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Fall Armyworm: An Invasive Pest of Maize

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The fall armyworm, *Spodoptera frugiperda* (J. E. Smith,1797) (Lepidoptera: Noctuidae) is a destructive invasive pest affecting maize globally and pose a serious threat to agriculture. Native to the America, it has spread rapidly, reaching Africa and Asia since 2016. The pest damages maize at various growth stages, leading to significant yield loss. Effective management is crucial to protect maize crops and mitigate economic losses caused by this invasive species. Control methods include physical traps, cultural practices like early planting and intercropping, biological controls using natural predators, chemical treatments, botanical insecticides derived from plants like neem and turmeric show good results in the management. Advances in agriculture, the ease of international trade and transportation, and human activities despite rigorous quarantine regulations may be to blame for the invasion of this pest.

Distribution

The fall armyworm, a pest native to tropical areas in North and South America, has been causing problems in the United States since at least 1797. A major outbreak occurred in 1912, affecting millets and corn. In early 2016, it was first reported in Africa, where it quickly spread to forty-four countries across Sub-Saharan Africa. By 2017, the pest had moved into South Asia, with reports of its presence in India by May 2018. Since then, it has spread to neighboring countries like Bangladesh and Burma by December 2018, as well as to Sri Lanka, China, and Nepal in January 2019. It also reached Thailand in December 2018, and later South Korea and Japan in July 2019. In 2019, there were reports of damage to maize in Vietnam, Malaysia and Indonesia.

Taxonomy of the insect

Fall armyworms come in two different strains, such as the rice strain and the corn strain. While the corn strain consumes maize, cotton and sorghum, the rice strain eats rice and other grazing grasses. Detailed classification of fall armyworm is shown in Table 1.

Domain	Eukaryota
Kingdom	Animalia
Phylum	Arthropoda
Sub phylum	Uniramia
Class	Insecta
Order	Lepidoptera
Family	Noctuidae
genus	*Spodoptera*
Species	*frugiperda*

Identification

The forewing of adult male moth is light brown and grey with a triangular white patch at the apical border and an oval-shaped light brown mark in the middle. Females have less pronounced markings on their forewings, which range from a uniform greyish brown to a subtle mottling of brown and grey without a triangular white patch at the apical border. Both sexes have straw-colored hindwings with a thin, dark border. The mature larva's dark body has white lateral and subdorsal lines. Larva has reddish brown head with a large inverted white "Y" mark and four bigger dark spots on the second-to-last segment which are organized in a square pattern.

Spread

The fall armyworm is a gregarious and can move both locally and over long distances. It does the most damage to maize plants during the fourth to sixth stages of its larval development, when it feeds heavily on the whorl, stem, and cob. Like other moths in the *Spodoptera* family, they can fly more than 500 kilometers before laying eggs. If conditions are right, they can even cover up to 1600 kilometers when the wind helps them. In many parts of the world, fall armyworms appear only during certain seasons. However, if they find alternative food sources and the weather is suitable, they can reproduce throughout the year and spread to nearby areas. They are particularly common in the fall, especially after dry periods. The damaging stage of the moth is its larvae, which usually come out to feed at night. These larvae can eat more than 350 types of plants, including many important crops. Some of the plants they damage include maize, sorghum, rice, sugarcane, cabbage, beetroot, groundnuts, soybeans, onions, cotton, pasture grasses, millets, tomatoes, and potatoes. Maize is their favorite target among these crops.

Economic Damage

The fall armyworm prefers maize and can also damage other grains like millets, affecting their economic value. The pest attacks maize from the seedling stage all the way to when the ears develop. A female fall armyworm can lay over a thousand eggs in clusters. When the eggs hatch, the tiny larvae release silky threads that the wind carries away. The first and second instar larvae scrape the upper surface of the leaves. As they reach the third instar stage, they start gathering in the plant's whorl, causing more noticeable damage with holes and leaving behind droppings. As the larvae grow, they eat more and produce larger droppings. By the sixth instar stage, they severely defoliate the whole plant and leave a lot of waste in the whorl. Sometimes, older larvae even bore into the developing sections and kills young maize plants.

Favorable conditions of pest

Climate factors affect fall armyworm populations and geographic spread. Studies show that environmental conditions significantly influence their growth, survival, and the number of generations they produce. They thrive in humid, cool areas, especially after heavy rainfall, which often leads to outbreaks. Warmer temperatures speed up their development, potentially increasing the number of generations each year. However, their development stops when temperatures drop below 10°C. In tropical and subtropical regions, fall armyworms can produce over 10 generations each year, while in temperate areas, they typically have only two generations. The life cycle of the fall armyworm usually lasts about 30 days at a daily temperature of 28°C, but it can stretch to 60-90 days during spring and winter. Their development occurs within a temperature range of 13.01°C to 30°C. The number of generations in a specific area depends on when the adult moths appear and the local weather conditions.

Life cycle

Egg: The female lays creamy white, dome shapped eggs on the upper or lower surfaces of the leaves. In some cases, particularly when the crop is young, she may also lay eggs on the stem portion. Two to four layers of 150–200 eggs are placed in large clusters. Egg masses have greyish scales covering them, giving them a rotten appearance. The existence of egg masses is crucial for process monitoring. One female can produce between 1000 and 1500 eggs. After two to three days of egg laying, an egg begins to hatch.

Larvae: Fall armyworm has six instars. Larvae in the first instar have a greenish colour and a black head. The dorsal side of the larva's body turns brownish as it ages, and white lateral lines start to appear. The body of an adult or late-stage larva is brownish in colour and has white lateral and subdorsal lines. Reddish brown head with a large white "Y" mark reversed. The second-to-last segment has four bigger dark spots organized in a square pattern, which is the most crucial feature for identification. The larval stage lasts between 14 and 16 days

Pupa: Pupa have a reddish brown colour. Pupation often occurs at a depth of 2 to 10 cm in the soil. The larva builds an oval-shaped cocoon. Larvae may weave together leaf fragments and other materials to create a cocoon on the soil surface if the soil is too hard. Pupal stage duration ranges from 8 to 9 days in the summer to 20 to 30 days in the winter.

Adult: The adult's wingspan ranges from 35 to 40 mm. The adult male moth's forewing is light brown and grey with a triangular white patch at the apical border and an oval-shaped light brown mark in the middle. Females have less pronounced markings on their forewings, which range from a uniform greyish brown to a subtle mottling of brown and grey without a triangular white patch at the apical border. Both sexes have straw-colored hindwings with a thin, dark border. The usual adult stage lasts for around 10 days, although it can last anywhere between 7 and 21 days.

Nature of damage

Larvae in their first instar feed briefly on the leaf tissue on one side while leaving the opposing epidermal layer unharmed. Larvae in their second and third instars start to chew holes in leaves and eat the leaf interiors. Larvae transfer from the foliage to the whorl at a later time as the plant goes through several stages of vegetative growth and begin to feed there. The leaves that emerge from the broken whorl have ragged holes on their surfaces in various patterns. When compared to the early and midstage whorl stages, the late whorl stage is the most vulnerable to larval attack. Larvae exhibit cannibalistic behaviour, which causes later stages to see just 1 or 2 larvae per plant. By consuming the leaves voraciously and only leaving the stalks and rib of the maize plant, later or old instar larvae severely defoliate the plant.

Management

Physical and Mechanical methods: Various traps, such as pheromone traps and blacklight traps, are used to catch moths. These sorts of traps are typically utilised during the whorl stage to identify the presence of moths. When moths are found, it's best to look through egg masses and larvae. If an egg mass or larvae are identified, collect and destroy it. The prevalence of fall armyworm can be reduced by installing pheromone traps @ 5/acre at the possible spreading area both during crop season and off-season.

Cultural Techniques: Early planting can significantly reduce the crop's vulnerability to assault by the fall army worm. Early crop planting to reduce pest densities, intercropping maize with non-host plants like sunflower, soybean, black gram and cowpea, crop rotation, variety selection, good soil tilth, routine field inspections and burning crop residues can all destroy eggs, larvae, pupa and adults that have been left in the field. According to a study, cultural methods account for 56% of pest management.

Biological control: Predators such as different ground beetles (Coleoptera: Carabidae), the striped earwig, *Labidura riparia* (Pallas) (Dermaptera: Labiduridae), the spined soldier bug, *Podisus maculiventris* (Say) (Hemiptera: Pentatomidae), and the insidious flower bug, Orius insidiosus (Say) (Hemiptera: Anthocoridae) were found to be effective against fall armyworm of maize as a means of biocontrol. Solitary parasitoids of the Hymenoptera genera Chelonus and Campoletis were recovered from *S. frugiperda* larvae.

Chemical control: Use of poison bait in whorls at the vegetative stage and disseminating in the mature crop have both showed promising results in suppressing infestations of fall armyworms. The procedure for making poison bait, which involved combining 5.0 kg of jaggery with 4-5 L of water. 625.0 mL of monocrotophos 36 SL were added to this solution. This mixture was then combined with 50 kg of rice or wheat bran, sealed in plastic or gunny bags, and left to ferment for 48 hours. Administration of this fermented bait, preferably in the evening, by broadcasting or insertion into maize whorls, greatly decreased the prevalence of fall armyworm in maize.

For the control of the fall armyworm, a variety of compounds have been suggested, including methyl parathion, methomyl, pyrethroids, cyfluthrin, and organophosphate pesticides. Emamectin benzoate 5 SG application had the highest acute toxicity, followed by spinetoram 11.7 SC and chlorantraniliprole 18.5 SC.

Botanical method: Fall armyworm is controlled globally using a variety of botanical approaches and locally accessible materials, including soil, sand, wood ash, lime, oils and soaps. Plant oils derived from *Corymbia citriodora*, *Eucalyptus urograndis*, and *Eucalyptus urograndis* demonstrated beneficial effects for guarding against larvae on maize plants. The first and second instars are significantly controlled by plant oils derived from turmeric, clove, palmarosa, and neem. *Cymbopogon citratus* and *Azadirachta indica* were discovered to be the most likely feeding deterrents. Several botanical extracts from plants like *Azadirachta indica*, *Millettia ferruginea*, *Croton macrostachyus*, *Phytolacca docendra*, *Jatropha curcas*, *Nicotiana tabacum*, and *Chrysanthem*um *cinerariifolium* have been used to successfully control the fall armyworm. *Azadirachta indica* seed cake extract and *Argemone ochroleuca* ethanolic extract both result in significant mortality of larvae due to the larvae's reduced food intake and subsequent slower growth.

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