

Fall armyworm

A new invasive pest of maize in India

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Fall armyworm, Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) is native to the America, spread to the African continent in January 2016. It was first noticed in India on May 18th, 2018 in Shimoga district of Karnataka. Currently, over 40 countries mostly of Africa and North and South America have identified the pest within their borders.

Keywords: Economic Threshold Level, Fall armyworm, Maize

FALL armyworm is likely to be a real threat to Indian agriculture in near future as it is currently observed to be causing damage only on maize in India and likely to spread to other crops due to its polyphagous nature. It is capable of spreading quickly across large geographic areas as adult moths can move up to 500 km. It does not undergo diapause in any stage of life cycle hence, can persist throughout the year on many crops and weeds.

Strains of fall armyworm

Based on the knowledge gained in USA, Fall armyworm is composed of two morphologically identical haplotypes which are near sympatric species that are defined by their host plant preferences. One strain was identified from populations feeding on corn, sorghum, and other large grasses (corn strain), and the other strain was identified from populations feeding on rice, bermuda grass, and other small grasses (rice strain). The two strains can be distinguished by strain-specific allozyme variants and genetic markers. However the insect has so far been detected only on

maize in India. Hence we have to assume that only maize haplotype is so far observed or present in India.

Host range

Fall armyworm caterpillars are major pests of cereals and forage grasses and feed on 186 plant species from 42 families. The fall armyworm is a cosmopolitan pest of the maize crop. It feeds on all growth stages of maize but most frequently in the whorl of young plants up to 45 days old. Fall armyworm larvae usually consume a large amount of foliage and sometimes destroy the growing points of the plant. In addition to maize, fall armyworm attacks many other economically important crops

like rice, sugarcane, sorghum, beetroot, tomato, potato, cotton and other plants like, alfalfa, barley, bermuda grass, buckwheat, clover, oat, millet, peanut, ryegrass, sugar beet, sudan grass, soybean, timothy, tobacco, and wheat. Among vegetable crops, only sweet corn is regularly damaged, but others are attacked occasionally. Other horticultural crops sometimes injured are apple, grape, orange, papaya, peach, strawberry and a number of flowering plants. Weeds known to serve as hosts include bentgrass, *Agrostis* sp.; crabgrass, *Digitaria* spp.; Johnson grass, *Sorghum halepense*; morning glory, *Ipomoea* spp.; nut sedge, *Cyperus* spp.; pigweed, *Amaranthus* spp.; and sandspur, *Cenchrus tribuloides*. Therefore fall armyworm could pose a risk to subsistence and cash crops in large parts of the world. In tropical areas, up to 8 generations a year can occur in maize fields. Maize yield reduction can reach approximately 57% under severe infestation.

Life cycle

Egg: Egg mass is laid under side of the leaf and each female lays 1,500-



Fall armyworm

2,000 eggs during its life time. Individual egg is dome shaped and measures about 0.3 mm in height and 0.4 mm in diameter.

Larva: Fall armyworm has typically six larval instars. Young larvae are greenish with black head and measure 1mm in length. Grown up larva becomes brownish with reddish brown head. A full grown larva has marked with a white inverted “Y” shaped suture. Full grown larva measures up to 45 mm in length. The most distinguishing feature for



Egg mass laid under side of the leaf

near the centre of the wing. The forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of grey and brown. The hind wing is iridescent silver-white with a narrow dark border in both sexes. Adults are nocturnal, and are most active during warm, humid evenings. After a pre oviposition period of 3 to 4 days, the female moth normally deposits most of her eggs during the first 4 to 5 days of life, but in some oviposition occurs up to 3 weeks. Duration of adult life is estimated to average

about 10 days, with a range of about 7-21 days.

Eggs are laid at night on the leaves of the host, in tight clusters of 100-300 in single layer and sometimes in two layers, usually covered with a protective layer of abdominal bristles.



Young larvae

measures 20 to 30 mm in length. The pupa is reddish brown in colour, measuring 14 to 18 mm in length and about 4.5 mm in width. Duration of the pupal stage is about 8 to 9 days during the summer, but reaches 20 to 30 days during cooler weather.



Pupa



Full grown larva

identification of FAW full grown larva is a set of four large spots that form a square on the upper surface of the last segment of its body.

Pupa: Cocoon is oval shaped and

Adult: Adult FAW moths have a wingspan of 32 to 40 mm. In the male moth, the forewing generally is shaded grey and brown, with triangular white spots at the tip and

Eggs are sometimes laid on leaf-sheath or stem. Hatching requires usually 2-3 days (sometimes extended up to 10 days during winter). The first two instars feed gregariously on



Adult FAW moth



Adult FAW female

the underside of the young leaves causing a characteristic skeletonizing or ‘windowing’ effect, the young larvae feed deep in the whorl; and the growing point can be killed. Grown up larvae become cannibalistic and thus one or two larvae per whorl are usual. The rate of larval development through the six instars is controlled by a combination of food and temperature conditions, and usually takes 14-21 days. Sometimes larval period is extended up to 30 days during cooler months. Larger larvae are nocturnal and feed voraciously on leaves. Sometimes the larvae enter the armyworm phase when they swarm and disperse, seeking other food sources. Usually the grown up larva descends to soil and pupation takes place inside a loose silken cocoon in an earthen cell, or rarely between leaves on the host plant. If the soil is hard, pupation of larva can occur on soil surface in host trash. Adults emerge at night, and fly for many kilometres during pre-oviposition period before settling to oviposit, sometimes migrating for as long as 500 to 1500 km. On average, adults live for 12-14 days sometimes up to 21 days.

A threshold temperature of 10.9°C and 559 day-°C is required for development. Sandy-clay or clay-sand soils are suitable for pupation and adult emergence. Emergence in sandy-clay and clay-sand soils was directly proportional to temperature and inversely proportional to humidity. Pupae require a threshold temperature of 14.6°C and 138 day-°C to complete their development.

Biology and seasonal prevalence

The life cycle is completed in about 30 days during the summer, but 60 days in the spring and autumn, and 80 to 90 days during the winter. The number of generations occurring in an area varies with the appearance of the dispersing adults. The ability to diapause is not present in this species. In U.S.A., in temperate states like



Windowing effect

Minnesota and New York, Fall Armyworm moths do not appear until August, although the temperatures are optimum from May month onwards. It is therefore thought that there may be a single

generation in those two states. In Southern states of USA with slightly higher temperatures, the number of generations is reported to be one to two in Kansas, three in South Carolina, and four in Louisiana. In coastal areas of North Florida with humid tropical climate, moths are abundant from April to December, but some are found even during the winter months also. However, in India, maize is grown in different states.

States like Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Bihar, Rajasthan, Gujarat, Madhya Pradesh, with moderate to severe winter, maize is normally sown in May to July as early *kharif* or *kharif* crop and

Table 1. Maize growing seasons in different states in India

State	Season Crop	<i>Kharif</i>	<i>Kharif</i> Maize	<i>Rabi</i> Maize
Himachal Pradesh	Sowing Harvesting		May (M)-June (E) Sep (M)-Oct (M)	
Punjab	Sowing Harvesting	Apr (B)-Mar (E) Sep (B)-Oct (E)	May (B)-June (E) Sep (B)-Oct (E)	
Haryana	Sowing Harvesting	Apr (B)-Apr (M) Oct (M)-Nov (M)	July (M)-Aug (B) Oct (M)-Oct (E)	
Uttar Pradesh	Sowing Harvesting	Apr (B)-June (E) Sep (B)-Nov (E)	Jun (B)-July (E) Sep (B)-Sep (E)	
Bihar	Sowing Harvesting		June (M)-July (B) Nov (B)-Dec (E)	Oct (M)-Nov (M) Feb (B)-May (B)
Rajasthan	Sowing Harvesting	Apr (B)-May (E) Nov (B)-Dec (E)	Jun (B)-July (E) Oct (B)-Nov (E)	
Gujarat	Sowing Harvesting	May (B)-May (E) Oct (B)-April (E)	June (B)-July (E) Sep (B)-Nov (E)	
Maharashtra	Sowing Harvesting		Jul (B)-Aug (E) Oct (B)-Nov (E)	
Madhya Pradesh	Sowing Harvesting		June (M)-July (E) Aug (M)-Dec (E)	
West Bengal	Sowing Harvesting	Oct (B)-Nov (E) Sep (B)-Sep (E)	Mar (B)-May (E) June (B)-Aug (E)	Nov (B)-Nov (E) Mar (B)-Mar (E)
Odisha	Sowing Harvesting	June-July Nov-Dec	June-July Sep-Oct	
Andhra Pradesh	Sowing Harvesting	June (E)-July (E) Dec (E)-March (M)	June (M)-July (M) Sep (M)-Oct (E)	Oct (E)-Jan (M) Feb (E)-May (B)
Telangana	Sowing Harvesting	June (E)-July (E) Dec (E)-March (M)	June (M)-July (M) Sep (M)-Oct (E)	Oct (E)-Jan (M) Feb (E)-May (B)
Karnataka	Sowing Harvesting		May (B)-June (E) Sep (B)-Oct (E)	Sep (B)-Oct (E) Jan (B)-Mar (E)
Kerala	Sowing Harvesting	June (B)-Oct (E) Dec (B)-March (E)		

B, Beginning; M, Middle; E, Ending. Source: Indian Council of Agricultural Research (Crop Science Division).

harvested from beginning of September to end of December. In states like West Bengal, Andhra Pradesh, Telangana, Tamil Nadu and Karnataka with tropical climate without severe winter, maize is sown during March to middle of July as *Kharif* crop and harvested in August to October. In these states with tropical climate, maize is also grown as *Rabi* crop from ending of October to March end.

Under these conditions, Fall armyworm can multiply during both the maize growing seasons (*kharif* and *rabi*) in West Bengal, Andhra Pradesh, Telangana and Karnataka on maize crop and on alternate crop or weed plants during off season. However, in all the temperate states of northern part of the country, Fall armyworm can multiply on maize during *kharif* season only and probably migrate towards West Bengal or Southern states of Andhra Pradesh, Telangana and Karnataka. However, the real picture about the number of generations and movement of adult moths etc. of FAW will be revealed by future research under Indian conditions.

Damage

The caterpillars of FAW feed mainly on leaves, munching on their edges and making holes, giving them a ragged and torn appearance. If the larvae are numerous, they can completely defoliate the plants. When they have exhausted their food source, they invade neighbouring vegetation - which may often be another crop - in large numbers ("armyworm"), devouring almost all suitable plant material in their path. Infestations often remain unnoticed at first, as the small larvae prefer feeding sites close to the ground. By far most of the damage, however, is caused by the last instar larva, which consumes more plant biomass than all of the other younger larval instars put together. This factor is often responsible for people thinking and assessing that the attacks by fall



Cob damaged by FAW

armyworm are sudden and occurred at once. In corn, the caterpillars feed deep in the whorl, often concealed under their own frass. While the leaves may be heavily damaged, the plant usually compensates for the loss. If the growing point is destroyed, however, "dead heart" symptoms will appear. As the crop grows to tasselling stage, emerging tassel often pushes the feeding larva out of the whorl. At this stage, some larvae may start feeding on the side leaves while some larvae may shift to the developing cob. The larvae shifted to developing cob frequently feed on the immature kernels inside the ear. This generally causes greater injury than the leaf damage. Further, the extent of loss depends on the stage of cob development at the time of attack and the extent of feeding by the larva on the cob.

When the larvae are very numerous they defoliate the preferred plants, acquire an "army-worm" habit and disperse in large numbers, consuming nearly all vegetation in their path. Due to cannibalistic behaviour of FAW, the larvae as they grow in size are forced to disperse to neighbouring plants from the plant where eggs are laid. Hence, only one or very few larvae can be found per plant, despite adults laying egg masses comprising hundreds of eggs (Sparks, 1979).

Integrated pest management practices of FAW

Economic threshold of fall army worm in maize: Economic

Threshold Level (ETL) is the level of the pest population or damage at which control action must be initiated to prevent the damage reaching Economic Injury Level (EIL). At EIL cost of control is economically equivalent to price of the produce otherwise lost due to such damage. ETL for FAW is highly variable depending on local conditions based on cost of plant protection and price of the produce. However, it is mostly fixed based on long experience of entomologists working on a pest in an area.

FAW can damage several crops and plants, the ETL for this pest can be computed as it is done in case of *Helicoverpa armigera* or *Spodoptera litura* which are comparable pests damaging many vegetable and fruit crops. Hence ETL and EIL of Fall army worm in Maize or Corn only is discussed here.

Pest monitoring: Monitoring of FAW damage can be done at weekly intervals starting from crop emergence. Each time observe at five places representative of the field. At each place observations on larval damage can be recorded on 10-20 plants. Compute the percentage damaged plants based on observations in all the five places in a field. At early crop stage an average of 20% of damaged plants (ranging from 10 to 30% damaged plants) has been fixed as ETL. Similarly, 40% damaged plants in late whorl stage (with a range of 30 to 50% damaged plants), and 20% damaged plants in tassel or silk stage (with a range from 10 to 30% damaged plants) have been fixed as ETL (Cruz *et al.*, 1999). Once the damage reaches ETL at a particular stage, it deserves immediate interference by insecticide application. All these details have been advised by experts from USA where the pest was endemic in many states since long time. However the details need to be worked out under Indian conditions.

Host plant resistance: Developing and deploying effective

host plant resistance (HPR) is one of the pillars of an effective Integrated Pest Management (IPM) strategy against fall armyworm. However it is too early to predict the usefulness of this approach for a lepidopterous pest of highly polyphagous nature to find resistance sources within a plant species or in related wild species. Future research under Indian conditions alone can throw real light on this aspect.

Bioagents: FAW has got abundant natural enemies like Ground beetles, ear wigs, soldier bugs, carabid beetles, ladybird beetles, birds, bats, spiders, ants and rodents which act as predators against this pest. Entomopathogens viz., SfNPV, *Metarrhizium anisopliae*, *M. rileyi* and *Beauveria bassiana* and *Bacillus thuringiensis*. However, the real exploitation of bioagents is a long term approach and needs lot of effort at research stage and implementation stage in a field crop like maize which hardly remains 3-4 months in the field.

IPM practices

Avoid staggered sowing of maize particularly sweet corn. Installation of pheromone traps @ 8-10 per acre. However, catches of male moths in pheromone traps does not really reveal the extent of field infestation and vice versa. Clean cultivation to avoid alternate hosts. Balanced application of fertilizers helps to reduce the incidence of fall armyworm, because of vigour of the plant (enhances immunity). Intercropped maize with pulses is less preferred over pure maize crop. FAW avoids egg laying on intercropped maize and it also helps to build natural enemies. Use of trap crops like Napier grass which attracts egg laying. However, practical and economic implementation is very difficult.

Desmodium plant acts as repellent in case of FAW. Release of egg parasitoids such as *Telenomus remus*, *Trichogramma* sps and larval parasitoid like *Cotesia marginiventris*.

Application of *Bt* formulation



Pheromone trap in field

strains @ 2g/lit or Neem seed kernel extract (Neem formulation 1,500 ppm) @ 5 ml/lit of water for control of early instars. Application of bio-insecticides sprays such as spinosad 45 SC @ 0.3 ml/lit or emamectin benzoate 5 SG @ 0.4 g/lit of water in plant whorls for the management of later instars. When the pest incidence is very high (if necessary) spray chlorantraniliprole 20 SC @ 0.3 ml / lit of water focussing on plant whorls.

Most important precaution is to avoid insecticide application in maize when the crop reaches the height above humans, as it is highly risky and hazardous. Hence control operations for FAW should be concentrated in early stage of maize crop. To control grown up larvae apply poison bait.

Preparation of poison bait: For one acre of field, 10 kg of rice bran + 2 kg of jaggery and add 2-3 litres of water, then mix thoroughly and keep overnight for fermentation, Later mix 100 g of thiodicarb to the rice bran mixture 30 minutes before the application. Make small pellets and distribute in the plant whorls during evening hours.

Future program on FAW management under Indian conditions

Research Strategies: Studies on

bio ecology of FAW under field conditions in different states. Differentiating the damage with other worms especially armyworm (*Mythamna* species). Host plant resistance studies to be continued at multi locations. Collection and identification of natural enemies of FAW in different maize growing seasons and regions of the country. Evolving forewarning systems based on weather parameters. Likely migration of FAW in different seasons and regions to be studied. Studies on effective new insecticides and insecticide resistance assessment to be continued. Exploitation of *Bt* maize depending on feasibility

Creating awareness among the farming community: Educating the farmers through community

approach. Alerts through radio, TV and various other media. Avoiding highly hazardous insecticide sprays to protect natural enemies. Maize has ability to compensate the damage caused by FAW as it was suggested under ETL. So farmers should not panic. Small farmers can be advised to monitor regularly and collect egg masses and destroy them. However, practical application of this approach is tedious and difficult due to labour shortage in villages. Installation of pheromone traps for monitoring of FAW in large areas. Trap catch however, should not be taken as guidance for insecticide application.

Usefulness of farmers' awareness program:

- Saves money wasted on ineffective chemical treatments.
- Reduces human and animal pesticide exposure in fields, food residues, and the environment.
- Protects natural enemies of FAW, which may also be killed by pesticides.
- Conserves soil and water quality.
- Manages insecticide resistance, helping to maintain the efficacy of existing chemical control options over time.

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