



Fall Armyworm (*Spodoptera frugiperda*) in Maize: Biology, Damage, Detection, and Management Strategies

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Maize (*Zea mays* L.) is one of the world's most important cereal crops, cultivated extensively across tropical, subtropical, and temperate regions. It belongs to the family Poaceae and is widely recognized as the "Queen of Cereals" due to its high productivity and versatile uses. Globally, maize occupies an area of nearly 197 million hectares, producing over 1.1 billion tonnes annually (FAO, 2022). The crop has immense importance for food security, nutritional value, and industrial applications. In India, maize is the third most important cereal crop after rice and wheat. It contributes substantially to agricultural growth and rural livelihoods. The adaptability of maize to different agro-ecological zones, ranging from humid to dry regions, has made it a highly dependable crop. Its role as a multipurpose commodity further increases its demand. Unlike rice and wheat, maize is not just a food grain but also an essential raw material for feed and industries, making it one of the fastest-growing crops in the Indian farming sector.

Area, Production, and Productivity of Maize in India

India ranks as the second-largest producer of maize in Asia. As of 2019, maize was cultivated on about 9.03 million hectares, producing nearly 27.7 million metric tonnes with an average productivity of around 3.1 tonnes per hectare (DAC&FW, 2021). Over the last two decades, maize production in India has shown a steady upward trend, rising from ~11 million tonnes in 2002 to more than 27 million tonnes in 2019. The major maize-growing states are Karnataka, Andhra Pradesh, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, and Bihar. Productivity levels vary across regions due to differences in rainfall, soil fertility, irrigation access, and cropping systems. While states like Andhra Pradesh and Karnataka achieve productivity levels above 4 t/ha, rainfed regions like Rajasthan and Madhya Pradesh often fall below the national average. The increasing demand for poultry feed, starch-based industries, and ethanol production has further boosted maize cultivation. Projections suggest that maize demand in India will continue to grow at over 4% annually, making it one of the most dynamic crops in the future agricultural scenario.

Uses of Maize: Food, Feed, and Fodder

One of the distinctive features of maize compared to other cereals is its multi-purpose utilization.

As Food: Maize is consumed in multiple forms—boiled corn, popcorn, flour for making chapati/roti, porridge, bakery products, and traditional dishes. In hilly and tribal regions of India, maize serves as a staple food crop, forming a major part of the diet.

As Feed: The poultry industry consumes nearly 53% of India's total maize production, highlighting its importance as a feed grain. The high energy content of maize makes it a preferred ingredient in livestock and poultry rations.

As Fodder: Both green maize and crop residues (stover) are valuable livestock fodder. Silage prepared from maize is considered highly nutritious for dairy cattle, improving milk yield and quality.

Industrial Uses: Maize is also used for starch extraction, biofuel (ethanol), sweeteners like high-fructose corn syrup, and brewing industries. Nearly 6–7% of maize production goes into industrial sectors, which is rapidly expanding.

This versatility underscores maize's position not just as a food crop, but as an industrial and commercial commodity of global relevance.

Introduction to Fall Armyworm (FAW)

The Fall Armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), is a highly destructive migratory pest belonging to the family Noctuidae. Native to the Americas, FAW gained global attention after its invasion of Africa in 2016. From there, it spread rapidly across Asia, with the first confirmed report in India during May 2018 in Karnataka (Sharanabasappa et al., 2018). Within a year, FAW had spread to more than ten states, posing a severe threat to maize production. The name “armyworm” refers to its behavior of moving in large groups like an army, devouring crops in its path. Its invasive success is attributed to its polyphagous feeding habit (feeding on more than 80 plant species), high fecundity, and ability to migrate long distances. Among its numerous hosts, maize is the most preferred, making it particularly devastating in maize-based farming systems.

Biology of FAW

Understanding the biology of FAW is crucial for devising management strategies. FAW undergoes a complete metamorphosis:

Egg Stage: Eggs are laid in masses of 100–200 on the underside of leaves, covered with scales. A female moth may lay up to 1,500 eggs in her lifetime.

Larval Stage: The larval stage is the most destructive. FAW larvae pass through six instars, feeding voraciously on maize leaves, tassels, and cobs. They can be recognized by an inverted “Y”-shaped marking on the head and four dark spots forming a square on the 8th abdominal segment.

Pupal Stage: Pupation occurs in the soil, where larvae burrow to form pupae that remain for 7–13 days.

Adult Stage: Moths are nocturnal and capable of flying long distances. They migrate seasonally, often traveling more than 100 km in a single night, contributing to their rapid spread.

The lifecycle is influenced by temperature, with development completed in 30 days during summer and up to 90 days in cooler months (CABI, 2020). This adaptability allows FAW to thrive across diverse environments.

Host Range of FAW

FAW is highly polyphagous, with a host range exceeding 80 plant species. Major hosts include maize, sorghum, rice, sugarcane, cotton, soybean, and several vegetable crops. In India, maize is the most severely affected host, but infestations have also been observed on sugarcane, sorghum, and paddy. Its ability to survive on multiple hosts throughout the year makes eradication nearly impossible and complicates management efforts.

Damaging Nature and Economic Losses

FAW is notorious for its damaging nature. Young larvae scrape leaves, while older larvae bore into whorls, tassels, and cobs. Severe infestations can leave maize plants with “ragged” leaves and damaged reproductive structures, leading to substantial yield reductions.

Economic losses caused by FAW are alarming:

In sub-Saharan Africa, FAW was estimated to cause annual maize yield losses of 8.3–20.6 million tonnes, valued between USD 2.5–6.2 billion (Day et al., 2017). In India, within nine months of its detection, FAW infestation reduced maize yields by 15–30% across major states (Kalleshwaraswamy et al., 2018). Severe infestations under field experiments have

shown up to 40% yield loss (Kumar et al., 2020). This pest not only reduces yields but also increases the cost of cultivation through higher pesticide usage, thereby reducing farmer profitability.

Early Detection of FAW Using Artificial Intelligence

One of the major challenges in FAW management is early detection. Traditional scouting methods are time-consuming and prone to error. Recent technological advances using Artificial Intelligence (AI) have shown promise.

Mobile-based AI Models: Tamil Nadu Agricultural University developed an AI-powered Expert System (AIPES) using deep learning (CNN architecture). Trained with over 11,000 images of maize leaves, tassels, and cobs, the system achieved 87% accuracy in detecting FAW infestations.

Drone and UAV Monitoring: UAVs equipped with RGB and thermal cameras can detect FAW-infested plants at the canopy level, enabling large-scale surveillance.

Satellite Remote Sensing: Sentinel-2 imagery has been used with NDVI anomaly analysis to detect FAW infestations at regional scales (accuracy $R^2 = 0.81$).

Hyperspectral Imaging: AI combined with hyperspectral sensors can detect pest-induced stress even before visual symptoms appear.

Such advancements in digital agriculture can revolutionize pest monitoring and enable real-time, site-specific interventions, reducing economic losses.

Management Strategies for FAW

FAW management requires an Integrated Pest Management (IPM) approach due to its rapid adaptability and resistance development.

Cultural Practices

- Early sowing of maize to avoid peak FAW populations.
- Intercropping (e.g., maize with legumes) and push-pull systems.
- Crop rotation and destruction of alternate hosts.
- Deep ploughing to expose pupae.

Mechanical & Physical Methods

- Handpicking of larvae and egg masses.
- Application of sand, ash, or lime into maize whorls to kill larvae.
- Use of pheromone traps for monitoring and mass trapping.

Biological Control

- Egg parasitoids like *Trichogramma chilonis* and *Telenomus remus*.
- Predators including earwigs, lacewings, and ladybird beetles.
- Biopesticides such as *Metarhizium anisopliae*, *Beauveria bassiana*, and Nuclear Polyhedrosis Virus (NPV).

Chemical Control

- Selective insecticides: Chlorantraniliprole, Spinosad, Emamectin benzoate.
- In India, spraying recommendations are limited to safe and registered molecules.
- Indiscriminate pesticide use should be avoided to prevent resistance.

Resistant Varieties

- Deployment of Bt maize hybrids in countries like USA, Brazil, and South Africa has shown success. In India, breeding programs are exploring both conventional and molecular approaches for resistance.

Integrated Pest Management (IPM)

- Combining cultural, mechanical, biological, and chemical methods ensures sustainable FAW control. Farmer training and awareness programs are crucial for effective implementation.

Conclusion

Maize is a cornerstone crop for food, feed, and industrial uses in India. However, the invasion of FAW has emerged as a serious threat to its productivity and farmer livelihoods. The pest's high reproductive potential, polyphagy, and migratory behavior make it difficult to manage using a single approach. Therefore, integrated strategies involving early detection (AI tools), cultural practices, biological control, safe chemical use, and resistant varieties are essential for long-term sustainable management. Future research should focus on enhancing digital agriculture, biological solutions, and breeding resistant maize varieties to safeguard this vital crop.

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