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Sustainable Management of Fall Armyworm (*Spodoptera frugiperda*) in Maize through Integrated Approaches

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***Abstract*:** Frontline demonstrations were conducted in twenty locations in various adopted villages of Krishna district, Andhra Pradesh to evaluate the efficacy of Integrated Pest Management (IPM) practices against fall armyworm (*Spodoptera frugiperda*) in maize during *rabi*, 2022-23 and 2023-24. The pooled results of two consecutive seasons revealed that IPM treated plots comprising erection of pheromone traps, spraying of *Bt* formulations and need based spraying of recommended insecticides had resulted in 66.9 & 70.03 per cent reduction in plant damage and 57.8 & 62.8 per cent reduction in cob damage due to fall armyworm incidence in maize during 2022-23 and 2023-24, respectively. The yield gain was observed to be 17.05 and 9.3 per cent with BC ratio of 1.79: 1 and 1.96: 1 during 2022-23 and 2023-24, respectively,

Keywords: Fall armyworm, IPM, Net returns, Per cent plant damage, Pheromone traps

Maize, a vital staple food in India next to rice, plays a crucial role in ensuring food security and supporting the livestock and agro-industrial sectors serving as a raw material for feed, in making of beverages and various industrial products. The invasion of the fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), a polyphagous lepidopteran pest native to the Americas, has severely disrupted maize cultivation since its first report in India during 2018 (Sharanabasappa et al., 2018). In Andhra Pradesh, it was reported for the first time in agency areas of Visakhapatnam in July, 2018 (Ramesh et al., 2020). FAW attacks maize at all growth stages, from seedlings to cobs, causing severe yield losses, particularly in southern and northeastern states. The high fecundity (up to 1,200 eggs per female) and ability to migrate facilitated by monsoon winds contribute to rapid population buildup, with 4-6 generations per year in tropical climates (Mousafa et al., 2023). Management of fall army worm in maize with sole dependence on chemicals alone often leads to pesticide residues in the crop produce, pest resurgence, secondary pest outbreak besides environmental pollution and severe health hazards. Hence, adoption of Integrated Pest Management (IPM) strategies will ensure management of fall army worm in more economical, sustainable and eco-friendly manner (Lakshmi Narayanamma et al., 2023). Therefore, frontline demonstrations (FLDs) were conducted in different adopted villages of Krishna district for two consecutive seasons during *rabi*, 2022-23 and 2023-24 to demonstrate the practical benefits, economic advantages and adoption potential of IPM practices for sustainable management of fall armyworm in maize under farmers' field conditions.

MATERIAL AND METHODS

Study area and experimental details: Frontline demonstrations were conducted in farmers' fields of adopted villages located in Ghantasala, Mopidevi, Movva and Challapalli mandals of Krishna district, Andhra Pradesh for two consecutive years during *rabi* seasons of 2022-23 and 2023-24. The demonstrations were conducted in ten locations each year with an objective of evaluating IPM strategies for the effective management of fall armyworm in maize.

Each treatment was implemented in an area of 0.4 ha area in farmers' fields with popular maize hybrids. The crop was grown following all the recommended package of practices. Regular field scouting was carried out for monitoring of pest population through pheromone traps and recording pest incidence. The pheromone traps were installed randomly covering the entire demonstration field and need based sprayings were applied whenever the pest population exceeded the economic threshold level (ETL) i.e., 5 % leaf damage or 15% whorl infestation (Manisha et al., 2024), using recommended insecticides.

Observations and data recording: Data was recorded on per cent plant infestation by randomly selecting 20 plants from each treatment (demonstration plot) leaving the border plants all around the field. The number of healthy and fall army worm damaged plants were counted to arrive per cent plant infestation in the treated plots and in farmer's practice. Similarly, the data on per cent cob damage was estimated by sampling hundred randomly selected cobs and the no. of healthy cobs and cobs damaged by fall army worm were counted at the time of harvest. Yield data were recorded from each treatment and economic parameters including cost of cultivation, gross and net returns, benefit cost (B:C) ratio were also calculated.

Statistical analysis: Data was analysed using using SPSS statistical package tools.

RESULTS AND DISCUSSION

The adoption of IPM practices against fall armyworm in maize significantly reduced pest damage. The mean per cent plant damage in IPM plots was 14.1 and 9.5 corresponding to 66.9 and 70.03 % reduction of plant damage over farmers practice during 2022-23 and 2023-24, respectively. Similarly, per cent cob damage in IPM demonstrated plots was 18.6 and 14.7 % during 2022-23 and 2023-24, respectively, as against higher damage levels of 44.1 and 39.5 during 2022-23 and 2023-24, respectively, under farmers practice (Table 2). Sharanabasappa et al. (2020) also reported that chlorantraniliprole followed by emamectin benzoate and spinetoram were found effective in managing fall armyworm in maize. Aarthi Helen (2021) with *Bt* formulations were effective against all armyworm instars. Palanivel et al. (2024) reported that the combined use of azadirachtin, *Metarhizium anisopliae* and emamectin benzoate in IPM treated plots reduced fall armyworm infestation from 49 to 17 per cent with 67.3 per cent control efficiency.

The implementation of IPM practices against fall armyworm in maize resulted in reduction of cost of cultivation and increase in net returns with higher BC ratio (Table 3). During 2022-23, the cost of cultivation in IPM was Rs. 74,875 per ha with net returns of Rs. 96,800 per ha and a BC ratio of 2.29: 1, whereas, farmers' practice incurred a higher cost of Rs. 80,475 per ha with net returns of Rs. 64,222 per ha and a BC ratio of 1.79: 1. Similarly, during 2023-24, IPM plots recorded a cost of cultivation of Rs. 76,125 per ha with net returns of Rs. 1,02,403 per ha and a BC ratio of 2.34: 1 whereas, famers' practice had as cost of cultivation of Rs. 84,590 per ha, net returns of Rs. 78,858 per ha and a BC ratio of 1.93: 1. These results demonstrate that IPM not only effectively reduces FAW incidence but also lowers production costs and improves profitability, emphasizing the practical and economic benefits of adopting integrated management strategies under farmers' field conditions.

In the present study, the reduction in per cent infestation by fall armyworm in IPM-demonstrated plots can be attributed to the integration of pheromone traps, which effectively trapped male adult moths and facilitated monitoring of pest population dynamics, enabling timely insecticidal applications (Kumar et al., 2022, Sisay et al., 2024). The erection of pheromone traps proved beneficial not

Table 1. Treatment details along with GPS coordinates of locations

Treatment	Details	Location with GPS (2022-23)	Location with GPS (2023-24)
Integrated Pest Management (IPM)	Seed treatment with Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg seed; installation of pheromone traps (*S. frugiperda*) @ 10 traps/ha; collection and destruction of egg masses; spraying of 5% neem seed kernel extract (NSKE) or azadirachtin 10000 ppm (500 ml/ha) if adult activity and egg masses are noticed; spraying of *Bacillus thuringiensis* formulations @ 2g/l at 5-10% infestation, and need based spraying of recommended insecticides: Chlorantraniliprole 18.5 % SC @ 0.3 ml/l; Spinetoram 11.7 % SC @ 0.5 ml/l; Emamectin benzoate 5% SG @ 0.4g/l.	L1: 16.1239°N, 80.8907°E L2: 16.1211°N, 80.8710°E L3: 16.1830°N, 80.9269°E L4: 16.1766°N, 80.8578°E L5: 16.2969°N, 80.8206°E L6: 16.1073°N, 80.8904°E L7: 15.4312°N, 81.3112°E L8: 16.1912°N, 80.9226°E L9: 16.1976°N, 80.8456°E L10: 16.1373°N, 80.8938°E	L1: 16.4969°N, 80.6390°E L2: 16.1024°N, 80.8914°E L3: 16.2182°N, 80.0836°E L4: 16.2356°N, 80.0376°E L5: 16.2577°N, 81.1454°E L6: 16.1809°N, 81.1303°E L7: 16.1712°N, 80.3112°E L8: 16.1159°N, 80.9779°E L9: 16.0526°N, 80.9396°E L10: 16.1749°N, 80.9516°E
Farmers practice	Chemical based management involving multiple sprays of insecticide mixtures such as Novaluron 5.25% + Emamectin benzoate 0.9% SC, Profenophos 50%EC, Flubendiamide 480SC and Chlorantraniliprole 18.5% SC after noticing the fall armyworm incidence at 4-5 days interval.		

Table 2. Effect of integrated pest management on fall armyworm infestation and yield in maize

Year	No. of locations	Mean No. of insects trapped		Mean Per cent plant damage (%)		Per cent reduction over check	Mean Per cent cob damage (%)		Per cent reduction over check	Yield (kg/ha)		Per cent increase in yield (%)
		IPM	FP	IPM	FP		IPM	FP		IPM	FP	
2022-23	10	11.3	-	14.1	42.6	66.9	18.6	44.1	57.8	8750	7475	17.05
2023-24	10	8.4	-	9.5	31.7	70.03	14.7	39.5	62.8	8542	7815	9.3
t value	-	-	-	4.05*		-	4.24*		-	4.77*		-

* - Significant at 5 per cent level of significance (P = 0.05); IPM- Integrated Pest Management; FP- Farmers' Practice

Table 3. Economic analysis of maize under integrated pest management and farmers' practice

Year	Average cost of cultivation (Rs/ha)		Average gross returns (Rs/ha)		Average net returns (Rs/ha)		BC ratio	
	IPM	FP	IPM	FP	IPM	FP	IPM	FP
2022-23	74,875	80,475	1,71,675	1,44,698	96,800	64,222	2.29: 1	1.79:1
2023-24	76,125	84,590	1,78,528	1,63,334	1,02,403	78,858	2.34: 1	1.93: 1
Mean	75,500	82,475	1,75,101.5	1,54,016	99601.5	71540	2.32: 1	1.86: 1

IPM- Integrated Pest Management; FP- Farmers' Practice

only for monitoring but also for mating disruption, resulting in comparatively lower egg laying in IPM- demonstrated plots than under the farmers' practice. The application of neem-based formulations during periods of adult activity likely exerted a repellent effect, thereby reducing oviposition. Spraying of selective insecticides further suppressed subsequent pest populations, minimized the development of resistance and reduced residual effects. Overall, the integrated approach was more effective than the farmers' conventional practice of relying solely on insecticides.

CONCLUSION

Fall armyworm is a major destructive pest of maize causing significant economic losses due to reduction in yield by damaging leaves, tassels and cobs. Adoption of IPM practices like seed treatment, installation of pheromone traps, spraying of neem, *Bt* formulations and need based spraying of selective insecticides viz., Chlorantraniliprole, Spinetoram and Emamectin benzoate effectively reduced fall armyworm infestation. Implementation of these IPM strategies led to increased maize yield and higher net returns compared to conventional farmers' practice. The findings also indicate that farmers are adopting the suggested IPM practices to suppress the fall armyworm incidence and to enhance the yield, highlighting the practical relevance and economic benefits of integrated management under field conditions.

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