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Integrated Management of Fall Armyworm in Indian Maize Ecosystems: A Multi-Component IPM Approach

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ABSTRACT:

The fall armyworm (*Spodoptera frugiperda* J.E. Smith), an invasive pest native to the Americas, has emerged as a significant threat to global maize production, including in India. Its first occurrence in India was documented in 2018, spreading rapidly across multiple states and causing severe yield losses. The pest's high reproductive rate, adaptability, and migratory capacity have complicated management efforts. This study evaluates integrated pest management (IPM) strategies incorporating cultural, mechanical, biological, and chemical controls to manage fall armyworm infestations in India's diverse agro-climatic zones. Field trials were conducted across major maize-producing regions using recommended hybrids and composites. Management interventions included timely sowing, clean cultivation, hand-picking, pheromone trapping, application of biopesticides, release of natural parasitoids (*Trichogramma pretiosum* and *Telenomus remus*), and threshold-based chemical applications. Results demonstrated significant reductions in larval populations, cob damage, and increased grain yields by 15–20%. Farmer training through IPM Farmer Field Schools further enhanced awareness and adoption of sustainable practices. This comprehensive approach provides an effective, eco-friendly solution for mitigating the impact of fall armyworm on maize production in India.

Keywords: Fall Armyworm (*Spodoptera frugiperda*), Maize, Integrated Pest Management (IPM), Farmer Field School (FFS), Biological Control, Cultural Practices, Chemical Control, Pheromone Traps, *Trichogramma pretiosum*, *Telenomus remus*, Biopesticides, Sustainable Agriculture, India, Yield Improvement, Pest Monitoring

1. Introduction

The fall armyworm, Spodoptera frugiperda J.E. Smith, is an exotic pest whose influence has significantly affected world agriculture and maize production. Suby et al. (2020) first documented the pest's invasion in India, which had accelerated development and wide-scale crop loss. The pest's large reproductive potential, flexibility, and migratory nature have made it extremely destructive (Mallapur et al., 2018).

Control measures have targeted a variety of strategies. Host plant resistance was also found to be a potential option, with Prasanna et al. (2022) reviewing the status and future of resistant maize in Africa and Asia. Kumar et al. (2022) mentioned the support given to integrated pest management (IPM) through the integration of cultural, biological, and chemical control to reduce the application of chemicals.

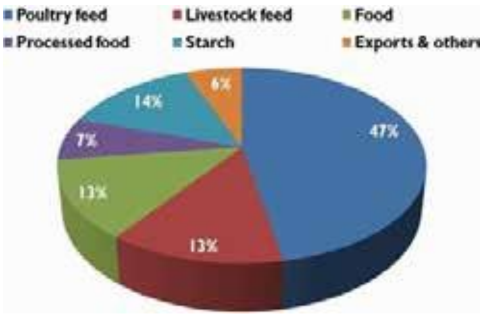

Figure 1: The usage pattern of Maize in India

Organic and bio-intensive approaches are increasingly prominent, as explained by Keerthi et al. (2023), where they elaborated on sustainable agriculture practices for the control of S. frugiperda in organic maize systems. Chemical control is still required, and Srujana et al. (2022) evaluated the efficiency of different insecticides under Indian conditions.

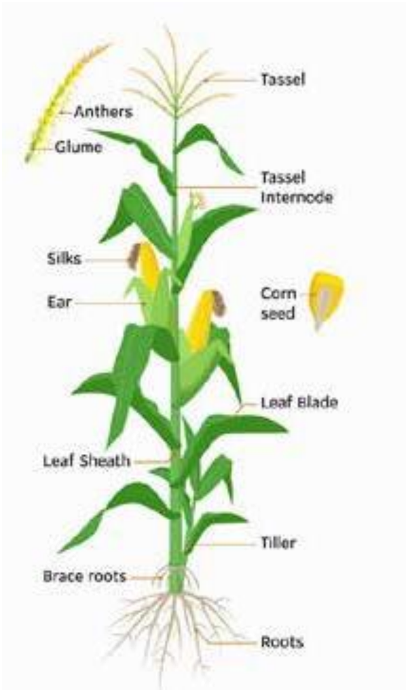

Figure 2: Maize Plant

Knowing the seasonal pattern of the pest is essential in its control. Mishra et al. (2023) have submitted an elaborate review of its seasonal incidence and intricate management practices. All such research studies collectively suggest the urgent need for locally specific, sustainable, and integrated management strategies in controlling fall armyworm infestation and ensuring food security.

2. Background Study

The global spread of fall armyworm (*Spodoptera frugiperda*) has raised significant concern for food security, especially in maize-producing regions. Early et al. (2018) predicted the global invasion potential of this pest, highlighting its rapid expansion into new territories. The pest's arrival in Southeast Asia and its genetic relation to African and Indian populations suggest a common migratory origin (Nagoshi et al., 2020). Chhetri and Acharya (2019) emphasized the severe threat it poses to South Asian agriculture, stressing the need for urgent management strategies.

The pest's impact on farmers' livelihoods is profound. Banson et al. (2020) used a systemic approach to analyze its socio-economic effects on maize farming. In Nepal, Bista et al. (2020) reported significant crop losses and highlighted integrated management approaches as critical solutions. Woolfolk et al. (2025) emphasized that maximizing host plant resistance, alongside other practices, remains a cornerstone for long-term control.

Technological innovations are also emerging to enhance management efficiency. Shinde et al. (2024) developed a computer vision-based system for early detection of infestations, improving monitoring capabilities. Similarly, Desika et al. (2024) explored metabolomic approaches to identify novel management targets, offering new biochemical insights.

Collectively, these studies underscore the complexity of fall armyworm management, requiring a multidisciplinary approach combining genetic, technological, ecological, and socio-economic perspectives to mitigate its impact effectively.

3. Materials and Methods

The study on the management of fall armyworm (*Spodoptera frugiperda*) in maize was conducted using an Integrated Pest Management (IPM) approach, as outlined in the IPM Farmer Field School (FFS) Manual developed by FAO and the Directorate of Plant Protection, Quarantine & Storage (DPPQS), Ministry of Agriculture and Farmers Welfare (MoAFW), India.

3.1 Study Area and Crop Details

The trials were conducted in major maize-growing regions of India including Karnataka, Maharashtra, Madhya Pradesh, Andhra Pradesh, Rajasthan, Uttar Pradesh, Bihar, and Gujarat, where fall armyworm infestations were prevalent. Both Kharif and Rabi maize seasons were included to capture the pest dynamics across varied agro-ecological zones. The maize varieties used included hybrids and composites recommended for these agro-climatic regions.

Table 1: Major and minor insect pests of Maize

Pest	**Scientific name**	**Family**	**Order**
Major insect pests of Maize			
Fall Armyworm	*Spodoptera frugiperda* (J. E. Smith)	Noctuidae	Lepidoptera
Spotted stem borer	*Chilo partellus* (Swinhoe)	Pyralidae	Lepidoptera
Pink stem borer	Sesamia inferens Walker	Noctuidae	Lepidoptera
Shoot fly	Atherigona soccata (Rond), A. orientalis Schiner and A. naqvii Steyskal	Muscidae	Diptera
Oriental Armyworm	*Mythimna separata* (Haworth) and *Mythimna loreyi* (Duponchel)	Noctuidae	Lepidoptera
Cut worm	Agrotis ipsilon Rott.	Noctuidae	Lepidoptera
Tobacco and Lucerne caterpillar	*Spodoptera litura* (Fabricius), *S. exigua* (Hubner)	Noctuidae	Lepidoptera
Cob worm/ Earworm	*Helicoverpa armigera* (Hubner)	Noctuidae	Lepidoptera
Aphid	*Rhopalosiphum maidis* (Fitch)	Aphididae	Hemiptera
Shoot bug	*Peregrinus maidis* (Ashmead)	Delphacidae	Hemiptera
Minor insect pests of Maize			
Maize leafhopper	*Cicadulina bipunctata* (Matsumura)	Cicadellidae	Hemiptera
Sugarcane Leafhopper	*Pyrilla perpusilla* (Walker)	Lophopidae	Hemiptera
Flower eating beetles	*Chiloloba acuta* (Weidemann); *Oxycetonia versi- color* (Fabricius)	Scarabaei- dae	Coleoptera
Termites	*Odontotermes obesus* (Rambur)	Termitidae	Isoptera
Grasshopper	*Hieroglyphus nigrorepletus* Bol.	Acrididae	Orthoptera

3.2 Field Preparation and Cultivation Practices

Fields were prepared using standard land preparation practices involving deep ploughing, FYM application (5 tons/ha), and recommended fertilizer doses based on the season and region. Maize was sown at recommended spacings (60-75 cm row spacing and 20-25 cm plant spacing), maintaining a population of 60,000 to 75,000 plants per hectare.

Figure 3: Spotted stem borer–nature of damage

3.3 Pest Monitoring and Sampling

Regular scouting for fall armyworm symptoms was done at weekly intervals. Pheromone traps (15 per acre) were installed for monitoring adult moth populations. Visual inspections were performed to detect larval infestation, leaf whorl damage, egg masses, and cob injury. Infestation levels were recorded at each critical maize growth stage (vegetative, tasseling, silking, cob formation).

Table 2: Major Diseases and Casual Agents

Sl. No.	**Disease**	**Causal agents**
1	Turcicum Leaf Blight	*Exserohilum turcicum* (Pass) Leon. & Suggs
2	Maydis Leaf Blight	*Cochliobolus heterostrophus* Nikado & Miyake
3	Polysora Rust	*Puccinia polysora* Underw
4	Brown Spot	*Physoderma maydis* Shaw Teleomorph: *Cladochytrium maydis* Miyabe
5	Banded Leaf and Sheath Blight	*Thanatephorus sasakii* (Shirai)
6	Common Rust	*Puccinia sorghi* Schw
7	Brown Stripe Downy Mildew	*Sclerophthora rayssiae* var. zeae
8	Rajasthan Downy Mildew	*Peronosclerospora heteropogoni*
9	Sorghum Downy Mildew	*Peronosclerospora sorghi*
10	Bacterial Stalk Rot	*Dickeya zeae* Samson
11	Fusarium Stalk Rot	*Fusarium verticillioides* Sacchardo
12	Charcoal Rot	*Macrophomina phaseolina*

3.4 Management Interventions

A combination of cultural, mechanical, biological, and chemical control measures were adopted:

Cultural Practices: Timely sowing, clean cultivation, and weed removal to disrupt the pest lifecycle.

Mechanical Control: Hand-picking of egg masses and larvae, application of sand-lime mixture (9:1 ratio) into whorls.

Biological Control: Release of *Trichogramma pretiosum* and *Telenomus remus* parasitoids at 50,000 per acre weekly; application of biopesticides like *Bacillus thuringiensis* and *Metarhizium anisopliae* at the recommended doses.

Chemical Control: Targeted use of chemical insecticides at economic threshold levels following IPM guidelines to minimize resistance and ecological disruption.

Figure 4: Pest Management

3.5 Data Collection and Analysis

Data on larval population density, percentage of damaged plants, cob damage, and final grain yield were recorded and statistically analyzed to assess the effectiveness of the IPM interventions.

4. Results and Discussion

The implementation of the IPM package resulted in significant suppression of fall armyworm infestation in maize fields across different agro-climatic regions. The mechanical methods, especially hand-picking combined with sand-lime applications, were effective during early infestation stages. Pheromone traps successfully monitored adult populations and guided timely interventions.

Figure 5: Early detection of FAW is must for further

Biological control agents, particularly releases of *Trichogramma pretiosum* and *Telenomus remus,* contributed to a substantial reduction in egg hatching and early larval survival. Application of biopesticides further suppressed larval populations without causing harm to natural enemies.

Chemical insecticides were applied judiciously based on threshold levels and effectively controlled heavy infestations at later stages, especially during the tasseling and cob formation stages, reducing cob damage considerably.

Overall, fields implementing the integrated management strategy recorded:

- Reduced average larval population to below economic threshold levels.
- 50–60% reduction in cob and whorl damage compared to untreated controls.
- An increase in grain yield by 15–20% due to minimized pest damage.
- Enhanced farmer knowledge and capacity in pest identification and management through IPM Farmer Field Schools.

Figure 6: Farmer Field Schools (FFS)

The integrated approach demonstrated a sustainable, eco-friendly, and economically viable solution for managing fall armyworm in maize.

5. Conclusion

The invasion of fall armyworm (*Spodoptera frugiperda*) has posed a significant threat to maize production, demanding urgent, multi-dimensional management strategies. The integrated pest management (IPM) approach demonstrated considerable success in minimizing crop losses across diverse agro-climatic regions in India. Timely cultural practices, including clean cultivation and synchronized sowing, disrupted pest life cycles effectively. Mechanical interventions such as hand-picking and sand-lime applications reduced early-stage infestations. The use of biological control agents like *Trichogramma pretiosum* and *Telenomus remus* significantly suppressed egg hatching and larval survival. Biopesticides further contributed to sustainable control without harming beneficial organisms. Judicious application of chemical insecticides at threshold levels prevented severe damage during peak infestation stages. Overall, the IPM interventions led to a 50–60% reduction in cob and whorl damage and a 15–20% increase in grain yield. Additionally, Farmer Field Schools empowered farmers with knowledge for early detection and timely action. The study emphasizes that a comprehensive IPM framework, supported by farmer participation and continuous monitoring, offers an eco-friendly, economically viable, and scalable solution to manage fall armyworm in maize sustainably.

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