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Silent Invaders: Invasive Insect Species Threatening Indian Agriculture and Ecosystems

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Invasive insect species are increasingly emerging as major threats to Indian agriculture, biodiversity, and ecosystem stability. Rapid globalization, international trade, climate change, and increased movement of agricultural commodities have accelerated the introduction and spread of alien insect pests across different agroecological regions of India. Many of these invasive species establish successfully due to their high reproductive potential, broad host range, strong dispersal ability, and absence of natural enemies in newly invaded habitats. During the last two decades, India has witnessed severe outbreaks of several invasive pests including fall armyworm (*Spodoptera frugiperda*), tomato leaf miner (*Tuta absoluta*), papaya mealybug (*Paracoccus marginatus*), rugose spiralling whitefly (*Aleurodicus rugioperculatus*), and cassava mealybug (*Phenacoccus manihoti*). These pests have caused substantial crop losses, ecological imbalance, increased pesticide dependence, and economic hardship for farming communities. Beyond agriculture, invasive insects also threaten native biodiversity, alter ecosystem processes, and disrupt ecological interactions. This article highlights the major invasive insect pests reported in India, their pathways of introduction, biological characteristics, ecological and economic impacts, and sustainable management approaches including quarantine regulations, biological control, ecological monitoring, and integrated pest management strategies. Strengthening biosecurity systems, early detection mechanisms, farmer awareness, and climate resilient pest surveillance will be essential for minimizing future invasive pest outbreaks and protecting Indian agroecosystems.

Keywords: Invasive insect pests; invasive alien species; biosecurity; integrated pest management; fall armyworm; tomato leaf miner; biological control; Indian agriculture

Introduction

India has historically been a centre of agricultural trade and biodiversity exchange. From ancient spice routes to modern global commerce, the country has remained deeply connected with international markets. While globalization has improved food security and agricultural development, it has also increased the risk of introducing invasive alien species into Indian ecosystems (Prajapati et al., 2024).

Invasive insect species are non-native organisms that establish outside their natural geographical range and cause ecological, economic, or agricultural damage. These pests often adapt quickly to new environments because they possess traits such as high reproductive capacity, broad host range, strong dispersal ability, rapid life cycle, and tolerance to diverse climatic conditions (Singh et al., 2024). The increasing movement of planting materials, agricultural commodities, and passengers through international trade has accelerated the accidental introduction of invasive pests into India (Kamboj et al., 2022). Climate change has further intensified the problem by creating favourable environments for the establishment and spread of tropical insect pests into newer regions.

Today, invasive insects are not only threatening crop productivity but are also disrupting native ecosystems, altering food webs, and reducing biodiversity. The recent outbreaks of *Spodoptera frugiperda* (fall armyworm), *Tuta absoluta* (tomato leaf miner), *Paracoccus marginatus* (papaya mealybug), and *Phenacoccus manihoti* (cassava mealybug) demonstrate how rapidly invasive pests can spread and become major agricultural threats in India (Sharanabasappa et al., 2018; Ballal et al., 2016).

How Do Invasive Insects Enter India?

The introduction of invasive species generally occurs through human-assisted pathways such as international trade, transportation, import of seeds and planting materials, ornamental plant movement, and accidental contamination during cargo transport (Kaur et al., 2025). The invasion process usually follows four important stages (Prajapati et al., 2024):

1. Introduction
2. Establishment
3. Naturalization
4. Spread

Some insects also disperse naturally through wind currents, migratory movement, or water transport. Once established, invasive species spread rapidly due to the absence of efficient natural enemies in the invaded ecosystem (Torchin et al., 2003).

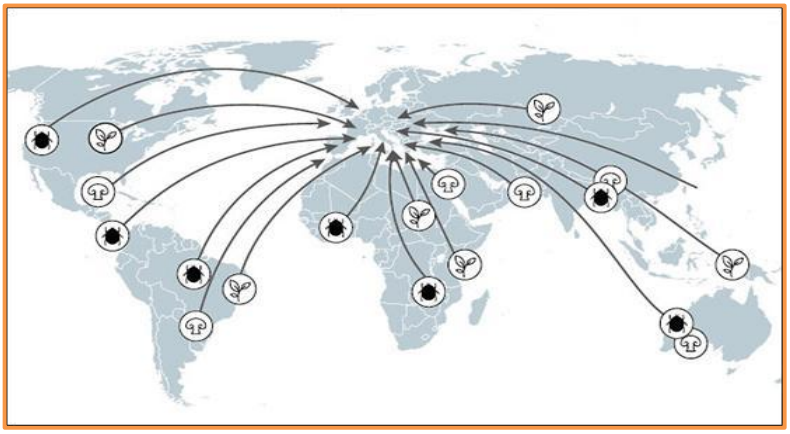

Figure 1. Major pathways involved in the introduction and spread of invasive insect species across agricultural ecosystems.

Characteristics That Make Invasive Insects Successful

Several biological and ecological traits contribute to the success of invasive insect pests (Kamboj et al., 2022; Singh et al., 2024).

Table 1. Important Characteristics of Invasive Insect Species

Characteristic	Significance
High reproductive capacity	Rapid population build-up
Broad host range	Ability to attack multiple crops
Strong dispersal ability	Rapid geographical spread
Short life cycle	Multiple generations annually
Absence of natural enemies	Uncontrolled population growth
Environmental adaptability	Survival under diverse climates

(Kamboj et al., 2022)

Because of these traits, invasive pests can quickly dominate agricultural landscapes and outcompete native species.

Major Invasive Insect Pests in India

Fall Armyworm: A Rapidly Expanding Threat

The fall armyworm, *Spodoptera frugiperda*, native to the Americas, was first reported in India during 2018 from maize fields in Karnataka (Sharanabasappa et al., 2018). Since then, it has spread rapidly across almost all maize-growing states of India. The pest attacks maize, sorghum, sugarcane, millets, rice, and several vegetable crops. The larvae feed aggressively on leaves and whorls, causing severe yield losses. Due to its strong migratory capacity and high reproductive potential, FAW has become one of the most destructive invasive pests in Indian agriculture. Studies have shown that invasive FAW populations can displace native *Spodoptera* species through interspecific competition (Song et al., 2021).

Tomato Leaf Miner (*Tuta absoluta*)

The South American tomato moth, *Tuta absoluta*, was first detected in Maharashtra during 2014 and later spread rapidly across major tomato-growing regions of India (Shashank et al., 2015). Larvae mine leaves, stems, and fruits, severely reducing marketable tomato yield. Fruit damage levels have been reported up to 100% in some regions of Karnataka (Ballal et al., 2016). This pest reproduces rapidly and survives throughout the crop season, making management extremely difficult under favourable climatic conditions.

Papaya Mealybug

Paracoccus marginatus emerged as a serious invasive pest in India after its first detection in Tamil Nadu during 2007 (Sakthivel, 2013). The pest attacks papaya, mulberry, cassava, cotton, guava, and several ornamental plants. Both nymphs and adults suck sap from plants and produce honeydew that promotes black sooty mould development, reducing photosynthetic efficiency. The outbreak severely affected mulberry cultivation and the sericulture sector in southern India.

Cassava Mealybug

The cassava mealybug, *Phenacoccus manihoti*, is another major invasive pest threatening cassava cultivation in India. Yield losses up to 80% have been reported under severe infestations (Mani, 2017). Fortunately, classical biological control using *Apoanagyrus lopezi* achieved remarkable success by suppressing pest populations and improving cassava productivity.

Table 2. Major Invasive Insect Pests Reported in India

Common Name	Scientific Name	Host Crop	First Report in India
Fall armyworm	*Spodoptera frugiperda*	Maize, sorghum	Karnataka, 2018
Tomato leaf miner	*Tuta absoluta*	Tomato	Maharashtra, 2014
Papaya mealybug	*Paracoccus marginatus*	Papaya, cotton	Tamil Nadu, 2007
Rugose spiralling whitefly	*Aleurodicus rugioperculatus*	Coconut, banana	Tamil Nadu, 2016
Cassava mealybug	*Phenacoccus manihoti*	Cassava	Kerala, 2020
Cotton mealybug	*Phenacoccus solenopsis*	Cotton	Punjab, 2006

(Kamboj et al., 2022; Kaur et al., 2025 and Singh et al., 2024)

Ecological Impacts of Invasive Insects

Invasive insects not only damage crops but also alter ecosystem functioning and biodiversity dynamics. Many invasive species become successful because they escape their natural predators and parasitoids in the invaded region (Torchin et al., 2003). This ecological release allows their populations to grow rapidly.

Invasive insects can also affect native species through:

- Competition for food and habitat
- Predation
- Alteration of food webs
- Disruption of ecological interactions

For example, invasive ladybird beetles such as *Harmonia axyridis* prey upon native coccinellid species and disturb ecological balance (Snyder et al., 2004). Similarly, the gypsy moth *Lymantria dispar* has caused extensive defoliation in oak forests, leading to long-term ecological shifts (Allen & Bowersox, 1989).

Climate Change and Invasive Pest Outbreaks

Climate change is emerging as a major driver of invasive pest outbreaks. Rising temperatures can increase insect survival, reproduction, and migration rates. According to recent studies, a temperature increase of 2°C may allow insects to complete one to five additional generations annually (Kaur et al., 2025). Warmer climates also facilitate the expansion of tropical pests

into temperate regions. Altered rainfall patterns, drought stress, and elevated carbon dioxide levels may further influence pest-host interactions and outbreak dynamics.

Biological Control: A Sustainable Solution

Biological control has emerged as one of the most successful approaches for managing invasive insect pests in India. Several exotic parasitoids and predators have been introduced successfully against invasive pests:

Table 3. Biological Control Agents Used Against Invasive Pests

Invasive Pest	Biological Control Agent
Papaya mealybug	*Acerophagus papayae*
Cassava mealybug	*Apoanagyrus lopezi*
Fall armyworm	*Bracon brevicornis*
Tomato leaf miner	*Trichogramma pretiosum*
Cottony cushion scale	*Rodolia cardinalis*

(Ballal et al., 2016; Ghosh et al., 2022).

The successful suppression of papaya mealybug and cassava mealybug through classical biological control represents a major achievement in Indian entomology.

Role of Quarantine and Biosecurity

India has strengthened its plant quarantine system to reduce the introduction of invasive pests (Kaur et al., 2025). Major agencies involved include:

- Directorate of Plant Protection, Quarantine and Storage
- ICAR institutes
- State Agricultural Universities
- National Bureau of Plant Genetic Resources (NBPGR)

Common preventive measures include:

- Inspection of imported materials
- Fumigation
- Pest risk analysis
- Molecular diagnostics
- Port surveillance
- Quarantine regulations

However, increasing international trade and porous borders continue to pose major challenges.

Emerging Technologies for Invasive Pest Management

Modern technologies are increasingly supporting invasive pest surveillance and management (Prajapati et al., 2024; Fricke & Olden, 2023). Some important innovations include:

- Ecological niche modelling
- Remote sensing
- Artificial intelligence-based pest detection
- Acoustic sensors
- Mobile-based pest reporting systems
- CRISPR/Cas9-based pest suppression technologies

Citizen science platforms such as iNaturalist and EDDMaps are also helping in early pest detection and monitoring.

Future Strategies for Sustainable Management

Managing invasive insect species in the future will require a coordinated and science-based approach that combines biosecurity, ecological monitoring, farmer participation, and sustainable pest management practices. With increasing globalization and climate change, the frequency of invasive pest introductions is expected to rise further, making early detection and rapid response systems extremely important for India. Strengthening quarantine

regulations at airports, seaports, and land borders will be essential to minimize the accidental entry of invasive pests through imported planting materials, agricultural commodities, and international trade pathways (Kamboj et al., 2022). Modern technologies such as remote sensing, artificial intelligence-based pest surveillance, ecological niche modelling, and mobile-based pest reporting systems can greatly improve monitoring and forecasting of invasive pest outbreaks. The integration of digital tools with field surveillance networks may help researchers and policymakers identify potential invasions before they become severe outbreaks. At the same time, promoting biological control and Integrated Pest Management (IPM) strategies will be important for reducing excessive pesticide dependence and preserving ecological balance. In the coming years, sustainable ecosystem-based management approaches, supported by scientific research and strong biosecurity systems, will play a vital role in protecting Indian agriculture and biodiversity from the growing threat of invasive insect species.

Conclusion

Invasive insect species are rapidly emerging as one of the greatest threats to Indian agriculture, biodiversity, and ecological sustainability. Their ability to spread quickly, adapt to diverse environments, and escape natural enemies makes them highly destructive under Indian conditions. The recent invasions of fall armyworm, tomato leaf miner, papaya mealybug, rugose spiralling whitefly, and cassava mealybug clearly demonstrate the vulnerability of Indian agroecosystems to biological invasions. Although biological control, quarantine regulations, and modern technologies offer promising management options, long-term success will depend on early detection, strong surveillance systems, farmer awareness, and sustainable ecosystem-based management strategies. Protecting Indian agriculture from invasive pests is not only essential for crop productivity and farmer livelihoods but also for preserving ecological balance and national food security.

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