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Evaluation of Biocontrol Methods and IPM Modules for Management of Fall Armyworm in Maize

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***Abstract*:** The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a serious, voracious and invasive pest that has caused significant yield losses in maize since its first report in Andhra Pradesh during August 2018. Biological control and integrated pest management (IPM) approaches offer sustainable solutions for the management of fall armyworm (FAW) in maize.An ad hoc trial was initiated under ICAR-NBAIR, Bengaluru during 2018–19 to 2020–21 at Acharya N.G. Ranga Agricultural University (ANGRAU), Andhra Pradesh to evaluate the efficacy of egg parasitoids (*Trichogramma pretiosum* and *T. chilonis*) and biopesticides in comparison with the insecticidal check, emamectin benzoate against maize FAW. Further studies were carried out during 2020-21 and 2021-22 to evaluate IPM modules for FAW management. Among the treatments, next to emamectin benzoate, the biocontrol-based approach involving the field release of *T. pretiosum* twice, combined with three sprayings of *Bacillus thuringiensis* (NBAIR Bt 25), or *T. pretiosum* release combined with *Metarhizium anisopliae* (ICAR-NBAIR Ma-35) sprayings, proved effective with lower FAW damage, higher larval mortality, and higher cob yield. Similar efficacy of biocontrol agents and biopesticides was also observed in maize sown with insecticide-treated seed. The biocontrol-based IPM module comprising three releases of *T. chilonis* along with three sprayings of either NBAIR Bt 25 or NBAIR Ma-35 provided a viable, eco-friendly alternative to sole chemical control of FAW in maize.

***Keywords*:** *Spodoptera frugiperda, Trichogramma pretiosum, Trichogramma chilonis, Bacillus thuringiensis, Metarhizium anisopliae,* Maize

The fall armyworm (*Spodoptera frugiperda* Smith) (Lepidoptera: Noctuidae) is a serious invasive pest. Native to the American continent, where it causes devastating damage to several crops and was first reported in India from Karnataka in July 2018 and subsequently in Andhra Pradesh in August 2018. Significant yield losses have been reported from Northern Zimbabwe due to damage on leaves, silks, and tassels (Chimweta et al., 2018). Management of FAW is particularly challenging because of its concealed feeding habit, high reproductive potential, strong migratory ability and wide exposure to chemical pesticides. Ecological pest management practices such as the use of crop spacing have been demonstrated as sustainable, cost-effective, and environmentally safe alternatives (Nivetha et al., 2022).

Currently various approaches including cultural practices, chemical pesticides, natural plant products and development of resistant maize varieties/ hybrids are employed for FAW management (Prasanna 2023). However, indiscriminate insecticide use has led to adverse impacts on soil health, the environment and beneficial organisms, including natural predators and parasitoids (FAO 2018). In this context, biological control and IPM strategies are gaining importance as eco-friendly and long-term solutions. The need to develop sustainable IPM technologies for *S. frugiperda* management in India, with reduced dependence on insecticides has been emphasized (Mallapur et al., 2018, Shylesha et al., 2018, Akutse et al., 2019). Karimou et al. (2024) focused on identifying climate-responsive IPM strategies for long-term control integrating biointensive and judicious insecticide practices. Earlier reports have shown that FAW larvae are susceptible to a range of biocontrol agents, including entomopathogenic bacteria, fungi, nematodes and viruses (Molina-Ochoa et al., 2003, Ríos-Velasco et al., 2010, Visalakshi et al., 2020). Field studies conducted at Regional Agricultural Research Station (RARS), Anakapalle during 2018-2022 evaluated biocontrol agents and entomopathogens both as standalone treatments and as components of IPM modules including the release of *Trichogramma* spp. egg parasitoids against FAW in maize.Although several international studies have demonstrated the potential of biocontrol agents against FAW, field-based evidence from Andhra Pradesh, India is limited. Therefore, the present study was undertaken to evaluate the efficacy of biocontrol agents individually and in IPM modules for the sustainable management of FAW in maize.

MATERIAL AND METHODS

An ad hoc field trial was initiated under ICAR-NBAIR, Bengaluru to evaluate the efficacy of the egg parasitoid *Trichogramma pretiosum* in combination with biopesticide sprayings *viz.*,*Bacillus thuringiensis* NBAIR Bt25, *Metarhizium anisopliae* NBAIR Ma35, *Beauveria bassiana* NBAIR Bb45, *Heterorhabditis indica*, and *Pseudomonas fluorescens* in comparison with pheromone traps alone and the insecticidal check, emamectin benzoate against maize fall armyworm (FAW) during rabi seasons of 2018-19 and 2019-20. The trials were conducted at RARS, Anakapalle, Visakhapatnam district, Andhra Pradesh (East Coast Plains and Hills Zone 11, 17°37′ N latitude, 83°01′ E longitude).The experiments were laid out in a completely randomized block design with eight treatments replicated thrice using maize hybrid Advanta 751. Seeds were sown manually in experimental plots measuring 5 m × 6 m with a spacing of 60 cm × 30 cm and irrigated regularly. Recommended agronomic practices including fertilizer application as per the package of practices of ANGRAU were followed to maintain crop health until harvest. The efficacy of *T. pretiosum* and *T. chilonis* releases along with biopesticide sprayings in maize sown with cyantraniliprole + thiamethoxam treated seed was further studied during four seasons from 2019-20 to 2020-21. Subsequently, field evaluations of IPM modules for FAW management as alternatives to chemical insecticide-based modules were carried out during *kharif* and *rabi* seasons of 2020-21 and 2021-22 at RARS, Anakapalle to identify effective IPM strategies for maize.

Biopesticide formulations were applied at the following doses: *M. anisopliae* NBAIR Ma35 and *B. bassiana* NBAIR Bb45 at 5 g/l (1 × 10^8 CFU/g), *B. thuringiensis* NBAIR Bt25 at 10 ml/l, *H. indica* at 20 g/l, and *P. fluorescens* at 10 g/l. Sprays were initiated at 20 days after sowing (DAS) upon the first incidence of FAW infestation and repeated at 10-day intervals for a total of three applications. Observations were recorded before treatment and five days after each spray. Data on the number of plants infested by FAW (20 plants per replication per treatment), number of damaged whorls, and larval counts (live/dead) were collected up to 50 days after sowing. For larval population estimation, five plants per replication were randomly selected and the number of *S. frugiperda* larvae per plant was counted. Egg masses collected from the field were maintained in glass vials, monitored for parasitoid emergence and percent parasitisation was calculated. The percent reduction in FAW plant damage was computed and crop yield was recorded at harvest. Yield increase (%) in each biocontrol treatment and IPM module was determined relative to the chemical control and untreated control.

Details of the Treatments

Study I: Ad hoc trial on the management of fall armyworm using biocontrol agents and biopesticides

The experiment consisted of eight treatments as follows:(T_1)**:** *T. pretiosum* @ 50,000/acre + *B. thuringiensis* NBAIR Bt25 @ 10ml/l, (T_2)**:** *T. pretiosum* @ 50,000/acre + *M. anisopliae* NBAIR Ma35 @ 5 g/l, (T_3): *T. pretiosum* @ 50,000/acre + *H. indica* @ 20 g/l, (T_4)**:** *T. pretiosum* @ 50,000/acre + *P. fluorescens* @ 10 g/l, (T_5)**:** *T. pretiosum* @ 50,000/acre alone, (T_6)**:** Pheromone traps (*S. frugiperda*) @ 10/acre, (T_7)**:** Insecticidal check - Emamectin benzoate 0.4 SG @ 0.4 g/l, and (T_8)**:** Untreated check. Each treatment was replicated three times in a Randomized **Complete** Block Design (RCBD).

Study II: Management of maize fall armyworm using biocontrol methods

The experiment comprised seven treatments as follows:(T_1) Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg + release of *T.pretiosum* @ 50,000/acre at 20 DAS (I window) + spraying *B. thuringiensis* @ 10 ml/l at 30, 40, and 50 DAS (II, III, IV windows), (**T_2**) Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg + release of *T. pretiosum* @ 50,000/acre at 20 DAS (I window) + spraying *Metarhizium anisopliae* @ 5 g/L at 30, 40, and 50 DAS (II, III, IV windows), (T_3) Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg + release of *T. pretiosum* @ 50,000/acre at 20 DAS (I window) + spraying *Beauveria bassiana* @ 5 g/l at 30, 40, and 50 DAS (II, III, IV windows), (**T_4**) Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg + release of *T. chilonis* @ 100,000/acre at 20 DAS (I window) + spraying *B. thuringiensis* @ 10 ml/l at 30, 40, and 50 DAS (II, III, IV windows), **(**T_5) Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg + release of *T. chilonis* @ 100,000/acre at 20 DAS (I window) + spraying *M. anisopliae* @ 5 g/l at 30, 40, and 50 DAS (II, III, IV windows), **(**T_6) Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg + release of *T. chilonis* @ 100,000/acre at 20 DAS (I window) + spraying *B. bassiana* @ 5 g/l at 30, 40, and 50 DAS (II, III, IV windows), and **(**T_7) Untreated control. Each treatment was replicated three times in a randomized complete block design**.**

Study III: Integrated pest management (IPM) module on fall armyworm in Maize

The experiment comprised ten IPM modules as treatments

Module 1: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + *B. thuringiensis* @ 10 ml/l (3 sprays from 25 DAS at 10-day intervals).

Module 2: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + *M. anisopliae* @ 5 g/l (3 sprays from 25 DAS at 10-day intervals).

Module 3: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + *B. bassiana* @ 5 g/l (3 sprays from 25 DAS at 10-day intervals).

Module 4: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + Neem formulation @ 5 ml/l (spray at 25 DAS) + Chlorpyriphos @ 2.5 ml/l (spray at 35 DAS).

Module 5: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + Neem formulation @ 5 ml/l (spray at 25 DAS) + Emamectin benzoate @ 0.4 g/l (spray at 35 DAS).

Module 6: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + Emamectin benzoate @ 0.4 g/l (spray at 35 DAS).

Module 7: *T. chilonis* @ 20,000 per acre (3 releases, weekly from one week after sowing) + Neem formulation @ 5 ml/l (spray at 25 DAS) + poison baiting in leaf whorls with rice bran (10 kg) + jaggery (2 kg) + thiodicarb (100 g) per acre at 35 DAS.

Module 8: Neem formulation @ 5 ml/l (spray at 10 DAS) + *M. anisopliae* @ 5 g/l (2 sprays from 25 DAS at 10-day intervals).

Module 9: Neem formulation @ 5 ml/l (spray at 10 DAS) + *B. bassiana* @ 5 g/l (2-3 sprays from 25 DAS at 10-day intervals).

Module 10: Farmers' practice (Chemical module) - Neem formulation @ 5 ml/l (spray at 10 DAS) + Chlorpyriphos @ 2.5 ml/l (spray at 20 DAS) + poison baiting in leaf whorls with rice bran (10 kg) + jaggery (2 kg) + thiodicarb (100 g) per acre at 30 DAS + Emamectin benzoate @ 0.4 g/l (spray at 40 DAS).

Each IPM module was replicated three times in a randomized complete block design .

RESULTS AND DISCUSSION

Study I: Ad hoc trial for management of fall armyworm using biocontrol agents and biopesticides

Ad hoc trials were conducted for two consecutive rabi seasons (2018-19 and 2019-20) to evaluate the efficacy of biocontrol agents and biopesticides against the invasive pest, fall armyworm (FAW) in maize. The results revealed that, next to the insecticide treatment emamectin benzoate, the biocontrol treatment consisting of field release of egg parasitoid *T. pretiosum* @ 20,000 parasitoids/acre/release (two releases from 7 days after seedling emergence) + spraying of *B. thuringiensis* (NBAIR Bt-25) @ 10 ml/l (three sprays from 21 days after seedling emergence) was highly effective. This treatment recorded significantly lower FAW damage (48.6%), higher larval mortality (35 dead larvae/plot) and higher cob yield (40.7 q/ha) followed by the treatment comprising two releases of *T. pretiosum* + three sprays of *M. anisopliae* (ICAR-NBAIR Ma-35) which recorded low plant damage (50.38%), high larval mortality (37.62 dead larvae/plot) and higher cob yield (39.27 q/ha) compared to high damage (78.29%) and low yield (22 q/ha) in untreated plots (Table 1).

Good parasitism of FAW eggs by *T. pretiosum* (8.05-15.34 parasitized egg masses/plot) was observed which suppressed FAW damage by 64.49-73.45 per cent compared to untreated control. In contrast, higher reduction in FAW damage was recorded in the insecticidal treatment (86.3%) up to 20 DAS, while pheromone treatment resulted in 69.76% reduction compared to untreated control. The insecticide emamectin benzoate recorded the highest efficacy with significantly lower damage (15.15%), high larval mortality (49.36 dead larvae/plot), maximum reduction in FAW damage (80.65%) and yield increase of 82.27 per cent over untreated check.

Among biocontrol-based treatments, *T. pretiosum* + Bt (NBAIR Bt-25) and *T. pretiosum* + *M. anisopliae* (ICAR-NBAIR Ma-35) showed good reduction in FAW damage up to 60 DAS (37.92% and 35.65%, respectively) and high yield increase (85% and 78.5%, respectively). Their efficacy was found to be comparable to emamectin benzoate. These findings indicate that biocontrol-based approaches particularly integration of *T. pretiosum* with microbial biopesticides can serve as a sustainable alternative to chemical insecticides for the management of FAW in maize.

Study II: Management of Maize fall armyworm using Biocontrol methods

Efficacy studies of biocontrol agents (*T.pretiosum* and *T.*

Table 1. Evaluation of biocontrol methods against Fall armyworm in maize during *Rabi* (2018-19 and 2019-20)

Treatment	Damage at 20 DAS (%)	Number of parasitized egg masses per 40m^2	Damage reduction over control at 20 DAS (%)	Damage at 60 DAS (%)	Number of dead larvae /40m^2	Grain yield (q/ha)	Damage reduction over control at 60 DAS (%)	Increase in yield over control (%)
T1 : TP +Bt	9.23	13.73	64.49	48.60	35.0	40.70	37.92	85.0
T2 : TP+ Ma	9.12	14.70	64.91	50.38	37.62	39.27	35.65	78.50
T3: TP+Hi	7.39	8.05	71.57	52.28	32.68	36.66	33.22	66.64
T4: TP+Pf	6.90	9.0	73.45	62.27	26.51	35.53	20.46	61.50
T5: TP alone	8.10	15.34	68.83	70.53	0.0	31.38	9.91	42.64
T6: Pheromones	7.86	0.0	69.76	74.73	0.0	29.09	4.55	32.27
T7: Insecticidal check	3.56	0.0	86.30	15.15	49.36	40.1	80.65	82.27
T8: Untreated Check	25.99	0.0		78.29	0.0	22.0		
CD (p=0.05)	10.2	6.75		13.75	14.82	8.29		

* Values represent mean of two years

chilonis) and biopesticides (*B. thuringiensis*, *M. anisopliae*, and *B. bassiana*) in maize sown with insecticide-treated seed were conducted during kharif and rabi seasons of 2019-20 and 2020-21.The results showed that T_1:seed treatment + *T. pretiosum*/*T. chilonis* (one release) + three sprays of *B. thuringiensis* (NBAIR Bt-25) was most effective recording significantly lower plant damage (32.95%), higher larval mortality (4.48 dead larvae/plot) and higher yields (44.02 q/ha) compared to untreated control (Table 2). The next best treatment was T_2: seed treatment + *T. pretiosum*/*T. chilonis* release + three sprays of *M. anisopliae*, which resulted in reduced plant damage (34.48%), higher larval mortality (3.92 dead larvae/plot) and good yields (42.35 q/ha). Egg parasitism studies indicated that *T. pretiosum* (6.42-7.91 parasitized egg masses/plot) was statistically on par with *T. chilonis* (6.53-7.78 parasitized egg masses/plot) confirming that both parasitoids performed equally well in parasitizing FAW eggs.

Seed treatment with cyantraniliprole 19.8% + thiamethoxam 19.8% @ 6 ml/kg seed effectively reduced FAW damage up to 20 DAS by 68.67-76.44% over untreated control. The combination of seed treatment + *T. pretiosum*/*T. chilonis* + Bt sprays resulted in 56 per cent reduction in plant damage and yield increases of 68.4 per cent, respectively. The next best integration was seed treatment + parasitoid release + *M. anisopliae* sprays, which recorded 53.97 per cent reduction in damage with yield increases of 62%.These findings confirm that integration of seed treatment with egg parasitoids and microbial biopesticides provides effective, eco-friendly management of FAW in maize corroborating earlier reports on the parasitisation capacity of *Trichogramma* spp. on *S. frugiperda* eggs (Tao Jin et al., 2021).

Study III: IPM module on fall armyworm in maize

The IPM modules evaluated against maize FAW clearly demonstrated the effectiveness of integrating biocontrol agents with biopesticides. The module involving *T. chilonis* releases (three times) + *B. thuringiensis* (NBAIR Bt-25) three sprays recorded significantly lower plant damage (30.46%), higher larval mortality (4.67 dead larvae/20 plants), good egg parasitisation (14%), and higher yield (44.05 q/ha) compared to other treatments (Table 3). Similarly, the module *T. chilonis* three releases + *M. anisopliae* (NBAIR Ma-35) three sprays also proved effective with plant damage of 33.35%, larval mortality of 4.23 larvae/20 plants, parasitisation of 12.08%, and yield of 41.03 q/ha. In contrast, the farmers' practice consisting of neem spray at 10 DAS, chlorpyriphos at 20 DAS, poison baiting at 30 DAS, and emamectin benzoate at 40 DAS recorded high FAW damage (55.42%), low larval mortality (2.7 larvae/20 plants), poor egg parasitism (1.33%), and the lowest yield (26.53 q/ha).The percent reduction in plant damage over farmers' practice was 45.04% in *T. chilonis* + NBAIR Bt-25 module and 39.82% in *T. chilonis* + NBAIR Ma-35 module, resulting in a corresponding yield increase of 66.04% and 54.66%, respectively.

Egg mass parasitisation was observed in the IPM modules with *T. chilonis* releases (12-14%), whereas it was negligible (1.33%) in the farmers' practice. *Trichogramma* egg parasitoids are considered excellent candidates for the biological control of FAW and play a crucial role as a component of integrated pest management (Navik et al., 2023).Cob yields were significantly higher in the IPM modules *T. chilonis* + NBAIR Bt-25 (44.05 q/ha) and *T. chilonis* + NBAIR Ma-35 (41.03 q/ha), compared to the chemical module (66.33 q/acre). The present findings clearly demonstrate the effectiveness of integrating *Trichogramma* releases with microbial biopesticide sprays in IPM modules for FAW management. Such integration minimized crop damage and enhanced yields while reducing dependence on chemical insecticides. These results agree with the

Table 2. Management of maize fall armyworm using biocontrol agents and biopesticides during *Kharif* seasons (2019 and 2020)

Treatments	FAW damage at 20 DAS (%)	Damage reduction) over control at 20 DAS (%)	FAW damage at 60 DAS (%)	Number of dead larvae per plants	Number of parasitized egg masses (no.)/ 40m^2	Grain yield (q/ha)	Damage reduction over control at 60 DAS (%)	Increase in yield over control (%)
T1	6.12	74.84	32.95	4.48	7.91	44.02	56.0	68.40
T2	5.73	76.44	34.48	3.92	6.76	42.35	53.97	62.0
T3	5.30	78.21	35.54	3.62	6.42	39.62	52.55	51.57
T4	7.62	68.67	34.13	4.33	7.78	42.92	54.43	64.20
T5	6.20	74.50	35.30	4.13	6.72	41.60	52.87	59.14
T6	6.16	74.67	36.0	3.39	6.53	33.95	51.94	29.88
T7	24.32		74.9	0.0	1.01	26.14		
CD (p=0.05)	9.81		11.35	1.21	3.34	14.29		

recommendations of Prasanna et al. (2018) on IPM tools for the management of the invasive maize FAW and with the findings of Tiwari and Bopp (2020) on biosafe alternatives against FAW in maize.

Metarhizium anisopliae (ICAR-NBAIR Ma-35) applied as three sprayings showed high larval mortality in ad hoc trials, with an average of 37.62 dead larvae per plot. The effectiveness of *M. anisopliae* as an eco-friendly and sustainable tool for FAW management has also been reported by several researchers (Kumar and Singh, 2020, Keerthi et al., 2023, Sharma and Thakur, 2019, Tavares et al., 2019, Visalakshi et al., 2023). Apart from its entomopathogenic activity, *Metarhizium* is recognized as a highly effective fungus that functions as a plant biostimulant, acting as both an endophyte and a rhizosphere colonizer (Wood et al., 2022).Among the chemical treatments, three sprays of emamectin benzoate applied from 20 days after crop establishment reduced plant infestation by 80.65%, outperforming biocontrol treatments. However, combinations of natural enemies viz., *T. pretiosum* + *B. thuringiensis* (NBAIR Bt 25) reduced infestation by 37.92% and *T. pretiosum* + *M. anisopliae* (NBAIR Ma-35) by 35.65% compared with the untreated control. In terms of yield, the highest increase over control was recorded in *T. pretiosum* + *B. thuringiensis* (85%), followed by emamectin benzoate (82.27%) and *T. pretiosum* + *M. anisopliae* (78.5%).Several studies corroborate the efficacy of emamectin benzoate in controlling FAW and increasing maize yields (Rakat and Bhala, 2018, Ghimire et al., 2020). Nonetheless, despite its high effectiveness, emamectin benzoate poses concerns such as the risk of resistance development, environmental impacts and crop residues. Hence, the value of IPM is increasingly recognized as a sustainable alternative strategy for FAW management in maize.

The cumulative efficacy of the biocontrol agent *T. chilonis* (three releases) in combination with biopesticide applications (*B. thuringiensis* NBAIR Bt 25 or *M. anisopliae* NBAIR Ma-35 three sprays) under the IPM module resulted in a substantial reduction of FAW infestation. This integrated approach recorded high larval mortality and increased egg parasitisation of FAW, ultimately contributing to higher maize yields. A comparative evaluation of different biocontrol strategies and IPM modules against the chemical module/ farmers practice (Neem spray + Chlorpyriphos + poison baiting + Emamectin benzoate) revealed marked differences in FAW damage and maize yields. The combined use of biocontrol agent releases with biopesticide sprayings consistently reduced FAW incidence and improved yields, demonstrating their potential as an effective and eco-friendly alternative to sole reliance on chemical insecticides for FAW management in maize.

The present study represents the first field-level validation of biocontrol agents and biopesticides against maize FAW under Andhra Pradesh conditions. Egg mass parasitisation and increased larval mortality clearly demonstrated the effectiveness of *Trichogramma* releases in combination with biopesticides (*B. thuringiensis* and *M. anisopliae*) in reducing infestation and enhancing maize yield. Integration of seed treatment, parasitoid releases and microbial sprays achieved yields comparable to or even superior to those obtained with chemical modules. These findings strongly highlight that biocontrol-based IPM strategies are not only effective but also yield superior results compared to chemical-based modules. Such strategies can

Table 3. Evaluation of IPM module on fall armyworm in maize during *Kharif* and *RABI* seasons (2019 and 2020)

Treatments	FAW damage (%) at 60 DAS	Dead larvae (no.)/ 20 plants	Parasitized egg masses (no.) /40m^2	Grain yield (Q/ha)	Damage reduction (%) over chemical module at 60 DAS	Increase (%) in yield over chemical module
Module 1	30.46	4.67	14.0	44.05	45.04	66.04
Module 2	33.35	4.23	12.08	41.03	39.82	54.66
Module 3	36.62	4.06	11.50	38.80	33.92	46.25
Module 4	39.82	2.74	5.50	30.94	28.15	16.62
Module 5	41.05	2.88	5.75	34.26	25.93	29.14
Module 6	36.42	4.44	5.69	46.40	34.28	74.93
Module 7	45.17	1.96	5.42	29.02	18.50	9.39
Module 8	45.18	2.37	3.59	27.65	18.48	4.22
Module 9	46.47	2.34	3.11	28.68	16.15	8.10
Module 10	55.42	2.70	1.33	26.53		
CD (p=0.05)	18.52	2.95	4.07	3.72		

*****Values represent mean of two years

therefore be recommended as viable alternatives to chemical insecticides for FAW management in maize as IPM plots consistently showed minimal infestation and significantly higher yields compared to chemical modules.

This study highlights the significance of integrating biological control agents and biopesticides which are highly potent, residue-free and effective in preventing resistance development. Such eco-friendly IPM approaches provide a sustainable alternative to chemical insecticides like emamectin benzoate for the effective management of fall armyworm in maize.

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