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Research Article

Bio-intensive management of fall armyworm, *Spodoptera frugiperda* (J.E. Smith), in maize and its benefit-cost in Telangana

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ABSTRACT: Fall Armyworm (FAW), *Spodoptera frugiperda* (J.E.Smith), a Lepidoptera insect pest, has emerged as a major threat to maize production worldwide. Although chemical insecticides are commonly used for its management, their indiscriminate application has led to adverse effects on human health and the environment. Therefore, there is a growing need to develop sustainable and eco-friendly management strategies. In this context, the present study evaluated a Bio-intensive Integrated Pest Management (BIPM) approach for controlling FAW under field conditions. The results of the demonstration indicated that BIPM practices achieved a 67.23% reduction in plant damage over the untreated control, which was comparable to the 62.94% reduction observed under farmers' practices. The highest population of natural enemies (greenbugs, coccinellids, and spiders) was recorded in the untreated control (5.20 per plant), which was statistically similar to the BIPM treatment (5.13 per plant). Although no significant difference was observed between BIPM and farmers' practices in terms of damage percentage (13.97% and 15.80%, respectively), both treatments significantly reduced damage compared to the untreated control (42.63%). Similarly, the number of dead larvae did not differ significantly between BIPM (2.46 per plant) and farmers' practices (2.40 per plant), but both were significantly higher than the untreated control (0.72 per plant). Yield data revealed that BIPM practices resulted in a 55.50% increase over the untreated control, while farmers' practices recorded a 60.45% increase. Economically, BIPM practices incurred a lower cost of cultivation (₹58,912.50 per ha) compared to farmers' practices (₹62,825 per ha). Although net returns were slightly higher under farmers' practices (₹1,01,050.00 per ha) than BIPM (₹97,775.00 per ha), the benefit-cost ratio was greater under BIPM (1.66) compared to farmers' practices (1.61) and the untreated control (0.55), indicating better economic efficiency of the bio-intensive approach.

KEYWORDS: Benefit-cost ratio, BIPM, fall armyworm, natural enemies

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INTRODUCTION

Maize (*Zea mays* L.) is a globally important cereal cultivated across all continents except Antarctica (Eckhoff and Paulsen, 1996). Despite its high yield potential compared to other major cereals, maize productivity is often constrained by several biotic and abiotic stresses. Among the biotic factors, the FAW, *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae), has emerged as a major invasive pest causing significant yield losses in maize (Assefa & Ayalew, 2019). This highly polyphagous insect feeds on a wide range of host plants (Dash *et al*., 2024; Prasanna *et al*., 2021) and poses a serious threat to global agriculture (Mishra *et al*., 2023). It is Native to the Americas; *S. frugiperda* is characterised by high reproductive capacity and strong migratory ability, capable of dispersing up to 100 km in a single night. Following its first detection in Africa in 2016 (Goergen *et al*., 2016), the pest spread rapidly across the continent (Garcia *et al*.,

2018) and subsequently invaded tropical and subtropical regions worldwide. Its rapid expansion has raised major concerns regarding food security, economic stability, and the livelihoods of millions of maize growers (Wyckhuys *et al*., 2024). In India, the pest was first reported in 2018 from Shivamogga, Karnataka (Sharanabasappa *et al*., 2018), and has since become a serious constraint in maize production.

For the manage FAW infestations, farmers largely depend on chemical insecticides, often applied indiscriminately. However, such practices have led to the development of resistance in pest populations, reducing the effectiveness of commonly used insecticides. Moreover, excessive and unregulated pesticide use disrupts ecological balance, adversely affects non-target organisms, and leads to environmental contamination. These challenges, coupled with rising input costs and declining farm profitability, have contributed to reduced maize cultivation in several regions, including Telangana (Krishnarao *et al*., 2021).

Given these limitations, there is an urgent need for sustainable and eco-friendly management strategies to ensure a resilient maize production system. Integrated Pest Management (IPM) has gained global recognition as an effective and environmentally sound approach for pest control. The development and adoption of region-specific IPM strategies are essential to mitigate the impact of FAW. In this context, the present study evaluates a Bio-intensive Integrated Pest Management (BIPM)-based model for the effective management of *S. frugiperda* in maize.

MATERIALS AND METHODS

Study area and experimental details

Frontline demonstrations were conducted to evaluate the effectiveness of bio-intensive management practices against FAW in maize during *Rabi* 2023-24 and 2024-25. The study was carried out in Narasingapuram village of Wanaparthy district and Cheryala village of Siddipeta district in Telangana, India. The soils at both locations are predominantly red in nature. At Cheryala, the soils are mainly light-textured sandy loams (locally referred to as red chalkas), whereas Narasingapuram is characterised by gravelly red loam soils.

Climatic conditions

The two locations fall under different agro-climatic zones of Telangana. Narasingapuram (16.40173° N, 77.865451° E) is situated in the Southern Telangana Zone, with mean temperatures ranging from 26.9°C to 27.8°C and an average annual rainfall of 731 mm. Cheryala (17.891887° N, 78.963107° E) lies in the Central Telangana Zone, with mean temperatures between 26.8°C and 27.9°C and an annual rainfall of 978 mm.

Table 1. BIPM module and farmers' pest management practices

Components of BIPM module	Farmers' practices
1. Variety -Syngenta NK 7884	1. Variety -Syngenta NK 7884
2. Spacing: 60X15	2. Spacing: 60X15
3. Soils - irrigated red soils	3. Soils: irrigated red soils
4. Pheromone traps @ 10 traps/acre installed	4. No Installation of pheromone traps
5. Released of *Trichogramma chilonis* (1,00,000 eggs/ha) (2 releases, 1st release after one week of sowing and 2nd release after one week of first release)	5. No biocontrol agent uses
	6. Without bio-pesticide application
6. Applied NBAIR *Bt*-25 @ 2ml/L (2 sprays first spray after 20 days after sowing, 2nd spray 10 days after first spray)	7. First Spray (15 Days after Sowing) Chlorantraniliprole @ 0.4 ml/l
	8. Second Spray (35 Days after Sowing): Acephate @ 1.5 g/l + Chlorantraniliprole @ 0.4 ml/l and Spinetoram@ 0.5 ml/l
7. Applied ICAR-NBAIR *Metarhizium anisopliae* (Ma-35) @ 5g/L (2 sprays 1st spray 10 days after first spray)	9. Third Spray (50 Days after Sowing): Emamectin benzoate @ 0.4 g/l, Chlorantraniliprole @ 0.4 ml/l

Treatment details

Prior to the establishment of frontline demonstrations, extensive diagnostic surveys and farmer interactions were conducted in the selected villages to understand existing crop management practices and assess farmers' readiness to adopt BIPM strategies. Participating farmers were trained on site selection, layout of demonstrations following standard procedures, preparation of bio-formulation spray solutions, safe spraying practices using knapsack sprayers, and handling of egg parasitoids (*Trichogramma chilonis*) in the form of Tricho-cards (20,000 *Corcera* sp. eggs/card parasitised with *T. chilonis*).

The BIPM package was developed based on recommendations of the ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru. The package included: installation of pheromone traps (25 traps/ha) five days after seedling emergence; two releases of *T. chilonis* (100,000 eggs/ha), with the first release one week after sowing and the second one week later; two sprays of *Bacillus thuringiensis* formulation (NBAIR *Bt*-25 @ 2 ml/L), starting at 20 days after sowing followed by a second spray at a 10-day interval; and two applications of the entomopathogenic fungus *Metarhizium anisopliae* (Ma-35 @ 5 g/L), applied alternately with *Bt* sprays at 10-day intervals beginning 20 days after sowing (Table 1). The demonstrations were conducted on one hectare under bio-intensive practices in each village. Adjacent farmer-managed fields followed conventional practices, including chemical pesticide use. An untreated control plot (1000 m²) was maintained for comparison. No chemical pesticides were used in the demonstration plots throughout the cropping period.

Data collection

Observations were recorded on percent plant damage, number of dead larvae (due to pathogens such as bacteria, viruses and fungi), and abundance of natural enemies (greenbugs, coccinellids, and spiders). Data were collected from 20 plants at each of seven randomly selected locations within the one-hectare demonstration area, both before treatment imposition and 60 days after treatment. Similar observations were recorded from the untreated control plot.

Statistical analysis

The experimental design followed a Randomised Complete Block Design (RCBD) to assess the significance of treatment effects. Farmers were compensated with ₹2000 for maintaining the untreated control area. Percent damage, reduction over control, and natural enemy population (number per plant) were computed. Grain yield and benefit-cost (B:C) ratio were calculated on a hectare basis using final harvest data. SPSS software used to perform Statistical analysis. Before applying ANOVA, the data collected in numbers and percentages were transformed in square root transformed log values and angular transformed values and were presented in parenthesis in the given tables. After ANOVA, Least Significant Difference (LSD) test was used to determine significance difference among treatment means. No transformations were done for Benefit-cost economics analysis, actual values were taken into account.

RESULTS

Pest incidence and natural enemies

Year-wise results obtained during the study are presented in Tables 2-4 and Figure 1. During 2023-24, the BIPM module recorded a 79.74 % reduction in plant damage over the untreated control, while the farmers' practice achieved a 70.45 % reduction. The highest population of natural enemies (greenbugs, coccinellids, and spiders) was observed in the untreated control (4.95 per plant), which was statistically on par with the BIPM treatment (4.65 per plant). No significant difference was observed between BIPM and farmers' practices with respect to percent plant



Figure 1. Observation of FAW damage (FAW larva feeding on plant and Pheromone trapped moths).

Table 2. Eco-friendly management of FAW in maize: Field demonstration during *Rabi* 2023-24

Treatments	Damage percentage (%)		Per cent reduction over control (%)	No. dead larvae/plant		Mean No. of natural enemies/plant		Average yield (kg/ha)	Per cent increase in yield (%)
	Before treatment	After treatment		Before treatment	After treatment	Before treatment	After treatment		
T1-BIPM	45.75 (36.45)	9.51 (17.82)	79.74	0.38 (0.94)	3.94 (2.02)	3.35 (1.90)	4.65 (2.23)	6125.00	41.00
T2-FP	46.55 (36.77)	13.87 (21.81)	70.45	0.28 (0.89)	4.08 (2.12)	3.41 (1.94)	0.52 (1.00)	6500.00	49.94
T3-Control	47.46 (37.29)	46.94 (43.21)		0.42 (0.87)	0.95 (1.18)	3.94 (1.97)	4.95 (2.28)	2875.00	
SEM	2.43	1.62		0.07	0.17	0.21	0.18		
CD (0.05%)	7.5	5		0.23	0.54	0.66	0.56		
CV	17.36	15.45		11.93	14.1	15.76	14.11		

Table 3. Eco-friendly management of FAW in maize: Field demonstration during *Rabi*-2024-25

Treatments	Percent damage		Per cent reduction over control (%)	Dead larvae/Plant		Mean No. of natural enemies/plant		Average yield (kg/ha)	Per cent increase in yield (%)
	Before treatment	After treatment		Before treatment	After treatment	Before treatment	After treatment		
T1-BIPM	35.64 (36.56)	18.44 (25.37)	51.90	0.25 (0.85)	0.83 (1.14)	3.07 (1.84)	5.08 (2.32)	7500.00	70.00
T2-FP	37.27 (37.42)	17.73 (24.83)	53.75	0.24 (0.84)	0.86 (1.15)	3.12 (1.89)	0.52 (1.00)	7750.00	70.96
T3-Control	36.7 (37.10)	38.34 (38.15)		0.24 (0.85)	0.49 (0.97)	3.37 (1.86)	5.38 (2.37)	2750.00	
SEM	1.81	1.45		0.07	0.09	0.19	0.17		
CD (05%)	5.59	4.47		0.21	0.3	0.59	0.54		
CV	12.86	12.94		11.61	12.79	14.67	13.1		

damage (9.51% and 13.87%, respectively) and number of dead larvae (3.94 and 4.08 per plot). However, both treatments showed a significant reduction in damage and increase in larval mortality compared to the untreated control, which recorded 46.94% damage and only 0.95 dead larvae per plant.

Table 4. Field demonstration of eco-friendly management of FAW in maize: Pooled data (2023-24 and 2024-25)

Treatments	Percent damaged		Damage Reduction over control	Dead larvae/plant		Mean No. of natural enemies/plant		Average yield (kg/ha)	Per cent increase in yield (%)
	Before treatment	After treatment		Before treatment	After treatment	Before treatment	After treatment		
T1-BIPM	39.46 (38.88)	13.97 (21.91)a	67.23	0.31 (0.88)	2.46 (1.71)a	3.21 (1.88)	5.13 (2.35)a	6812.50	55.50
T2-FP	40.93 (39.62)	15.80 (23.37)a	62.94	0.37 (0.90))	2.40 (1.66)a	3.27 (1.92)	0.54 (1.01)b	7125.00	60.45
T3-Control	40.31 (39.24)	42.63 (40.68)		0.33 (0.90)	0.72 (1.09)	3.65 (1.92)	5.20 (2.34)a	2812.50	
SEM	1.84	1.26		0.07	0.11	0.2	0.15		
CD @ 5%	5.69 (NS)	3.9		0.22	0.34	0.61	0.46		
CV%	12.36	11.6		11.57	10.62	14.82	11.15		

Table 5. Pooled analysis of yield and benefit-cost economics of FAW management demonstrations (two seasons combined - 2023-24 and 2024-25)

Season/Year	Treatment	Cost of cultivation (Rs./ha.)	Yield (kg/ha)	Yield increase over control (%)	Gross returns (Rs./ha.) (Rs. 23/kg)	Net returns (Rs./ha.)	B:C ratio
Rabi 2023-24	T1-BIPM	59825.00	6125.00	41.00	140875.00	81050.00	1.35
Rabi 2024-25	T1-BIPM	58000.00	7500.00	70.00	172500.00	114500.00	1.97
Pooled (Two Seasons combined)	T1-BIPM	58912.50	6812.50	55.50	156687.50	97775.00	1.66
Rabi 2023-24	T2-FP	62325.00	6500.00	49.94	149500.00	87175.00	1.40
Rabi 2024-25	T2-FP	63325.00	7750.00	70.96	178250.00	114925.00	1.81
Pooled (Two Seasons combined)	T2-FP	62825.00	7125.00	60.45	163875.00	101050.00	1.61
Rabi 2023-24	T3-Control	41750.00	2875.00		66125.00	24375.00	0.58
Rabi 2024-25	T3-Control	41750.00	2750.00		63250.00	21500.00	0.51
Pooled (Two Seasons combined)	T3-Control	41750.00	2812.50		64687.50	22937.50	0.55

During 2024-25, the BIPM module resulted in a 51.90% reduction in damage over control, while farmers' practices recorded a slightly higher reduction of 53.75%. The untreated control again recorded the highest population of natural enemies (5.38 per plant), which was comparable with the BIPM treatment (5.08 per plant). Similar to the

previous year, no significant differences were observed between BIPM and farmers' practices in terms of plant damage (18.44% and 17.73%, respectively) and dead larvae (0.83 and 0.86 per plot). Nevertheless, BIPM treatment differed significantly from the untreated control, which recorded higher damage (38.34%) and lower larval mortality (0.49 per plant).

The pooled analysis (2023-24 and 2024-25) indicated that BIPM practices achieved a 67.23% reduction in damage over control, compared to 62.94% under farmers' practices. The highest mean population of natural enemies recorded in the untreated control (5.20 per plant), and remained statistically on par with the BIPM treatment (5.13 per plant). No significant difference was observed between BIPM and farmers' practices for plant damage (13.97% and 15.80%, respectively). However, both treatments significantly reduced damage compared to the untreated control (42.63%). Similarly, the number of dead larvae did not differ significantly between BIPM (2.46 per plant) and farmers' practices (2.40 per plant), but both were significantly higher than the untreated control (0.72 per plant).

Yield and Economic Analysis

The results on yield and economic returns, B:C ratios (benefit-cost analysis) are presented in Table 5. During 2023-24, BIPM practices resulted in a 41.00% increase in yield over the untreated control, while farmers' practices recorded a higher increase of 49.94%. In 2024-25, the yield advantage of 70.00% under BIPM and 70.96% under farmers' practices was recorded.

Pooled analysis showed that yield improvement was 55.50% under BIPM and 60.45% under farmers' practices compared to the untreated control. The cost of cultivation under BIPM was lower than farmers' practices in both years, amounting to ₹59,825.00 and ₹58,000.00 per hectare during 2023-24 and 2024-25, respectively, compared to ₹62,325.00 and ₹63,325.00 per hectare under farmers' practices. Pooled data further confirmed that the average cost of cultivation was ₹58,912.50 per hectare in BIPM, which was lower than ₹62,825.00 per hectare in farmers' practices. The Net returns were also compared between the two treatments.

During 2023-24, BIPM recorded net returns of ₹81,050 per hectare, while farmers' practices yielded ₹87,175.00 per hectare. In 2024-25, the net returns were ₹1,14,500.00 and ₹1,14,925.00 per hectare under BIPM and farmers' practices, respectively. Pooled results indicated that the net returns of ₹97,775.00 per hectare under BIPM and ₹1,01,050.00 per hectare under farmers' practices. Despite slightly lower net returns in some cases, the benefit-cost ratio was higher under BIPM, recorded 1.35 and 1.97 B:C ratio values compared to farmers' practices which was recorded 1.40 and 1.81 B:C ratio values respectively during 2023-24 and 2024-25. The pooled data reflect a benefit-cost ratio higher in BIPM (1.66) than in farmers' practices (1.61), and substantially greater than the untreated control (0.55).

DISCUSSION

In India, FAW continues to be a high-priority pest, with management strategies still largely dependent on chemical insecticides despite the availability of diverse Integrated Pest Management (IPM) options. This underscores the need to strengthen our understanding of seasonal pest dynamics and promote ecologically sustainable approaches (Kalisetti *et al*., 2024). IPM is widely recognised as a holistic and effective approach for long-term pest suppression, integrating multi-compatible control measures while minimising environmental risks (Kogan, 1988). However, its successful implementation requires continuous farmer awareness, motivation, and technical support (Dreves, 1996). Biological control agents and biopesticides represent key components of IPM, offering environmentally safe alternatives to conventional insecticides (Varshney *et al*., 2021). At the village level, the adoption of IPM practices should prioritise economic feasibility to ensure wider acceptance among farmers (Sanon *et al*., 2025). Furthermore, a better understanding of interactions between FAW populations and natural enemies is critical for designing effective and sustainable management strategies (Kenis *et al*., 2023). The development of cost-effective, adaptable biopesticide-based interventions can further enhance the adoption of such eco-friendly approaches. In this context, the present study evaluated a BIPM module under field conditions. The results in pooled data indicated that BIPM practices reduced plant damage by 67.22% over the untreated control, which was slightly higher than the reduction observed under farmers' practices (62.93%). These findings are in line with earlier studies on the effectiveness of biological control agents against FAW. For example, the application of entomopathogenic fungi such as *Nomuraea rileyi* has been shown to reduce pest incidence by 59-63% (Mallapur *et al*., 2018). Similarly, it was found that after

application of *Bacillus thuringiensis* (NBAIR-BT25) and *Metarhizium anisopliae* (NBAIR-Ma-35), there was a 76% and 71.64% reduction in FAW egg mass, followed by an 80% and 74.44% larval population, respectively (Varshney *et al.*, 2021). Previous studies have also highlighted the efficacy of entomopathogenic fungi after application of *M. anisopliae* (ICAR-NBAIR Ma-35) and *B. bassiana* (ICAR-NBAIR Bb-45), the FAW infestation was reduced 68% and 69% in 2018 and 70% and 76% in 2019, respectively (Shylesha *et al.,* 2018; Shylesha, 2020). Additionally, natural epizootics caused by indigenous entomopathogens and parasitoids have been reported to induce substantial mortality in FAW populations across different agro-ecological regions (Firake & Behere, 2020). These findings corroborate the present results, where increased larval mortality was observed under BIPM treatments. The abundance of natural enemies (greenbugs, coccinellids, and spiders) was highest in the untreated control but remained statistically signifies with BIPM plots. This suggests that bio-intensive approaches are relatively safe to beneficial organisms and help to conserve natural enemy populations. In contrast, conventional pesticide-based practices (farmer's practices) may adversely affect these enemies, thereby disrupting ecological balance, though the difference in per cent plant damage between BIPM and farmers' practices was not statistically differed but both treatments significantly reduced the damage when compared with the untreated control. Similar results have been reported in earlier studies, where treated plots consistently recorded lower damage levels across different seasons (Bakry & Abdel-Baky, 2024). The higher number of dead larvae observed under both BIPM and farmers' practices further confirms the effectiveness of these interventions in enhancing pest mortality. Previous reports have also documented increased larval mortality following the application of biological control agents compared to untreated conditions (Bakry & Abdel-Baky, 2024).

From an economic perspective, as per pooled analysis, BIPM practices resulted in a 55.50% increase in yield over the untreated control, comparable to the 60.45% increase observed under farmers' practices. Notably, the cost of cultivation was lower under BIPM (₹58,912.50 ha^{-1}) compared to farmers' practices (₹62,825.00 ha^{-1}), reflecting reduced reliance on chemical inputs. Although net returns were marginally higher under farmers' practices, the benefit-cost ratio was greater in BIPM (1.66) than in farmers' practices (1.61), indicating superior economic efficiency of bio-intensive approaches. These findings are consistent with earlier reports from India, where IPM modules integrating pheromone traps, *Bacillus thuringiensis*, neem-based products, and entomopathogenic fungi resulted in yield improvements of 38-42% (Varshney *et al*., 2021).
Overall, the present study demonstrates that Bio-intensive IPM strategies can effectively manage FAW populations while conserving natural enemies and improving economic returns. The integration of biological control agents in IPM practices provides a robust and sustainable alternative to conventional pesticide-dependent practices, with strong potential for large-scale adoption in maize-growing regions.

CONCLUSION

The findings of the present study indicate that Bio-intensive Integrated Pest Management (BIPM) is a viable and sustainable alternative to conventional farmers' practices, which depend on chemical pesticides, for the management of FAW in maize. The level of damage reduction achieved under BIPM (67.22%) was comparable to that of farmers' practices (62.93%). Similarly, yield enhancement under BIPM (55.50%) was close to that of farmers' practices (60.45%) when compared to the untreated control. Importantly, the BIPM practices gave a clear economic advantage in terms of reduced cost of cultivation (₹58,912.50 per ha) over farmers' practices (₹62,825.00 per ha). Though net returns were marginally higher in farmers' practices (₹1,01,050.00 per ha) than the BIPM (₹97,775.00 per ha), the benefit-cost ratio was better in BIPM practices (1.66) compared to farmers' practices (1.61), indicating better cost benefits. Further, the performance of BIPM improved in the second year, with higher yields, reduced input costs, and increased net returns compared to the first year. This suggests that bio-intensive strategies become more effective over time. The BIPM can be promoted through capacity building, farmer training programs and extension systems to a larger extent.

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REFERENCES

Assefa, F., and Ayalew, D. 2019. Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. *Cogent Food Agric*, **5**(1): Article 1641902. https://doi.org/10.1080/23311932.2019.1641902

Bakry, M. M. S. and Abdel-Baky, N. F. 2024. Impact of the fall armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae) infestation on maize growth characteristics and yield loss. *Braz J Biol*, **84**: Article e274602. https://doi.org/10.1590/1519-6984.274602 PMid:37493657

Dash, S., Korada, R. R. and Mishra, B. K. 2024. Spodoptera frugiperda (JE Smith) in India: Pervasiveness, host range, and management. *Environ Ecol*, **42**(2B): 780-789. https://doi.org/10.60151/envec/NDRG4974

Dreves, A.J. 1996. Village-level integrated pest management in developing countries. *J Agric Entomol*, **13**(3): 195-211.

Firake, D. M. and Behere, G. T. 2020. Natural mortality of invasive fall armyworm, Spodoptera frugiperda (JE Smith) (Lepidoptera: Noctuidae) in maize agroecosystems of northeast India. *Biol Control*, **148**: 104303. https://doi.org/10.1016/j.biocontrol.2020.104303

Garcia, A. G., Godoy, W. A. C., Thomas, J. M. G., Nagoshi, R. N. and Meagher, R. L. 2018. Delimiting strategic zones for the development of fall armyworm (Lepidoptera: Noctuidae) on corn in the state of Florida. *J Econ Entomol*, **111(**1): 120-126. https://doi.org/10.1093/jee/tox329 PMid:29267899

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A. and Tamò, M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (JE Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PloS One*, **11**(10): Article e0165632. https://doi.org/10.1371/journal.pone.0165632 PMid:27788251

Kalisetti, V. S., Reddy, M. L., Mallaiah, B., Sreelatha, D., Bhadru, D., Kumar, M.V.N.,…, Sivalakshmi, Y. 2024 Assessment of newer molecules for the management of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on maize in India. *Int J Trop Insect Sci*, **44:** 1853-1864. https://doi.org/10.1007/s42690-024-01279-5

Kenis, M., Benelli, G., Biondi, A., Calatayud, P. A., Day, R., Desneux, N., …, Verheggen, F., 2023. Invasiveness, biology, ecology, and management of the fall armyworm, Spodoptera frugiperda. *Entomol Gen*, **43**(2). https://doi.org/10.1127/entomologia/2022/1659 PMCid:PMC10259777

Kogan, M., 1988. Integrated pest management theory and practice. *Entomol Exp Appl*, **49**(1-2): 59-70. https://doi.org/10.1111/j.1570-7458.1988.tb02477.x

Krishnarao, G., Misra, H. P., Samal, T. and Jayanthi, P. K. 2021. Incidence and distribution of fall armyworm, *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) in different geographical regions of Odisha, Andhra Pradesh and Telangana. *Pest Manage Hortic Ecosyst*, **27**: 65-69. https://doi.org/10.5958/0974-4541.2021.00012.6

Mallapur, C. P., Naik, A. K., Hagari, S., Praveen, T., Patil, R. K. and Lingappa, S. 2018. Potentiality of *Nomuraea rileyi* (Farlow) Samson against the fall armyworm, *Spodoptera frugiperda* (JE Smith) infesting maize. *J Entomol Zool Stud*, **6**(6): 1062-1067.

Mishra, P. K., Kumar, A., Aman, A. S., Verma, S. K., Kumar, A., Kumar, J., …, Rajpoot, P. K. 2023. A comprehensive review on seasonal incidence of fall armyworm, *Spodoptera frugiperda* (JE Smith) and their Management. *Int J Environ Clim Change*, **13**(10): 2458-2467. https://doi.org/10.9734/ijecc/2023/v13i102912

Prasanna, B. M., Huesing, J. E., Peschke, V. M., and Eddy, R. 2021. Fall Armyworm in Asia: A guide for integrated pest management. Mexico, CDMX: CIMMYT.

Sanon, A., De Bauw, P., Lehmann, E., Muriuki, L., Compaoré, I., Sanou, M.R. and Lopes, T., 2025. Development of viable Integrated Pest Management (IPM) strategies to control fall armyworm (*Spodoptera frugiperda*) on maize. *Crop Prot*, Article 107359. https://doi.org/10.1016/j.cropro.2025.107359

Sharanabasappa, S. D., Kalleshwaraswamy, C. M., Asokan, R., Swamy, H. M. M., Maruthi, M. S., Pavithra, H. B., …, Prabhu, S. T. 2018. First report of the fall

Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae), an alien invasive pest on maize in India. *Pest Manag Hortic Ecosyst*, **24**(1): 23-29.

Shylesha, A. N., Jalali, S. K., Gupta, A., Varshney, R., Venkatesan, T., Shetty, P., …, Bakthavatsalam, N., 2018. Studies on new invasive pest *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) and its natural enemies. *J Biol Control*, **32**(3): 1-7.

Shylesha, A. N. 2020. Effect of entomopathogenic fungi against invasive pest *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in maize. *Egypt J Biol Pest Control*, **30**(1): 1-5. https://doi.org/10.1186/s41938-020-00291-4

Varshney, R., Poornesha, B., Raghavendra, A., Lalitha, Y., Apoorva, V., Ramanujam, B., …, Chaudhary, M., 2021. Biocontrol-based management of fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) on Indian Maize. *J Plant Dis Prot*, **128**(1): 87-95. https://doi.org/10.1007/s41348-020-00357-3

Wyckhuys, K. A., Akutse, K. S., Amalin, D. M., Araj, S. E., Barrera, G., Beltran, M. J. B., …, Colmenarez, Y. C. 2024. Global scientific progress and shortfalls in biological control of the fall armyworm *Spodoptera frugiperda*. *Biol Control*, **191**: Article 105460. https://doi.org/10.1016/j.biocontrol.2024.105460

AUTHOR CONTRIBUTION

A. Rama Krishna Babu- writing - original draft, methodology, data curation, conceptualisation, investigation; Vani Sree K - writing - review and editing; Archana P- writing - review and editing; Anitha G - writing - review and editing. All authors have read and agreed to the published version of the manuscript.