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RESEARCH ARTICLE

Assessment of farmers friendly IPM modules for the management of fall armyworm, *Spodoptera frugiperda* (JE Smith) in maize

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Abstract

In recent years, fall armyworm (*Spodoptera frugiperda*) has emerged as a significant invasive pest in several countries, including India, causing extensive damage to maize production and driving increased pesticide use. Sustainable management strategies are therefore urgently needed. In this study, four treatment modules and an untreated control were assessed for their efficacy against fall armyworm under field conditions across three agro-climatic zones of Bihar (Zones II, IIIA and IIIB) during both the Rabi and Kharif seasons. The results indicated that Module IV, encompassing the collection and breaking up of egg masses and larvae feeding in groups at the initial stage (15-25 DAS), application of a 1:1 sand-to-ash mixture (after whorl formation), a first spray of indoxacarb 14.5 SC @ 1 ml/L five days after sand and ash application and a second spray of thiamethoxam 12.6 % + lambda-cyhalothrin 9.5 % @ 0.5 ml/L 15 days later, was the most effective. This module significantly reduced the number of damaged leaves, larvae and holes, followed by modules I and II. Module IV also achieved the highest yields (81 q/ha in Rabi and 63 q/ha in Kharif) and benefit-cost ratios (1:2.85 in Rabi and 1:2.29 in Kharif). The economic viability of integrated management strategies for FAW was assessed over three consecutive years in the eastern region of India. Results consistently demonstrated their potential for sustainable FAW management, highlighting cost-effectiveness and long-term benefits. These findings support the adoption of integrated approaches to mitigate FAW infestations while ensuring economic sustainability for farmers.

Keywords: grain yield; IPM module; leaf damage; maize; *Spodoptera frugiperda*

Introduction

Fall Armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a highly polyphagous invasive insect native to the Americas, that has prolonged its distribution from western to eastern hemisphere (1-2). It was first noticed in Africa in 2016, has swiftly disseminated to over 70 countries across Asia and Oceania (1, 3, 4). It poses a significant threat to cereal crop productivity, particularly maize and sorghum, which are essential staple foods for smallholder farmers in these regions (5). FAW's rapid spread is attributed to its high reproductive capacity, lack of diapause and broad host range. Its ability to infest multiple crops, with a primary focus on maize, presents a severe challenge to food security in affected regions (1). FAW poses a significant threat to global food safety due to its impact on cereal crops, particularly maize, which is a staple in the diets of smallholder farmers. Beyond food consumption, FAW-induced damage to maize could severely affect dependent industries such as bioethanol production, poultry and animal farming (6). Fall Armyworm (FAW) infestation has led to significant maize yield losses in India, with reported reductions of 33-36 % (7, 8). Since its invasion, FAW has emerged as a serious pest across various Indian states, affecting approximately 1.4 lakh hectares in Karnataka, 85000 hectares in Madhya Pradesh, 59000 hectares in Rajasthan, 2000 hectares in Maharashtra, 1747.9 hectares in Mizoram, 200 hectares in Tamil Nadu and 137 hectares in Andhra Pradesh (9). However, the area under maize cultivation in India is 77.85 lakh hectares, with a production of 226.81 lakh tonnes and a productivity of 2914 kg/ha (10). The management of FAW remains challenging due to its polyphagous feeding behaviour, robust flight skills, high reproductive potential, lack of diapause and increased resistance to multiple pesticide classes. Farmers have employed various physical, chemical and biological methods to manage the destructive FAW; however, these tactics have principally been ineffective when used individually (11). For long-term FAW management, Integrated Pest Management (IPM) approaches that incorporate a variety of additional tactics are indispensable. IPM is an ecosystem-based approach that focuses on the long-term suppression of pests and their associated damage. It employs an integrated approach, incorporating strategies such as biological control, habitat manipulation, cultural practice modification and the use of resistant crop varieties, ensuring sustainable and effective pest management. The management of FAW involves a combination of cultural practices, handpicking and the use of insecticides such as lambda-cyhalothrin and diazinon, with handpicking being employed in campaigns and at the household level (12). In light of the significant impact of FAW on maize yield and its widespread infestation across India, the present experiment was undertaken to evaluate farmer-friendly Integrated Pest Management (IPM) modules and their goal of boosting the resilience of the agroecosystem while reducing the pest's reproductive potential and dispersion.

Materials and Methods

Planning, consent and farmers preference

The study involved interviewing 100 farmers from various locations to understand their preferences for pest management practices, specifically for controlling the fall armyworm (FAW). Scientists at Bihar Agricultural University, Sabour developed the survey questionnaire. Prior to conducting the interviews, the required consents were secured from the host organization, Bihar Agricultural University, Bhagalpur, Bihar, India. The meetings were conducted in compliance with institutional recommendations and the technical database favoured by the Institute Research Committee (IRC). Additionally, informed consent was obtained from the farming communities prior to the discussions taking place. The selection of Integrated Pest Management constituents was based on the farmers' preferences for different control methods, aiming to identify sustainable approaches for FAW management.

Experimental details and treatment details

In the aforementioned context, field experimentation was conducted over three consecutive years, namely 2019-20, 2020-21 and 2021-22, in both the Kharif and Rabi seasons. Climatic conditions were also recorded during this time (Fig. 1 & 2). The experiment was carried out in four locations for three consecutive years from 2019-2020 to 2021-22 viz., Bihar Agricultural College (BAC), Sabour, Bhola Paswan Shastri Agriculture College (BPSAC), Purnea, Mandan Bharti Agriculture college (MBAC), Saharsa and Nalanda College of Horticulture (NCOH), Noorsarai, Nalanda. The trial was conducted in a randomized block design with four replications and five treatments. The plot size was 5 x 3 m^2, with row-to-row and plant-to-plant spacing of 60 cm and 20 cm, respectively. The treatments were in module form which has mentioned in the Table 1.

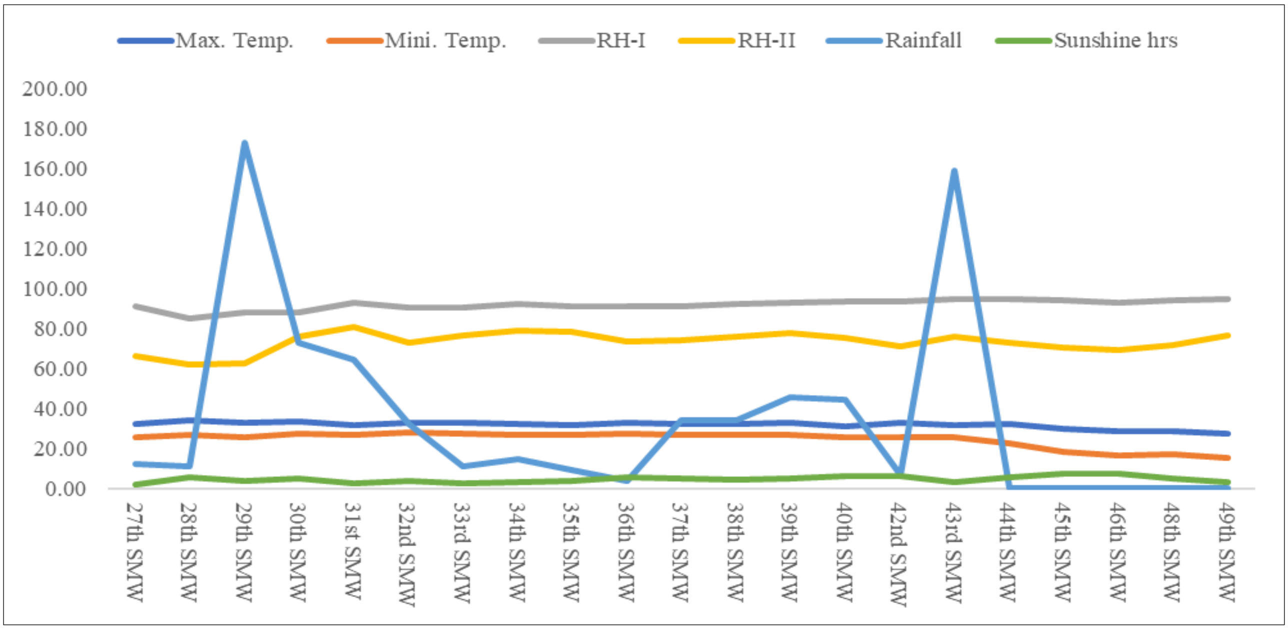

Fig. 1. Climatic conditions during the Kharif season in the experimental plot.

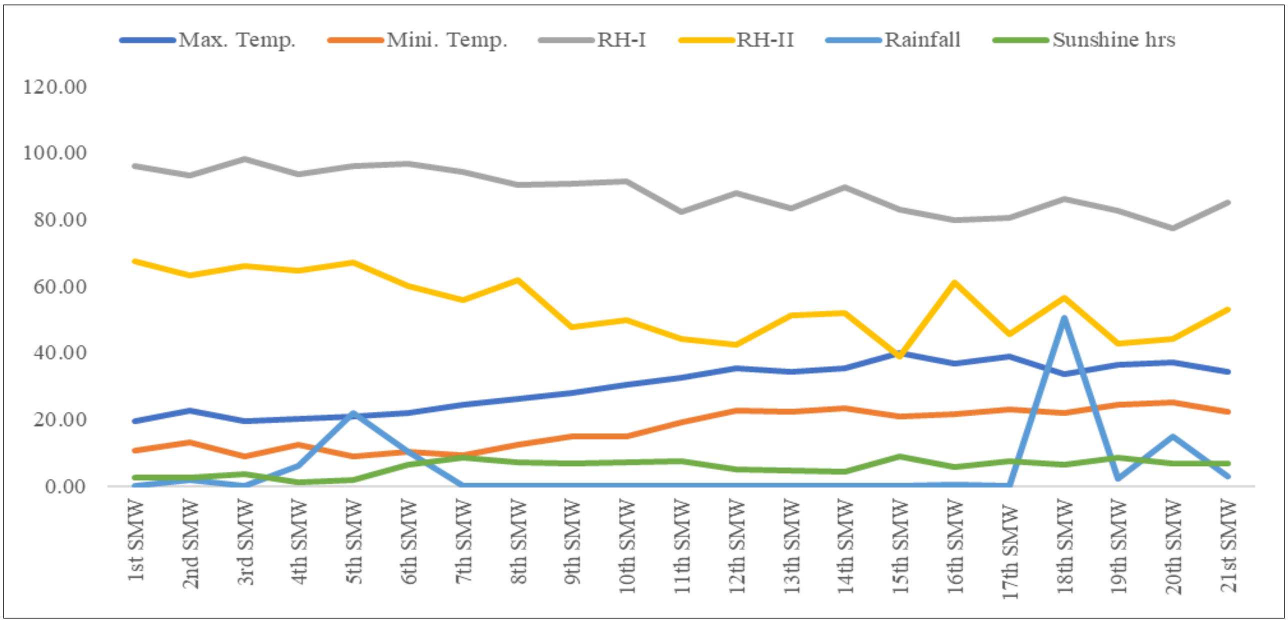

Fig. 2. Climatic conditions during the rabi season in the experimental plot.

Table 1. Information on different treatments module

Module	Details of the module
Module-I	Collection and destruction of egg masses and larvae feeding in groups at the initial stage (15-25 DAS) Application of sand (after whorl formation) Spraying of *Beauveria bassiana* @ 1×10^8 cfu/ml after 5 days of application of sand Spraying of Emamectine benzoate 5SG @0.4g/L at 15 days after Ist spray
Module-II	Collection and destruction of egg masses and larvae feeding in groups at the initial stage (15-25 DAS) Application of ash (after whorl formation) Ist Spray with *Metarhizium anisopliae* @ 1×10^8 cfu/mL after 5 days of application of ash Spraying of Spinosad 45SC @0.2mL/L at 15 days after Ist spray
Module-III	Collection and destruction of egg masses and larvae feeding in groups at the initial stage (15-25 DAS) Application of poison bait (after whorl formation) Ist Spray with NSKE 5 % after 5 days of application of sand + fly ash Spraying of Fipronil 5SC @1mL/ at 15 days after Ist spray
Module-IV	Collection and destruction of egg masses and larvae feeding in groups at the initial stage (15-25 DAS) Application of sand + ash in 1:1 ratio (after whorl formation) Ist spray with Indoxacarb 14.5 SC@1mL/L after 5 days of application of sand + ash Spraying of Thiamethoxam 12.6 % + Lambda-cyhalothrin 9.5 % @ 0.5ml/l at 15 days after Ist spray
Module-V	Untreated control

For the experimentation variety, P3355 (a Pioneer hybrid variety, a brand of Corteva Agriscience) was grown during Rabi and variety 4366 (a Hybrid variety developed by Siri Seed) was grown during *Kharif*. P3355 is a high-yielding maize hybrid known for its robust performance and wide adaptability across diverse agro-climatic conditions. Similarly, Variety 4366 is recognized for its high yield potential, excellent drought tolerance and suitability for cultivation during the rainy season. It is also noted for achieving 100 % tip filling. The same variety was used in all four locations in both seasons. The crop was raised as per recommended agronomic practices.

Observations recorded

For observation, this included a careful examination of corn plants, wherein they investigated the number of larvae, the number of damaged leaves and the number of windows (holes). The investigation was carried out by walking in a "W" pattern diagonally the experimental plot, excluding 3-4 outer rows. Larvae were counted by selecting clusters of 10 plants along the first undeviating line, continuing in a “W” pattern diagonally the field. This method ensured data collection from at least 10 plants per plot. The grain yield was verified after harvesting and converted into quintal per hectare. Cost economics was worked out by taking into account the cost of treatments, labour charge and market price of the grains.

Statistical analysis

The statistical analysis of the field experiments involved the utilization of a two-way analysis of variance (ANOVA) with a Randomized Complete Block Design (RCBD).

Results

Based on this data, the majority of farmers (66%) desire the use of pesticides for managing Fall Armyworm (FAW). The combined practice of pheromone traps, along with pesticide sprays, attracted 12 % of the farmers, indicating some attention to integrated approaches (Fig. 3). Physical or cultural controls were less popular, with only 1% of farmers preferring them. Compounding pesticides with cultural practices garnered 6 % of the farmers' interest. A total of 10 % of the growers did not respond, indicating potential gaps in awareness or understanding of available FAW control methods. This emphasizes the dominance of pesticides in FAW management, but also highlights the potential for greater adoption of integrated methods, such as pheromone traps combined with pesticide sprays. The non-response rate suggests a need for further education on sustainable and integrated pest management options. The analysis focused on the mean values for the number of damaged leaves, number of larvae and number of holes per 10 plants caused by *S. frugiperda*

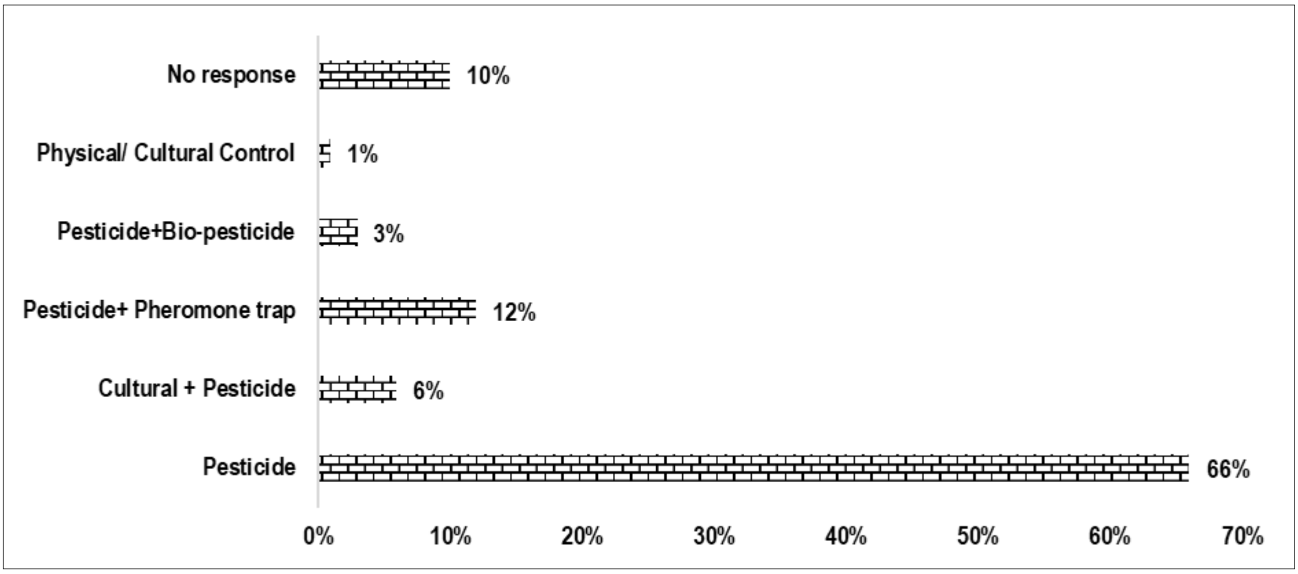

Fig. 3. Preference of farmers towards different management practices for FAW management.

(Fall Armyworm) during the rabi and kharif seasons over three successive years (2019-20, 2020-21 and 2021-22). These values were assessed after applying different treatment modules and are presented in Fig. 4 & Table 2 -3, respectively.

No. of damaged leaves

A three-year study evaluated the effectiveness of various modules for managing fall armyworm during the Rabi and Kharif seasons. Results showed that Module IV was significantly superior, recording the lowest number of damaged leaves per ten plants across all four locations (Fig. 4). Module I ranked as the next-best treatment, followed by Module II. All tested modules were remarkably more efficient than the untreated control.

Number of larvae

The three-year data on the effectiveness of various modules on fall armyworm during *Rabi* season revealed that module IV was the most effective, recording the lowest number of larvae (2.10 per ten plants, ranging from 1.55 to 2.88) and achieving a 76.22 % reduction in larval population related to the untreated control (Table 2). Module I ranked second with 5.16 larvae per ten plants and 41.56 % reduction in larval population over control and it was followed by module II (5.59 larvae per ten plants and 36.69 % reduction over control). All modules significantly outperformed the untreated control. Parallel trends were observed during the Kharif season, with Module IV consistently demonstrating superior efficacy in reducing larval populations compared to other modules.

Number of holes (Window)

The results on the number of holes (windows) per ten plants in different treatment modules during the Rabi season demonstrated that Module IVwas the most effective, recording the lowest number of holes (windows) per ten plants across all locations. During the Rabi season, Module IV observed 6.88 holes per ten plants, representing a 64.39 % reduction over the untreated control (Table 3). Module I was the second-best treatment, with 11.29 holes per ten plants and a 41.46 % reduction, followed by module MIII with 12.39 holes and a 35.87 % reduction. Parallel trends were observed during the Kharif season, where Module IV continued to exhibit superior efficacy, recording 6.33 holes per ten plants and a 69.89 % reduction over the control. All modules significantly outperformed the untreated control in both seasons.

Grain yield

The impact of various treatment modules on grain yield during Rabi and Kharif seasons for 2019-20, 2020-21 and 2021-22 was evaluated (Table 4). Results revealed that all four modules significantly outperformed the untreated control (module V) across seasons and years. Module IV achieved the highest grain

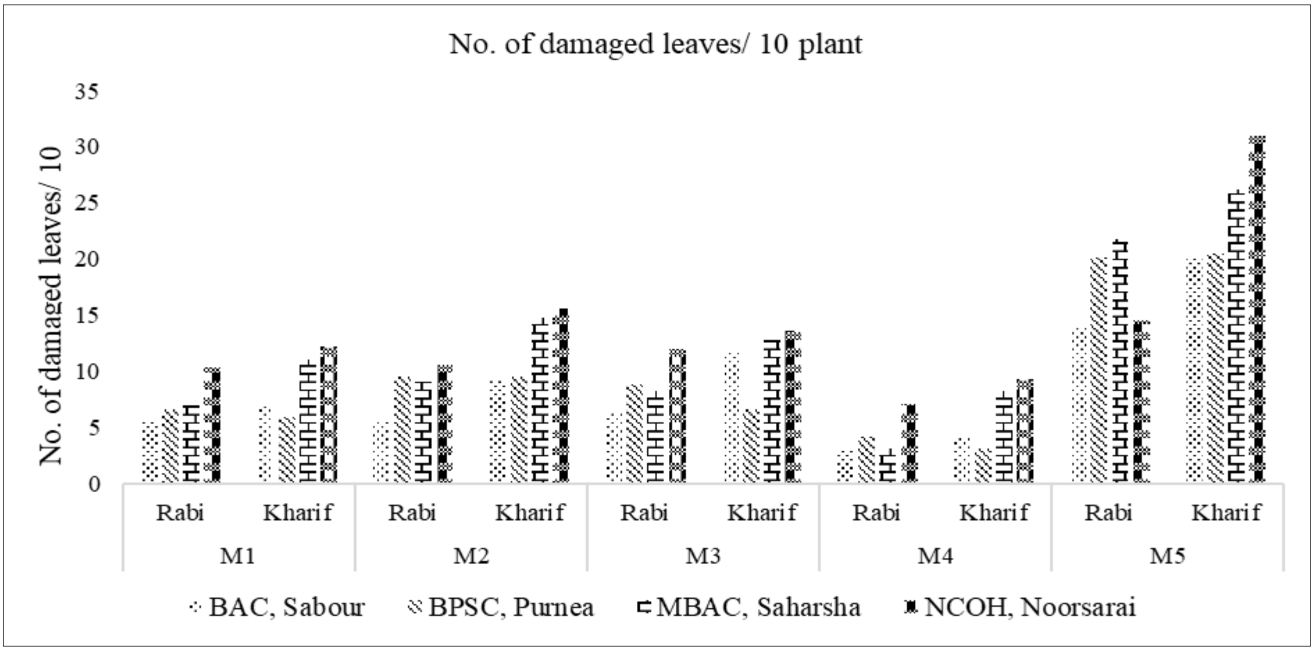

Fig. 4. No. of damaged leaves/10 plants during *Rabi* & Kharif (Mean value of three years from 2019-2020 to 2021-22).

Table 2. No. of larva/10 plants during *Rabi* & Kharif (Mean value of three years from 2019-2020 to 2021-22)

Modules	BAC, Sabour		BPSC, Purnea		MBAC, Saharsa		NCOH, Noorsarai		Rabi		Kharif	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Mean	PROC	Mean	PROC
M-I	4.75* (2.35)^{b**}	7.06 (2.74)^{bcd}	4.47 (2.40)^{bcd}	4.02 (2.38)^{cd}	3.61 (2.00)^{c}	6.61 (2.66)^{b}	7.80 (2.38)^{cd}	6.11 (2.55)^{bcd}	5.16	41.56	5.95	38.28
M-II	4.97 (2.44)^{bc}	7.39* (2.75)^{bc**}	6.10 (2.55)^{b}	6.61 (2.67)^{b}	5.69 (2.46)^{b}	8.13 (2.56)^{bc}	5.59 (2.46)^{c}	7.06 (2.70)^{bc}	5.59	36.69	7.30	24.27
M-III	5.52 (3.01)^{ab}	7.67 (2.84)^{b}	5.38 (2.41)^{bc}	5.50 (2.45)^{c}	4.83 (2.30)^{bc}	5.34 (2.41)^{c}	8.35 (2.96)^{b}	7.67 (2.84)^{b}	6.02	31.82	6.54	32.16
M-IV	1.83 (1.52)^{c}	1.24 (1.03)^{c}	2.15 (1.61)^{c}	1.81 (1.50)^{d}	1.55 (1.41)^{d}	2.18 (1.60)^{d}	2.88 (1.82)^{d}	1.87 (1.53)	2.10	76.22	1.77	81.64
M-V	8.60 (3.04)^{a}	12.8 (3.65)^{a}	8.42 (2.97)^{a}	8.13 (2.91)^{a}	7.99 (2.89)^{a}	8.87 (3.03)^{a}	10.30 (3.27)^{a}	8.78 (3.34)^{a}	8.83	-	9.64	-
S. Em (±)	0.06	0.06	0.06	0.06	0.05	0.06	0.04	0.06	-	-	-	-
CD (p=0.05)	0.20	0.19	0.20	0.18	0.19	0.18	0.15	0.19	-	-	-	-

*Mean value; ** Angular transformed value; *PROC= % reduction over control; *Means followed by the same letter are not significantly different by the DMRT at P=005.

Table 3. No. of holes (window)/10 plants during *Rabi* & Kharif (Mean value of three years from 2019-2020 to 2021-22)

Modules	BAC, Sabour		BPSC, Purnea		MBAC, Saharsa		NCOH, Noorsarai		Rabi		Kharif	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Mean	PROC	Mean	PROC
M-I	13.32* (3.65)^{b**}	10.61* (3.33)^{c**}	11.48 (3.29)^{c}	5.65 (2.46)^{d}	8.23 (2.87)^{d}	4.72 (3.45)^{d}	12.13 (3.54)^{bcd}	13.81 (3.78)^{c}	11.29	41.46	8.70	60.49
M-II	10.76 (3.28)^{c}	16.54 (4.13)^{b}	16.31 (3.93)^{b}	9.27 (3.12)^{b}	11.76 (3.45)^{b}	15.77 (4.02)^{b}	12.53 (3.64)^{bc}	17.58 (4.22)^{b}	12.84	33.54	14.79	32.83
M-III	10.08 (3.50)^{bc}	14.78 (3.90)^{bc}	15.07 (3.79)^{bc}	7.15 (2.76)^{c}	10.22 (3.21)^{c}	13.36 (3.70)^{c}	14.18 (3.81)^{b}	16.17 (4.07)^{bc}	12.39	35.87	12.93	41.28
M-IV	5.59 (2.60)^{d}	7.37 (2.77)^{d}	7.60 (2.65)^{d}	3.36 (1.93)^{e}	4.74 (2.19)^{e}	7.79 (2.87)^{e}	9.59 (3.17)^{c}	8.02 (2.91)^{d}	6.88	64.39	6.63	69.89
M-V	20.06 (4.52)^{a}	24.62 (5.01)^{a}	23.28 (4.72)^{a}	15.96 (4.05)^{a}	18.56 (4.33)^{a}	21.95 (4.72)^{a}	15.38 (3.98)^{a}	25.55 (10.19)^{a}	19.32	-	22.02	-
S. Em (±)	0.05	0.13	0.05	0.04	0.04	0.03	0.06	0.6	-	-	-	-
CD (p=0.05)	0.18	0.28	0.16	0.13	0.11	0.10	0.19	0.17	-	-	-	-

*Mean value; ** Angular transformed value; *PROC= % reduction over control; *Means followed by the same letter are not significantly different by the DMRT at P=005.

Table 4. Yield (q/ha) during *Rabi* & Kharif (Mean value of three years from 2019-2020 to 2021-22)

Modules	BAC, Sabour		BPSC, Purnea		MBAC, Saharsa		NCOH, Noorsarai		Rabi		Kharif	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Mean	PIOC	Mean	PIOC
M-I	63.51^{bc}	50.46^{b}	71.90^{bcd}	62.00^{ab}	66.32^{b}	48.25^{b}	68.66^{c}	55.50^{b}	67.59	23.56	54.05	39.63
M-II	68.23^{b}	47.13^{bc}	74.61^{bc}	61.09^{ab}	62.01^{bc}	45.42^{bc}	75.83^{b}	51.58^{bc}	70.17	28.28	51.30	32.52
M-III	65.74^{bc}	50.50^{b}	76.81^{b}	59.49^{abc}	63.16^{bc}	42.16^{bcd}	71.33^{cd}	54.00^{bc}	69.26	26.62	51.54	33.14
M-IV	78.41^{a}	57.66^{a}	85.90^{a}	63.48^{a}	77.80^{a}	54.46^{a}	84.35^{a}	66.78^{a}	81.61	49.19	60.59	56.52
M-V	51.08^{d}	35.00^{c}	62.98^{c}	44.06^{b}	49.68^{d}	33.83^{c}	55.08^{d}	41.94^{c}	54.70	-	38.71	-
S. Em (±)	2.49	1.98	1.16	0.82	2.50	1.68	2.36	2.37	-	-	-	-
CD (p=0.05)	6.74	5.22	3.65	2.46	7.46	5.04	6.15	6.94	-	-	-	-

*PIOC= % increase over control *Means followed by the same letter are not significantly different by the DMRT at P=005.

yield (Rabi: 81.61 q/ha, Kharif: 60.59 q/ha), with yield increases over control of 49.19 % (Rabi) and 56.52 % (Kharif). The next best-performing module was module II (Rabi: 70.17 q/ha, Kharif: 51.30 q/ha), followed by module I (Rabi: 67.59 q/ha, Kharif: 54.05 q/ha).

Cost economics of different modules

As far as economic return is concerned, in both the season i.e., Rabi and Kharif, module IV achieved the highest gross returns (Rs. 155,078 and Rs. 119,871) and net returns (Rs. 114,828 and Rs. 83424) with cost-benefit ratios of 1:2.85 (Rabi) and 1:2.29 (Kharif) (Table 5 & 6). Module I ranked second in economic performance (cost-benefit ratios: 1:2.25 and 1:1.94), followed by module II (1:1.24 and 1:1.64). These findings confirm module IV as the most efficient module in terms of yield and profitability during both seasons.

Discussion

In this experiment, module IV recorded the lowest number of damaged leaves, larvae per plant and holes per plant, while achieving the highest grain yield and benefit-cost ratio, followed by Modules I and II. To address this fall armyworm, specific treatment modules *viz.*, indoxacarb 14.5 % SC, thiamethoxam 12.6 % + lambda-cyhalothrin 9.5 %, *Beauveria bassiana* @ 1×10^8 cfu/mL, emamectine benzoate 5SG @ 0.4g/L, *Metarhizium anisopliae* @ 1×10^8 cfu/mL, spinosad 45 SC were added in the modules. These findings align with research indicating similar trends in reduced *Spodoptera frugiperda* populations with treatments such as chlorantraniliprole, spinetoram and emamectin benzoate under field conditions (13). Research suggests that the effectiveness of various insecticides, including emamectin benzoate (14). Their

Table 5. Yield and cost economics of different modules against Fall armyworm in maize (*Rabi*)

Modules	Yield (q/ha)	Total cost of cultivation (Rs. /ha)	Gross Return (Rs. /ha)	Net Return (Rs./ha)	C:B Ratio
M-I	67.59	39,545	1,28,421	88,876	1: 2.25
M-II	70.17	41,075	1,33,323	92,248	1: 2.24
M-III	69.26	41,590	1,31,594	90,004	1: 2.16
M-IV	81.62	40,250	1,55,078	1,14,828	1: 2.85
M-V	54.70	34,600	1,03,930	69,330	1: 2.00
S. Em (±)	2.12	-	-	-	-
CD (p=0.05)	6.00	-	-	-	-

Table 6. Yield and cost economics of different modules against fall armyworm in maize (*Kharif*)

Modules	Yield (q/ha)	Total cost of cultivation (Rs. /ha)	Gross Return (Rs. /ha)	Net Return (Rs./ ha)	C: B Ratio
M-I	54.05	35,745	1,04,937	69,192	1: 1.94
M-II	51.30	37,275	98,439	61,165	1: 1.64
M-III	51.54	37,790	97,926	60,136	1: 1.59
M-IV	60.59	36,450	1,19,871	83,421	1: 2.29
M-V	38.71	30,800	73,530	42,730	1: 1.38
S. Em (±)	1.91	-	-	-	-
CD (p=0.05)	5.35	-	-	-	-

study demonstrated that emamectin benzoate effectively controlled the pest, resulting in a remarkably higher grain yield compared to untreated control plots. Research indicates that spinetoram 11.7 SC, 0.117 %, emamectin benzoate 5 SG, 0.0025 %, chlorantraniliprole 18.5 EC, 0.006 % and thiodicarb 75 WP, 0.11 % were found more effective in checking the larval population, plant and cob damage in maize, which also reflected on grain and fodder yield as well (15). Among the insecticides tested against S. frugiperda, emamectin benzoate 5 SG was the most efficacious treatment over the control, followed by chlorantraniliprole 18.5 SC, flubendiamide 39.35 SC, indoxacarb 14.5 SC, thiamethoxam 12.6 + lambda-cyhalothrin 9.5 ZC, spinosad 45 SC and profenophos 50 EC. The maximum grain yield was obtained with emamectin benzoate 5 SG @ (42.5 q/ha) followed by chlorantraniliprole 18.5 % SC (40.01 q/ha), flubendiamide 39.35 SC (38.5 q/ha) and thimethoxam 12.6 + lambda cyhalothrin 9.5 ZC (37.6 q/ha) (16). The present outcomes align closely with research that indicates spinetoram achieved a 98.13 % reduction in pest population seven days after application, accompanied by emamectin benzoate and spinosad, which resulted in a 96.26% reduction (17). In contrast, thiamethoxam 0.25 % WG and fipronil 0.5 SC were the least efficacious, with 68.65 % and 73.14 % mortality, respectively. Research indicates that among the evaluated biopesticides in field conditions, Beauveria bassiana at 10 g/L was the most efficacious compared to all other treatments in reducing the population of *Spodoptera frugiperda* (FAW). The *Metarhizium anisopliae* 10 g/L was the subsequent most effective treatment, followed by EPN 10 g/L, *B. bassiana* 8 g/L and *M. anisopliae* 8 g/L (18). The outcomes of this study align closely with research indicating 70 % and 76 % reductions in FAW infestation using *Metarhizium anisopliae* and *Beauveria bassiana*, respectively (19).

Conclusion

Based on three-year field trials conducted in FAW-infested plots in Bihar, India, Module IV demonstrated the highest efficacy in reducing damaged leaves, larvae and holes, while also achieving the highest yield and B:C ratio during both Rabi and Kharif seasons across all four locations. The module included the collection and break up of egg masses and larvae feeding in groups at the initial stage (15-25 DAS), application of a sand-to-ash mixture (1:1) after whorl formation, a first spray of indoxacarb 14.5 SC @ 1 ml/L five days after applying sand and ash, followed by spraying thiamethoxam 12.6 % + lambda-cyhalothrin 9.5 % @ 0.5 ml/L 15 days after the first spray. The eco-friendly and farmer-adaptable nature of the module further supports its large-scale applicability, contributing to sustainable pest management and resilience of the agroecosystem.

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Authors' contributions

KK planned and designed the work. TS performed statistical analysis and drafted the manuscript. PN observations were taken and data were collected from BPSAC, Purnea, Bihar. SBS observations taken and collected the data from MBAC, Saharsha, Bihar. SKC observations taken and collected the data from NCOH, Noorsarai, Bihar. BBS compiled and analyzed the data from NCOH, Noorsarai, Bihar. All the authors approved and read the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflicts of interest to declare.

Ethical issues: None

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