



Biology of fall armyworm (*Spodoptera frugiperda*) infesting sugarbeet (*Beta vulgaris*)

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The Fall armyworm (FAW), scientifically known as *Spodoptera frugiperda*, Smith & Abbot, 1797 belongs to the Noctuidae (Lepidoptera). Originating from tropical and subtropical regions of the Americas, FAW is a nocturnal insect pest. Remarkably, within just two years, it managed to expand its habitat to two additional continents (Early *et al.* 2018). The invasion of FAW in west Africa was first documented by Georgen *et al.* (2016), marking its entry into the region. The subsequent year, 2017, witnessed FAW's presence in 28 sub-Saharan African countries. From there, the pest further dispersed to countries across south Asia, south-east Asia, and Australia (Day *et al.* 2017). Even in Europe, FAW appeared as a continuous quarantine interception (CABI 2018). The year 2019 brought reports of FAW's occurrence in Sri Lanka, Myanmar, China, and Bangladesh (CABI 2018). Interestingly, FAW demonstrates heightened incidence when exposed to climatic conditions characterized by low temperatures and substantial rainfall (CABI 2018). This migratory insect was first observed in India's Karnataka district in July 2018, subsequently establishing its presence throughout the country (Sharanapasappa *et al.* 2018). In Tamil Nadu, FAW was noted in maize during August 2018 in Karur, and it made an appearance in sugarcane in November 2018 in Erode (Srikanth *et al.* 2018). This voracious feeder displays polyphagous behaviour, targeting over 100 different host plants. FAW has a remarkable capacity to consume, involving 353 plant species from 76 different families (Montezano *et al.* 2018). Among its primary hosts causing substantial damage are maize, sorghum, rice, and sugarcane. Maize experienced the most severe impact, with damage recorded at 77.2%, followed by sorghum at 60.1%,

and pearl millet at 41.4% (Suby *et al.* 2020). FAW poses a threat across various growth stages of plants, including seedling, vegetative, flowering, and reproductive/fruiting stages. Despite being observed in various millet crops, records of FAW infestation in sugarbeet were lacking in India (Montezano *et al.* 2018). Therefore, a study was conducted to investigate the biology of FAW in sugarbeet and to ascertain the durations of its different life stages.

Present study was carried out during June and March, 2021 at the Agricultural College and Research Institute (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Madurai, Tamil Nadu. The survey encompassed five sugarbeet (*Beta vulgaris* L.) plots. The precise geographical coordinates of each fall armyworm occurrence site were meticulously recorded. Larvae were systematically gathered from these plots, and field symptoms were meticulously observed across sugarbeet cultivars, specifically SZ 35 and PAC 60008. The collected larvae were subsequently transported to the Insectary at Agricultural College and Research Institute, Madurai, Tamil Nadu where they underwent individual rearing. The process of identifying the fall armyworm species involved morphological analysis, drawing from the insights presented in the study on fall armyworm biology conducted by Kalleshwaraswamy *et al.* (2018). The key characteristics of the larvae were instrumental in confirming their identification as fall armyworms. Notably, a distinctive arrangement of four spots in a square pattern on the last segment of the second abdominal region, in addition to trapezoidal arrangements on other segments, were key indicators. Moreover, the larvae exhibited a dark head featuring an inverted Y-shaped sclerite on the anterior side.

In order to gauge the extent of infestation by *S. frugiperda*, a comprehensive roving survey was undertaken. Larvae obtained from the sugarbeet fields were meticulously collected, provided with sugarbeet leaves as sustenance, and individually reared in specialized trays to prevent cannibalism. Advanced-stage larvae were housed

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within sand-filled trays, facilitating their pupation process. The pupae subsequently underwent transfer to rearing cages designated for adult emergence. The emerging adults were sustained within these cages, being nourished with a mixture of honey solution and vitamin E tablets to facilitate egg-laying. This cyclic methodology enabled the study of fall armyworm biology within the context of sugarbeet. The research maintained ten replications, enabling robust observations pertaining to the duration of various life stages such as eggs, larvae, pupae, and adults. Additionally, the fecundity rate of female fall armyworms was diligently monitored across successive cycles.

Adult fall armyworms were commonly observed resting on the lower portions of leaves, and they laid their eggs on the underside of newly emerged leaves. The infestation by these insects initiated during the seedling stage and persisted until the point of harvest. In the initial seedling phase, larvae were identified in the rhizosphere region of the leaves (Fig. 1A), where they inflicted damage by severing the central shoot, ultimately leading to the withering of the central shoot (Fig. 1B). As the plants progressed into the vegetative stage, the fall armyworms caused extensive defoliation (Fig. 1C) without exhibiting the characteristic parallel-hole symptoms seen in maize. Notably, the petiole region of the leaves was subject to cutting by *S. frugiperda* during instances of significant damage (Fig. 1D). The degree of infestation during the seedling, vegetative, and reproductive stages ranged from 9–13%, 50–60%, and 62–77%, respectively. In terms of larval population, there were approximately 0.2, 0.5, and 0.9 larvae/plant during these respective stages. The fall armyworm's impact on sugarbeet was notably severe, spanning from the initial seedling phase through to the eventual harvest. Following hatching, numerous small caterpillars would often be present on the same plant, but typically only one or two larger larvae managed to persist on each plant, accompanied by larval droppings. In the case of younger plants, the infestation

usually led to the death of the plant, whereas older plants managed to endure the inflicted damage.

Egg deposition took place in aggregated masses and was accompanied by a tuft of hair covering. The incubation period for the eggs was found to be approximately 3.2 ± 0.17 days. These eggs exhibited a creamy appearance with a dome-shaped structure, a flattened base, and a curved apex, typically laid in clusters of two to four layers. The eggs were primarily positioned in the crown region and on the outer side of leaves. Notably, each egg mass was characterized by small grey anal tuft hairs placed between and over the eggs, creating a furry and mold-like appearance (ICAR-NBAIR 2018). Under laboratory conditions, the egg period closely aligned with previous research at 3.2 ± 0.17 days, corroborating findings by CABI (2018), while Kalleshwaraswamy *et al.* (2019) reported a range of 2–3 days under warm conditions. Initially, the eggs were pale yellow, and over a two-day period, they matured to a light brown hue just prior to hatching. Each egg mass contained an estimated 150–200 eggs, with hatching occurring in 2–3 days under warm conditions (CABI 2018). Larvae exhibited distinctive traits, including four characteristic spots arranged in a square pattern on the last segment of the second abdominal segment, as well as an inverted 'Y' shaped marking on the head. These larvae progressed through six instars, with durations of 3.8 ± 0.65 days, 3.2 ± 0.90 days, 2.9 ± 0.14 days, 3.1 ± 0.36 days, 3.6 ± 0.24 days, and 6.8 ± 0.74 days for the first to sixth instars, respectively (Table 1). The overall larval duration spanned 19–25 days, with an average of 23.4 ± 3.20 days. Similar life stages of FAW in barnyard millet were observed, as reported by Moorthy *et al.* (2024), with larval periods of 3.2 ± 0.83 days, 3.0 ± 0.70 days, 2.4 ± 0.54 days, 2.6 ± 0.54 days, 3.4 ± 0.89 days, and 6.0 ± 0.70 days for the first to sixth instars, respectively. In the sixth instar, larvae reached a length of 48 mm, displaying an inverted Y-shaped suture on the head and characteristic spots arranged in square and

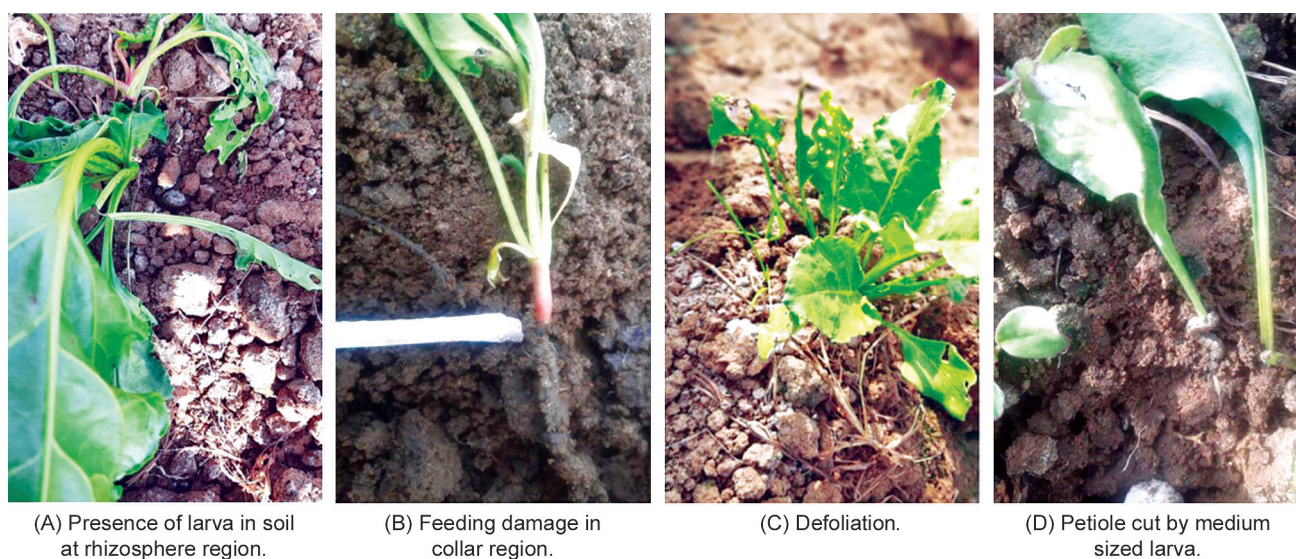


Fig. 1 Incidence of fall armyworm in sugarbeet.

Table 1 Biology of fall armyworm in sugarbeet

Life stage	Mean $\pm$ SE *
Egg duration	3.2 $\pm$ 0.17 Days
Larval duration	
I instar	3.8 $\pm$ 0.65 Days
II instar	3.2 $\pm$ 0.90 Days
III instar	2.9 $\pm$ 0.14 Days
IV instar	3.1 $\pm$ 0.36 Day
V instar	3.6 $\pm$ 0.24 Days
VI instar	6.8 $\pm$ 0.74 Days
Total larval period	23.4 $\pm$ 1.20 Days
Pupal duration	9.3 $\pm$ 1.80 Days
Adult duration	10.2 $\pm$ 2.04 Days
Total life cycle	43.8 $\pm$ 0.94 Days
No. of egg mass laid by gravid females	8.0 $\pm$ 1.55 Egg mass

*Each value is the mean of five replications; Mean followed by standard deviation.

trapezium shapes on different segments of the body. Head capsule widths ranged from 0.35 mm for the first instar to 2.6 mm for the sixth instar. Neonates were green with a 1 mm black capsule, transitioning to brown after the second instar, followed by the development of lateral lines in the third instar. The fall armyworm larvae utilized a ballooning mechanism for dispersal between plants (CABI 2018) and tended to hide during bright light. Larval duration varied according to climate, spanning 14 days in summer and 30 days in winter (CABI 2018, Deshmukh *et al.* 2021). Upon reaching the prepupal stage, the larva descended to the ground for pupation. During this stage, the larva transformed from a light green to a dark brown colour and constructed an oval-shaped cocoon. Pupation occurred at depths of 2–5 cm in the soil or within leaf debris. The pupal period averaged 9.3 $\pm$ 1.80 days, while Prasanna *et al.* (2018) noted variations from 9–30 days in summer and winter, respectively. Nocturnal adult moths displayed heightened activity in warm and humid conditions. Male moth forewings exhibited a grey with a central circular spot and a triangular white patch at the wing tip, while female forewings were uniformly fine greyish-brown. Both male and female hind wings featured a narrow dark border and a silvery-white appearance (Sharanabasappa *et al.* 2018, CABI and FAO 2018). The adult life span was approximately 11.1 $\pm$ 1.94 days. Female moths initiated egg laying on the fourth day and continued up to the third week of their lifespan. Each female laid around 8.0 $\pm$ 1.55 egg masses during her lifetime, containing 180–220 eggs/mass. The total life cycle of the fall armyworm in the context of sugarbeet, under laboratory conditions, encompassed roughly 43.8 $\pm$ 6.94 days. In barnyard millet, Moorthy *et al.* (2021) similarly reported a lifecycle of 42.2 $\pm$ 4.26 days for the fall armyworm.

SUMMARY

The potential for damage caused by the maize fall armyworm (FAW) varies considerably, ranging from 9.0–62.5% across different seasons and regions in India.

This poses a significant threat to the food and nutritional security of numerous farmers in the country. Notably, the FAW has been identified as a new host for sugarbeet, marking the first instance of such an occurrence. A comprehensive examination of the fall armyworm's behaviour in this new host was conducted. The infestation of the FAW in sugarbeet commenced during the seedling stage and persisted until the harvesting phase. During the initial seedling stage, larvae within the rhizosphere region induced defoliation of leaves and inflicted damage to the collar region. This led to the drying of the central shoot, mirroring the symptoms of dead heart, although no scraping symptoms were observed. As the plants entered the vegetative stage, they experienced further defoliation and wilting. In terms of its life cycle, the FAW exhibited distinct stages. The egg stage lasted around 3.2 $\pm$ 0.17 days. Larvae generally underwent 6 instars, with durations of 3.8 $\pm$ 0.65 days, 3.2 $\pm$ 0.90 days, 2.9 $\pm$ 0.14 days, 3.1 $\pm$ 0.36 days, 3.6 $\pm$ 0.24 days, and 6.8 $\pm$ 0.74 days for the first to sixth instars, respectively. The overall larval period ranged from 19 to 25 days, with an average of 23.4 $\pm$ 3.20 days. The pupal and adult stages lasted approximately 9.3 $\pm$ 1.80 days and 11.1 $\pm$ 1.94 days, respectively. Consequently, the complete life cycle of the fall armyworm in the sugarbeet, as observed under laboratory conditions, spanned approximately 43.8 $\pm$ 6.94 days.

REFERENCES

- CABI and FAO. 2018. Community-based fall armyworm (*Spodoptera frugiperda*) monitoring, early warning and management, training of trainers. edited by food and agricultural organization.
- CABI. 2018. *Spodoptera frugiperda* (Fall armyworm). In Invasive Species Compendium.
- Day R, Abrahams P, Bateman M, Beale T, Clotney V, Cock M, Colmenarez Y, Corniani N, Early R and Godwin J. 2017. Fall armyworm: Impacts and implications for Africa. *Outlooks on Pest Management* 28(5): 196–201.
- Deshmukh S S, Prasanna B M, Kalleshwaraswamy C M, Jaba J and Choudhary B. 2021. Fall armyworm (*Spodoptera frugiperda*). Polyphagous Pests of Crops. *Springer* 349–72.
- Early R, Gonzalez-Moreno P, Murphy S T and Day R. 2018. Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. *Neo Biota* 40(40): 25–50.
- Goergen G, Kumar P L, Sankung S B, Togola A and Tamo M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in west and central Africa. *Plos one* 11(10): 165632.
- ICAR-NBAIR. 2018. Pest alert *Spodoptera frugiperda* (Smith J E) (Insecta: Lepidoptera). India.
- Kalleshwaraswamy C, Maruthi M and Pavithra H. 2018. Biology of invasive fall army worm *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) on maize. *Indian Journal of Entomology* 80(3): 540–43.
- Kalleshwaraswamy C, Asokan R, Mahadevaswamy H and Sharanabasappa C. 2019. First record of invasive fall armyworm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) on rice (*Oryza sativa*) from India. *Journal of Entomology and Zoology Studies* 7: 332–37.

- Montezano D G , Specht A, Sosa-Gomez D R, Roque-Specht V F, Sousa-Silva J C, Paula-Moraes S D, Peterson J A and Hunt T. 2018. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *African Entomology* **26**(2): 286–300.
- Moorthy A V, Roopika M, Srinivasan G and Shanthi M. 2024. First record of barnyard millet as a host for fall army worm *Spodoptera frugiperda* (J E Smith). *Indian Journal of Entomology* **16**: 1–3.
- Prasanna B, Huesing J, Eddy R and Peschke V. 2018. *Fall Armyworm in Africa: A Guide for Integrated Pest Management*. USAID, CIMMYT, Mexico.
- Sharanabasappa S, Kalleshwaraswamy C M, Asokan R, Swamy H M, Maruthi M S, Pavithra H B, Kavita Hegde K H, Shivaray Navi S N, Prabhu S T and Goergen G. 2018. First report of the fall armyworm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. *Pest Management in Horticultural Ecosystems* **24**(1): 23–29.
- Srikanth J, Geetha N, Singaravelu B, Ramasubramanian T, Mahesh P, Saravanan L, Salin K P, Chitra N and Muthukumar M. 2018. First report of occurrence of fall armyworm *Spodoptera frugiperda* in sugarcane from Tamil Nadu, India. *Journal of Sugarcane Research* **8**(2): 195–202.
- Suby S, Soujanya P L, Yadava P, Patil J , Subaharan K, Prasad G S, Babu K S, Jat S, Yathish K and Vadassery J. 2020. Invasion of fall armyworm (*Spodoptera frugiperda*) in India: Nature, distribution, management and potential impact. *Current Science* **119**(6): 44–51.