individuals per five leaves, respectively. These values were statistically comparable to IPM Package 3 (mechanical control + Biotrin® 0.5% AS + sex pheromone trapping + Bio-Chamak® 1% EW), which recorded 3.40, 6.02, and 5.59 per five leaves, respectively (Table 2). In contrast, the farmer's practice (weekly spray of Voliam Flexi® 300SC) showed moderate suppression, while the untreated control recorded the highest pest densities (9.09, 14.16, and 16.69 per five leaves, respectively). The highest reduction in aphid, jassid, and whitefly populations was achieved by IPM Package 4 (78.78%, 58.75%, and 67.23%, respectively), followed by IPM Package 3 (62.60%, 57.49%, and 66.50%). The farmer's practice resulted in comparatively lower reductions over control (67.77%, 45.34%, and 54.94%, respectively) (Table 3). Similar trend of results was also found in the Rabi 2020-21 season (Tables 2 & 3).

Table 2. Effect of different IPM packages on the mean population of sucking pests in brinjal over two cropping seasons

Cropping season	Management packages	Number of aphid /5 leaves	Number of Jassid /5 leaves	Number of Thrips /5 leaves	Number of Epilachna /5 leaves	Number of Whitefly /5 leaves
2020-21	IPM package-1	3.09 b	6.51 c	-	-	6.50 b
	IPM package-2	3.14 b	7.24 b	-	-	6.82 b
	IPM package-3	3.28 b	6.14 c	-	-	6.39 b
	IPM package- 4	1.81 c	5.74 c			5.26 c
	Farmer's practice	2.84 b	7.61 b	-	-	7.31 b
	Untreated Control	8.97 a	14.02 a	-	-	13.47 a
2021-22	IPM package-1	3.21 b	6.63 c	-	-	6.71 b
	IPM package-2	3.26 b	7.36 b	-	-	6.93 b
	IPM package-3	3.40 b	6.02 c	-	-	5.59 c
	IPM package- 4	1.93 c	5.84 c			5.47 c
	Farmer's practice	2.96 b	7.74 b	-	-	7.52 b
	Untreated Control	9.09 a	14.16 a	-	-	16.69 a

Means within the same column for a crop growing season that share the same letter are not significantly different at $P > 0.05$ according to the LSD test.

Table 3. Percent reduction of major sucking pest populations over untreated control in brinjal under different IPM packages across two cropping seasons

Management packages	Percent pest population reduction over untreated control					
	2020-21			2021-22		
	Aphid	Jassid	Whitefly	Aphid	Jassid	Whitefly
IPM package-1	65.55	53.57	51.74	65.68	53.17	59.80
IPM package-2	64.99	48.36	49.37	64.14	48.02	58.48
IPM package-3	63.43	56.21	52.56	62.60	57.49	66.50
IPM package-4	79.82	59.06	60.95	78.78	58.75	67.23
Farmer's practice	68.34	45.72	45.73	67.77	45.34	54.94
Untreated Control	-	-	-	-	-	-

Previous studies reported similar trends, where integration of biorationals and physical controls effectively suppressed sucking pests in brinjal (Dutta *et al*. 2012, Aparna and Dethe 2011). The superior efficacy of Afidopyropen and Matrine can be attributed to their novel biochemical modes of action on chordotonal organs and feeding inhibition (Kandasamy *et al*. 2017), while Spinosad provided additional ingestion toxicity with minimal harm to beneficial insects. These results confirm that new-generation biorationals, when combined with pheromone-based and mechanical tactics, can serve as sustainable alternatives to synthetic pesticides in vegetable IPM systems.

Effect of IPM packages on shoot and fruit infestation: The brinjal shoot and fruit borer (BSFB) remained the dominant pest throughout the cropping period, and infestation levels differed significantly among treatments ($p \leq 0.05$) during both cropping seasons (2020-2021 and 2021–2022). The untreated control recorded the highest infestation, with 22.54% of shoots and 30.03% of fruits affected (Table 4). All IPM packages significantly suppressed pest damage. During Rabi 2021-22 season; the lowest shoot (5.34%) and fruit (7.83%) infestations were observed in IPM Package 2 (mechanical control + Fizimite® 10% + sex pheromone trapping + + Spinomax®), which was statistically comparable to IPM Package 3 (mechanical control + Biotrin® 0.5% AS + sex pheromone trapping + Bio-Chamak® 1% EW). These packages achieved 76.31% and 74.06% reduction in shoot infestation and 74.44% and 73.80% reduction over untreated control in fruit infestation, respectively. In Rabi 2020-21 season; the lowest shoot (6.39%) and fruit (8.01%) infestations were observed in IPM Package 3 (mechanical control + Biotrin® 0.5% AS + sex pheromone trapping + Bio-Chamak® 1% EW) which was statistically comparable to IPM Package 4 (mechanical control + Sefina® 5 DC + sex pheromone trapping + Success®). Overall, all four IPM packages reduced shoot and fruit infestation by approximately 70%, whereas the conventional farmer practice achieved only 19.40-22.31% and 24.59-27.34% reduction, respectively in both the cropping season. These results corroborate previous findings by Mamun *et al*. (2014) and Awal (2012), who reported substantial suppression of BSFB infestation through combined pheromone traps and spinosad sprays. Similarly, Noor *et al*. (2017) observed that spinosad-treated plots recorded only 2.45% fruit damage, corresponding to 92.44% reduction over the untreated control. The superior efficacy of the IPM packages in the present study is likely due to a synergistic effect, wherein pheromone traps disrupt mating while bioinsecticides (Spinosad and Bt) induce larval mortality, effectively targeting multiple pest stages.

Pheromone trap catches: Weekly monitoring indicated that the peak capture of BSFB male moths occurred between 60-80 days after transplanting (DAT), coinciding with the peak fruiting period. Treatments integrating both pheromone traps and bio-insecticides (T_1-T_4) captured a considerable number of adult male moths, with an average of 1.7 moths per trap per week (range: 3.0–13.0) in Rabi 2021-22 season whereas 1.3 moths per trap per week (range: 3.0–11.0) in Rabi 2020-21 season (Table 4). Mass trapping of males not only reduces mating success but also contributes to lower shoot and fruit infestation, emphasizing its critical role in multi-tactic IPM strategies.

Effect of IPM packages on yield: Significant differences in marketable fruit yield were observed among treatments ($p \leq 0.05$). All IPM packages produced higher yields compared to the untreated control (8.93- 9.41 t ha^{-1}). The highest yield was recorded in IPM Package 2 (27.0 t ha^{-1}), followed by IPM Package 3 (26.65 t ha^{-1}), IPM Package 4 (25.96 t ha^{-1}), and IPM Package 1 (24.91 t ha^{-1}) in the Rabi 2021-22 cropping season. In contrast, the conventional chemical-based farmer practice yielded only 13.72 t ha^{-1} (Table 4). But in the Rabi 2020-21 cropping season the highest yield was recorded in IPM Package 3 (26.01 t ha^{-1}), followed by IPM Package 4 (25.61 t ha^{-1}), IPM Package 2 (24.53 t ha^{-1}), and IPM Package 1 (23.91 t ha^{-1}). The yield enhancement under IPM treatments can be attributed to reduced pest pressure,

Table 4. Effect of different IPM packages on shoot and fruit infestation by BSFB and marketable yield of brinjal in two cropping seasons

Crop growing season	Treatments	Shoot infestation (%)	Reduction of shoot infestation over control (%)	Fruit infestation (%)	Reduction of fruit infestation over control (%)	Yield (t/ha)	Mean number of moths captured per trap per week (range)
2020-21	IPM package-1	7.73 c	68.08	9.98 c	65.04	23.91 b	1.30 (3-11)
	IPM package-2	7.34 c	69.69	8.31 d	71.81	24.53 b	
	IPM package-3	6.39 d	73.61	8.01 d	72.83	26.01 a	
	IPM package-4	6.74 d	72.17	8.42 d	71.43	25.61 a	
	Farmer's practice	19.40 b	19.90	24.59 b	16.59	12.59 c	-
	Untreated Control	24.22 a	-	29.48 a	-	8.93 d	
2021-22	IPM package-1	6.72 c	70.19	9.52 d	69.32	24.91 b	1.7 (3-13)
	IPM package-2	5.34 d	76.31	7.83 c	74.06	27.01 a	
	IPM package-3	5.76 d	74.44	8.05 c	73.80	26.65 ab	
	IPM package-4	6.29 c	72.09	8.67cd	72.06	25.96 b	
	Farmer's practice	17.51b	22.31	22.55 b	27.34	12.32 c	-
	Untreated Control	22.54 a	-	31.03a	-	9.41 d	

Means within the same column for a crop growing season that share the same letter are not significantly different at $P > 0.05$ according to the LSD test.

Note: IPM Package 1: Mechanical control + Bio-clean® 5% SL + pheromone trap + Success® 2.5SC; IPM Package 2: Mechanical control + Fizimite® 10% + pheromone trap + Spinomax®; IPM Package 3: Mechanical control + Biotrin® 0.5%AS + pheromone trap + Bio-Chamak® 1% EW; IPM Package 4: Mechanical control + Sefina® 5 DC + pheromone trap + Success® 2.5SC; Farmer practice: weekly Voliam Flexi® 300 SC and untreated control.

improved fruit quality, and effective synchronization of mechanical, biological, and biorational control tactics. These results align with previous reports (Adiroubane and Raghuraman 2008, Awal 2012, Noor *et al*. 2017), which demonstrated that combining Spinosad or Oxymatrine with pheromone-based management enhances fruit marketability and reduces pest-induced losses.

Benefit-cost analysis: Economic assessment indicated that all IPM packages achieved substantially higher marginal benefit-cost ratios (MBCR) compared to the conventional farmer's practice (Table 5). The highest MBCR (7.77) was recorded from IPM Package 3, followed by IPM Package 1 (6.66), IPM Package 2 (6.48), and IPM Package 4 (5.68), whereas the farmer's chemical-based practice yielded a considerably lower MBCR of 1. 05. Although IPM Package 2 produced the higher gross return due to maximum marketable yield, its slightly elevated input costs resulted in a marginally lower MBCR relative to Package 1 (Table 5). These findings align with Awal (2012), who reported an MBCR of 7.15 for an IPM strategy integrating pheromone traps, Spinosad, and mechanical sanitation in brinjal. The results confirm that multi-component IPM approaches not only enhance productivity but also ensure economic sustainability by optimizing input-output efficiency.

Ecological and practical implications: The combination of mechanical control, pheromone trapping, and novel bio insecticides such as Afidopyropen, Matrine, *Celastrus angulatus* extract, Spinosad, and *Bacillus thuringiensis* demonstrates the efficacy of multi component strategies for sustainable brinjal pest management. Unlike conventional programs relying on repetitive synthetic insecticide applications, these biorational interventions operate through diverse biochemical modes of action, thereby reducing the risk of pest resistance and preserving natural enemy populations. Moreover, they minimize environmental contamination, safeguard beneficial arthropods, and enhance ecological stability within brinjal ecosystems. The study highlights a paradigm shift toward ecologically synchronized pest management, where adoption of multi component IPM packages can substantially reduce pesticide dependency, lower production costs, improve fruit quality, and support safer, more sustainable vegetable production systems in Bangladesh and other South Asian agro ecological regions.

Table 5. Economic evaluation of different IPM packages for management of major brinjal pests

Treatment/ packages	Average two years 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)
IPM package 1	24.41	366150	29840	336310	198760	6.66
IPM package 2	25.77	385500	33140	352360	214810	6.48
IPM package 3	26.33	394950	29350	365600	228050	7.77
IPM package 4	25.79	386850	37340	349510	211960	5.68
Farmer's practice	12.46	186900	23985	162915	25365	1.05
Untreated control	9.17	137550	0	137550	-	-

Cost of relevant materials/activities are as follows:

[1]Farmgate price of brinjal @ Tk. 15.00 per kg

[2][Cost of Bio-clean 5% SL: Tk. 2400/L; Cost of Success 2.5SC: @ Tk. 3000/L; Cost of Fizimite 10.0%: @ Tk. 4000/L; Cost of Spinomax: @ Tk 3000/L; Cost of Biotrin 0.5% AS @ Tk. 2300/L; Cost of Bio-chamak 1%EW @ Tk. 3000/L; Cost of Sefina 5DC @ Tk. 3500/Kg; Cost of Voliam flexi 300 SC: @ Tk. 5300/L; Cost of BSFB pheromone: @ 100 Tk./trap with installation; Cost of mechanical control: 2 laborers/ha @ Tk 450.00/labor/day; Cost of spray: Two laborers/spray/ha @ Tk. 450.00/labor/day; Spray volume required: 500L /ha.].

CONCLUSION

The present study demonstrated that the integration of mechanical control, pheromone trapping, and new-generation biorational insecticides provides an effective, eco-friendly, and economically viable approach for the sustainable management of major insect pests of brinjal. All IPM packages significantly reduced the populations of sucking pests (aphid, jassid, and whitefly) and minimized shoot and fruit infestation by *L. orbonalis* compared to the untreated control and farmers' conventional chemical practice. Among the tested combinations, IPM package 3 (mechanical control + Biotrin® 0.5% AS + pheromone trapping + Bio-Chamak®), IPM package 1 (mechanical control + Bio-clean® 5% SL + sex pheromone trapping + Success® 2.5 SC) and IPM package 2 (mechanical control + Fizimite® 10% + pheromone trapping + Spinomax®) exhibited the highest suppression of pest populations and fruit infestation, coupled with superior marketable yields and favorable marginal benefit-cost ratios. This integrated strategy can substantially reduce pesticide dependency in intensive vegetable systems, aligning with the national goal of promoting safe, residue-free vegetables for domestic and export markets. Future research should focus on the long-term ecological impacts, compatibility with natural enemies, and optimization of these biorational IPM components under varying agro-climatic conditions for broader adoption by smallholder farmers.

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