Biology and Management of Fall Armyworm (*Spodoptera Frugiperda*) in Maize

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Introduction

Except Antarctica, maize, *Zea mays* L. (Poaceae), is one of the most adaptable crops, with a greater tolerance for a variety of agro-climatic circumstances. Because of its great genetic yield potential among cereals and ranking third in importance globally behind wheat and rice, maize is regarded as the "Queen of Cereals" by everyone. More than 100,000 hectares of maize are planted in 70 countries, including 53 developing nations [Bueno *et al.*,2011]. In India, maize is grown for a variety of uses, including food processing, animal and poultry feed, human consumption, and the extraction of starch, dextrose, corn syrup, and corn oil. With a composition of roughly 72% carbohydrate, 10% protein, and 4% fat, maize has an energy density of 365 kcal/100 g. Numerous entities target the crop among them these three insect pests have caused significant problems in India up until recently: the shoot fly (*Atherigona* spp.), pink stem borer (*Sesamia inferens* Walker), and spotted stem borer (*Chilo partellus* Swinhoe). Besides these, in May 2018, the invasive pest known as fall armyworm (*Spodoptera frugiperda*) had spread quickly throughout every Indian maize-growing ecology except for Himachal Pradesh and Jammu and Kashmir casting a shadow on maize production.

It is mostly found in maize, the major host, but it has also been found in rice, sorghum, sugarcane, and a variety of vegetables, which are secondary hosts. (Abrahams *et al.*, 2017 and Day *et al.*, 2017). Being a polyphagous insect, it is known to attack more than 100 hosts. Fall armyworm (FAW) is composed of two strains: rice strain "R," which favors rice and turf grass, and corn strain "C," which feeds mostly on maize, sorghum, and cotton (Naghoshi and Meagher., 2016). FAW was initially discovered in India, in the maize fields of the College of Agriculture (UAHS), Shivamogga, Karnataka (Sharanabasappa *et al.*, 2018). The word frugiperda means "lost fruit" in Latin. FAW is not a "worm," but rather a caterpillar. As suggested by its name, it conjures up images of hordes of larvae marching in unison and spreading destruction in their wake. North and South America's tropical zones are home to the Fall Armyworm (FAW) (Sisay *et al.*, 2019). In India, this pest is endangering the food security and livelihoods of millions of small-scale farmers. It has also been reported from sorghum, sugarcane, and maize in India (Saranbassappa *et al.*, 2018). It results in a significant yield loss in maize, up to 57.6% to 58%. The problems seen in the maize plant include loss of photosynthetic area, reduced reproduction, direct damage to grain, lodging, and structural damage in the whorl (Chimweta et al., 2019). In Kharif and Rabi combined, 20,118 MT and 8,634 MT of maize were produced in 2017–18, for a total of 28,753 MT in India. Following Fall Armyworm's arrival, the production decreased to 27,720 MT overall in 2018–19, 19,410 MT in Kharif, and 8300 MT in Rabi (Indiastat.,2019). The pest, which is highly migratory by nature, has the potential to seriously harm crop species.

Biology of FAW

Eggs

Gravid females lay their eggs in whorls, at the base of the plant, and on the underside or upper surface of maize leaves in masses between 985 and 1243.9 (Devi *et al.*, 2024). The female deposits more than a thousand eggs in one or more clusters. The average fecundity for each female was determined to be 1104.4 ± 93.60 eggs. Either one or more layers may contain eggs. The creamy-colored eggs may have a hair tuft in the anal region or may not have any hair at all. According to Prasanna *et al.* (2018), the FAW egg has a dome-shaped base that is flattened and measures 0.4 mm in diameter and 0.3 mm in height.

Larva

The fall armyworm has six instars. Larvae in their first instar are greenish with a black head; in their second instar, the head turns orange. Larvae in their third instar had a striking shift in body color. When completely developed, the larvae had a distinctive inverted "Y" form on their head capsule and were brownish and four dark areas on the second-to-last segment that combined to form a square. On the dorsal side, the larvae were light brown, and on the ventral side, they were greenish. The white stripes on the dorsal and sub-dorsal flanks were visibly discernible and the black dots grew in size. The fifth and sixth instars of the adult larvae exhibit cannibalistic behavior, feeding on the younger larvae (Chapman *et al.,* 1999). Regardless of food densities, this behavior was ubiquitous, but it was more prevalent when food densities were low on the second-to-last segment, FAW larvae are identified by four distinctive dots that create a square or rectangle. The mean total larval period is e 16.6 ± 0.82 days.

Pupa

By creating a loose, oval-shaped earthen cocoon out of soil fragments and leaf detritus, late instar larvae pupate in soil up to a depth of 2 to 8 cm using silken threads. The pupa's color changes from orange-brown to reddish-brown throughout time. The pupals lasts 9.2 ± 1.64 days on average. The female pupa's and male pupa's genital openings are exposed on the eighth and ninth abdominal segments, respectively (Helen *et al.*,2021).

Table 1 Life span of FAW *Spodoptera frugiperda* in laboratory conditions (Helen *et al.,* 2021)

S N	Phase of Life Stage	Period (days)	
		Range	Mean SD ±
1	**Egg stage**		
	Incubation	3-4	
	Hatching percentage (%)	-	96 %
2	**Larval stage**		
	Total larval stage	16-18	16.6 ± 0.82
	First instar larva	2.5-3	2.8 ± 0.27
	Second instar larva	2.5-3	2.5 ± 0.35
	Third instar larva	2-2.5	2.1 ± 0.22
	Fourth instar larva	2-2.5	2.2 ± 0.27
	Fifth instar larva	2.5-3	2.6 ± 0.41
	Sixth instar larva	4.5-5	4.4 ± 0.41
3	**Pupal stage**	8-12	9.2 ± 1.64
4	**Adult stage**		
	Pre-oviposition	3-4	3.4 ± 0.55
	Oviposition	2.5-3	2.8 ± 0.27
	Post-oviposition	6-6.5	6.2 ± 0.41
5	Fecundity of female moth	957-1289	1094 ± 0.92
	Longevity of female moth	11.5-13	12.4 ± 0.54
	Longevity of male moth	10-11	10.4 ± 0.41
	Egg to adult stage in Female	37-40.5	38.2 ± 1.35
	Egg to adult stage in male	35-38	36.2 ± 1.25

Adult

Adults are nocturnal creatures that are most active in warm, muggy evenings. In general, female moths are larger than male ones. A mature moth's wingspan is between 32 and 40 mm. The male moth can be identified by its speckled forewing and triangular white spots located in the center and tip of the wing. Forewings of the female moth are grayish brown. Both moths have bright, silvery white hind wings with a short white border. The adult phase lasts for seven to eleven days. According to Prasanna *et al*. (2018), female moths have a pre-oviposition period of three to four days, after which they lay their eggs within the first four to five days of life—or even up to three weeks in some situations. The adult moth's life spans around seven to twenty-one days, with an average of ten days.

Management Practices

Cultural Control

The cultural approach is essentially an agronomic technique used by farmers to produce their crops. We can say that this is a method where no additional costs are incurred in order to manage the plants.It is advised to plough deeply before planting. Predators will be exposed to fall armyworm pupae as a result. Avoid staggered sowing and planting; timely seeding will minimize the occurrence of pests (Singh *et al.,* 2020). Incorporating a bird perch within a cropping area enables insectivorous birds to perch and collect insects, which they can subsequently consume (Badhai *et al.,* 2020). Establishing and cultivating early maturing cultivars is a crucial cultural practice for managing FAW. By increasing soil health and fertility, restricting the passage of larvae from plant to plant, stopping female moths from laying eggs likely by olfactory disturbance, and creating habitat for natural enemies, intercropping with legumes lowers pest damage (Lalruatsangi., 2021). Repelling adult female FAW moths by intercropping plants like Tephrosia and Desmodium also lessens the quantity of eggs laid on host plants (Harrison *et al.,* 2019). It increased output by 2.7 times while reducing FAW infection to 86% (Midega *et al.,* 2018).

Mechanical Control

Another excellent technique for managing FAW is pest monitoring. The most common methods for monitoring fall armyworms are the pheromone trap and the light trap. According to Batista-Pereira *et* *al*. (2006), pheromones are mostly used to catch male fall armyworms. Pheromone trap installation facilitates monitoring and mass-trapping fall armyworm adults (Sisay *et al.*, 2024). Applying soil inside the whorls. Using pheromone traps, mass capture of male moths at 15/acre (Lalruatsangi., 2021).

Biological Control

Microbes that are considered entomopathogenic, including nematodes, viruses, bacteria, and fungi: These pathogens have the ability to regulate foot and mouth disease (FAW) (Komivi *et al.*, 2019). The entomofungal pathogen *Nomuraea rileyii* was shown to cause 10–15% of larval infections (Sharanabasappa *et al.*, 2019). Numerous studies have revealed that a wide range of natural enemies attract FAW, and that the combined mortality rate of these adversaries can be rather high. According to Shylesha *et al.* (2018), *S. frugiperda* coexists with a variety of natural enemies, including earwigs (Forficula sp.) and parasitoids that feed on eggs and larvae.

Botanical control

As an economical method for managing insect pests, plant-derived pesticides are enticing substitutes for synthetic ones. In their study of the biological versus chemical control of lepidoptera stem borers and fall armyworms in maize, Kammo et al. (2019) found that neem oil (1.40 l/ha) applied weekly at 76 days post-planting significantly decreased the frequency and intensity of FAW attacks as well as the number of larvae during the trial.

Chemical Control

On severe infestation, we can go for chemical control practices. We can apply poison baits to control the larval population of fall armyworm. In research done by Kumar et al., 2020, compared to the untreated control, there was a significant drop in larvae numbers following the administration of baits in all treatments. The plots treated with spinetoram, chlorantraniliprole, and novaluron had the lowest observed larval population, followed by those treated with emamectin benzoate, thiodicarb, and azadirachtin. This demonstrates unequivocally that using poison baits to kill out the larval populations is effective. Due to these insecticides' systemic nature, their residual toxicity may increase over time after application (Birhanu et al. 2019).

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