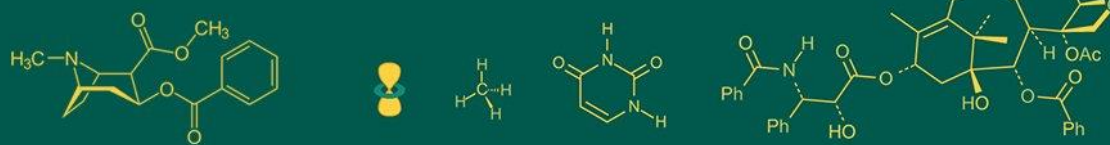


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Biology and morphometrics of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on sorghum

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Abstract

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) has emerged as a serious invasive pest of sorghum. The present investigation was carried out in laboratory and field conditions at N. M. College of Agriculture, Navsari Agricultural University, Navsari during *kharif*-2025. An investigation on the biology of fall armyworm, *S. frugiperda* revealed that fall armyworm completed its life cycle with egg, six larval instars, pupa and adult stages. An incubation period was recorded as 2.38 ± 0.60 days with a hatching percentage of 78.96 ± 4.52 per cent. The length and breadth of eggs were 0.44 ± 0.04 mm and 0.42 ± 0.04 mm, respectively. The first to sixth instar larval period was 1.98 ± 0.51 , 2.18 ± 0.39 , 2.34 ± 0.69 , 2.28 ± 0.54 , 2.74 ± 0.78 and 3.70 ± 0.61 days, respectively with total larval period of 15.22 ± 1.43 days. The length of first to sixth instar larvae were 1.09 ± 0.04 , 3.72 ± 0.22 , 6.58 ± 0.53 , 12.84 ± 0.92 , 22.55 ± 2.19 and 30.33 ± 2.04 mm, whereas breadth were 0.22 ± 0.03 , 0.54 ± 0.07 , 0.87 ± 0.08 , 1.16 ± 0.15 , 2.35 ± 0.38 and 3.14 ± 0.64 mm, respectively. The pre-pupa and pupal period were 1.32 ± 0.47 and 8.92 ± 0.70 days, respectively. The length and breadth of pupa was 17.08 ± 1.28 and 4.87 ± 0.13 mm, respectively. The sex ratio (male: female) was 1:1.27. The longevity of male and female adults were recorded as 8.04 ± 0.84 and 10.00 ± 0.82 days, respectively. The body length of male and female adults were measured as 17.27 ± 1.46 and 14.23 ± 1.72 mm, whereas wing expanse were 31.68 ± 0.94 and 32.28 ± 0.27 mm, respectively. The pre-oviposition, oviposition and post-oviposition periods were 3.44 ± 0.65 , 2.84 ± 0.69 and 3.76 ± 0.78 days, respectively. The fecundity was 1216.88 ± 152.98 eggs per female. The total life span of male and female adults were 35.08 ± 1.98 and 37.56 ± 2.24 days, respectively.

Keywords: Fall armyworm, sorghum, biology, life cycle, fecundity

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an essential crop of semi-arid tropics. It is the fifth major cereal crop after rice, wheat, maize and barley in world (Sharma *et al.*, 2003) ^[15]. Sorghum is a staple food for more than 600 million people who live in the semi-arid tropics and is grown in more than half of the world's semi-arid regions (Mohammed *et al.*, 2015). Sorghum grain is highly nutritious, containing carbohydrates (70-80%), protein (11-13%), fat (2-5%), fibre (1-3%) and ash (1-2%). Being gluten-free, sorghum protein makes it suitable for individuals with diabetes and celiac disease (Prasad & Staggenborg, 2009) ^[12].

There are many biotic and abiotic factors that affect the quality and quantity of sorghum. Among them, insect pests are major factors that cause appreciable damage that ultimately effects on yield of sorghum. Nearly 150 insect species have been reported as pests on sorghum (Sharma, 1985) ^[16]. In India, there was a 35 per cent crop loss due to insect pests estimated at \$580 million in sorghum and millet fields (Okosun *et al.*, 2021) ^[11]. The fall armyworm, originally native to the Americas, is a highly polyphagous pest that causes substantial economic losses to crops such as maize, sorghum, beans and cotton (Abrahams *et al.*, 2017) ^[1]. During migration, adult moths are capable of travelling more than 500 km before oviposition. Initially, outbreaks of this pest caused considerable panic among farmers; however, over time awareness has increased and farmers have learned to identify the pest and adopt appropriate management practices based on guidance and advisories from reliable sources. Fall armyworm is native to tropical and subtropical regions of the Americas (Goergen *et al.*, 2016) ^[8]. The occurrence and prevalence of this invasive pest were noticed for the first time by Sharanabasappa *et al.* (2018) ^[14] from Karnataka, India, which is the first reported infestation in Asia, in July 2018 and subsequently, it has spread into ten other states

of our country till the middle of March 2019. Bandi *et al.* (2023) ^[4] reported that 16 per cent of yield losses in sorghum due to fall armyworm. For any pest the biology is important step for identifying the various stages and its behaviour for successful IPM. Hence, the present study focused on the biology of FAW on sorghum under laboratory conditions.

Materials and Methods

The investigation on the biology of fall armyworm was carried out during *kharif* season of 2025 at the P. G. Research Laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari. The larvae of fall armyworm were collected from a pesticide-free field and brought to the laboratory for rearing under room temperature conditions. The larvae were reared individually in Petri dish and fed on tender sorghum leaves. Fresh sorghum leaves were supplied daily to larvae in each Petri dish until they reached the pupal stage. A biology study was carried out on second generation population. Emerged male and female adults were allowed to mate in glass jar (21 × 15 cm) properly lined with paper and placed in adult rearing cage. The adults were fed with honey solution (5%) soaked on cotton pads in small plastic caps placed inside the jar and replaced daily. Observations were recorded daily 8:00 to 9:00 AM to check the egg laying on leaves and muslin cloth.

The incubation period was calculated based on the date of egg laying to the date of hatching. The hatching percentage was determined based on the number of eggs hatched out of the total number of eggs observed. The duration of each larval instar was determined by recording the time interval between successive moults. The number of instars, duration of each instar and total larval period were recorded by observing larvae. Pre-pupal and pupal period were recorded by observing the duration from cessation of feeding to pupation and from pupation to adult emergence, respectively. Adult longevity, fecundity, oviposition period and sex ratio were also recorded under laboratory conditions.

Morphometrical measurements of egg, larva, pupa and adults were recorded using suitable microscopic observations and measuring scales. The observations were statistically analysed.

Results and Discussion

Incubation period and hatchability

The biological observations of *S. frugiperda* under laboratory conditions are presented in Table 1. The incubation period varied from 2 to 4 days with an average of 2.38 ± 0.60 days.

The present findings are in more or less similar with Kranthi *et al.* (2021) ^[10] who observed 2.47 ± 0.05 days of incubation period reared on sorghum. Chaudhary *et al.* (2023) ^[5] noted 3.06 ± 0.45 days of incubation period on maize.

The hatchability varied from 73.86 to 89.13 per cent with an average 78.96 ± 4.52 per cent. The present findings are in more or less similar with Chaudhary *et al.* (2023) ^[5] who observed that *S. frugiperda* egg hatchability was 73.23 ± 6.72 per cent in maize. Siddhapara *et al.* (2021) ^[17] reported that *S. frugiperda* egg hatchability ranging from 72.00 to 95.54 per cent with a mean of 83.34 ± 9.87 per cent in maize. However, higher hatchability was reported by Gamil

(2020) ^[7] and Vinay *et al.* (2022) ^[19] who recorded values up to 97.33 per cent and 96.26 per cent, respectively on maize.

Larval and pupal period

The larva of *S. frugiperda* passed through six distinct larval instars. The duration of first to sixth larval instar ranged from 1 to 3, 2 to 3, 1 to 3, 2 to 4, 2 to 4 and 3 to 5 days, respectively. The average duration of first to sixth instar larvae were 1.98 ± 0.51 , 2.18 ± 0.39 , 2.34 ± 0.69 , 2.28 ± 0.54 , 2.74 ± 0.78 and 3.70 ± 0.61 days, respectively. The total larval period varied from 12 to 19 days with an average of 15.22 ± 1.43 days under laboratory conditions (Table 4.1). The present investigations are supported by Sharanabasappa *et al.* (2018) ^[14] who reported that a total larval period on maize ranging from 14 to 19 days with a mean of 15.90 ± 1.45 days. Kalyan *et al.* (2020) noted that total larval period completed in a mean duration of 16.97 days in maize. Devi *et al.* (2024) ^[6] stated that a mean total larval duration of 17.65 ± 1.59 days in maize. The variation in the findings may be due to different environmental conditions and the host used for the study.

The duration of pre-pupal stage ranged from 1 to 2 days with a mean of 1.32 ± 0.47 days (Table 4.1). The present findings are in partial agreement with Chaudhary *et al.* (2023) ^[5] who recorded that the duration of the pre-pupal stage ranged from 1 to 2 days with an average of 1.57 ± 0.50 days in maize.

The pupal period of *S. frugiperda* ranged from 8 to 10 days with a mean duration of 8.92 ± 0.70 days. The present findings are in partial agreement with Kashyap and Malik (2024) who recorded an average pupal duration of 9.20 ± 1.64 days. Chaudhary *et al.* (2023) ^[5] noted pupal period ranged from 8 to 13 days with an average of 9.24 ± 1.60 days. Siddhapara *et al.* (2021) ^[17] reported a mean pupal duration of 9.30 ± 0.65 (range of 8-10 days) days

Sex ratio and adult longevity

Out of the total 50 adults emerged, 28 were females and 22 were males, indicating a higher proportion of female adults of *S. frugiperda*. Hence, the sex ratio (male: female) was calculated as 1:1.27. The present findings are more or less agreed with reports of Ahir *et al.* (2020) ^[2] who observed a male-to-female ratio of 1:1.30. Siddhapara *et al.* (2021) ^[17] also reported a female-biased sex ratio in *S. frugiperda* (male: female 1:1.13).

Female adults exhibited a longer lifespan compared to males. The longevity of male adults ranged from 7 to 9 days with an average of 8.04 ± 0.84 days, whereas females survived for 8 to 11 days with an average of 10.00 ± 0.82 days (Table 4.1). The studies on adult longevity are more or less in accordance with Siddhapara *et al.* (2021) ^[17] who reported that adult longevity of *S. frugiperda* were 7.90 ± 0.84 days in males and 10.60 ± 1.22 days in females. Similarly, Sharanabasappa *et al.* (2018) ^[14] noted that female adults survived longer (mean 10.80 days) than males (mean 8.20 days). Ahir *et al.* (2020) ^[2] observed adult longevity in males (mean: 8.63 ± 1.05 days) and females (mean: 10.73 ± 0.72 days).

Pre-oviposition, Oviposition period, Post-oviposition period and fecundity

The pre-oviposition period of *S. frugiperda* ranged from 3 to 5 days with an average of 3.44 ± 0.65 days under laboratory conditions (Table 4.1). The findings of the present

investigation are in close confirmity with the report of Kalyan *et al.* (2020) and Siddhapara *et al.* (2021)^[17] who reported pre-oviposition periods of 3.47 days and 3.50 ± 0.51 days, respectively. Chaudhary *et al.* (2023)^[5] noted a pre-oviposition period of 3.08 ± 1.24 days.

The oviposition period of *S. frugiperda* ranged from 2 to 4 days with an average of 2.84 ± 0.69 days (Table 4.1). Sharanabasappa *et al.* (2018)^[14] and Kalyan *et al.* (2020) reported oviposition period recorded as mean of 2.8 days and 2.96 days, respectively. Siddhapara *et al.* (2021)^[17] showed mean oviposition period of 3.20 ± 0.89 days. Thus, the results of the present observation are more or less similar with past findings.

The post-oviposition period of *S. frugiperda* ranged from 3 to 5 days with an average of 3.76 ± 0.78 days (Table 4.1). The present study was closely tally with Siddhapara *et al.* (2021) who observed 3.90 ± 0.71 days of post-oviposition period. Sharanabasappa *et al.* (2018)^[14] reported a post-oviposition ranged from 4 to 5 days (mean 4.30 days). Ashok *et al.* (2020)^[3] and Chaudhary *et al.* (2023)^[5] reported comparatively lower mean post-oviposition period of 2.60 ± 0.69 64 days and 1.22 ± 1.52 days, respectively. The variation in post-oviposition period among different studies may be attributed to differences in environmental conditions such as temperature and relative humidity as well as laboratory rearing techniques.

Under laboratory conditions, a single female of *S. frugiperda* laid an average of 1216.88 ± 152.98 eggs with minimum egg laying of 832 to maximum 1428 eggs (Table 4.1). The fecundity recorded in the present study was accordance with Chaudhary *et al.* (2023)^[5] who revealed that each female of *S. frugiperda* laid 1272.88 ± 503.15 eggs with a range of 460 to 2424 eggs. Siddhapara *et al.* (2021)^[17] recorded 1145.43 ± 182.15 eggs per female with a range of 766 to 1389 eggs. Devi *et al.* (2024)^[6] observed that an average fecundity of *S. frugiperda* was 1104.4 ± 93.60 eggs per female.

Total life span

The total life span of male *S. frugiperda* was an average of 35.08 ± 1.98 days with a range of 30 to 38 days (Table 4.1). Ahmad *et al.* (2021) recorded an average total life cycle of *S. frugiperda* males ranged from 36 to 40 days with a mean of 35.32 ± 4.02 days. Siddhapara *et al.* (2021)^[17] reported total life span of *S. frugiperda* male was 34.50 ± 1.80 days (range: 32-38 days). Thus, the present findings are closely confirmity with past reports. The total life span of female *S. frugiperda* was an average of 37.56 ± 2.24 days with a range of 32 to 40 days (Table 4.1). The present findings are in close agreement with Siddhapara *et al.* (2021)^[17] who reported that total female lifespan of *S. frugiperda* was 37.20 ± 2.52 days (range: 32-40 days). Tiwari and Deole (2021)^[18] also recorded total female life cycle with a mean of 36.0 ± 0.75 days (range: 30-45 days).

Morphometrical measurements of egg, larva, pupa and adult

The eggs were dome shaped, dorso-ventrally flattened and pale green in colour initially, which turned golden yellowish and blackish in colour before hatching. The length and breadth of eggs were 0.44 ± 0.04 mm and 0.42 ± 0.04 mm, respectively (Table 2). These measurements are accordance with Siddhapara *et al.* (2021)^[17] who recorded that *S. frugiperda* egg dimensions were 0.43 ± 0.01 mm in length and 0.42 ± 0.03 mm in width. Similar observations were observed in Prasanna *et al.* (2018)^[13] and Chaudhary *et al.* (2023)^[5], respectively.

The neonate larvae were very small with a comparatively large black head. The larval body was pale green to yellowish in colour, bearing two black setae on each segment. The mature larvae had reddish brown head with cream body bears three white dorsal lines and alight lateral line. An inverted 'Y' shaped epicranial suture on the head and four black spots arranged in exact square on 8th abdominal segment were the key identification characters of sixth instar larvae. The length of first to sixth instar larvae were 1.09 ± 0.04 , 3.72 ± 0.22 , 6.58 ± 0.53 , 12.84 ± 0.92 , 22.55 ± 2.19 and 30.33 ± 2.04 mm, whereas breadth were 0.22 ± 0.03 , 0.54 ± 0.07 , 0.87 ± 0.08 , 1.16 ± 0.15 , 2.35 ± 0.38 and 3.14 ± 0.64 mm, respectively. Similar observations were observed in Kalyan *et al.* (2020).

The pre-pupa was pale green to bright brown in colour, darker and wrinkled body. The pupa was reddish brown in colour and with a pair of cremasters at the posterior end. The pupa was obect type. The distance between genital opening and anal slot was more in female pupa compared to male pupa. The length and breadth of pupa was 17.08 ± 1.28 and 4.87 ± 0.13 mm, respectively. The present investigations are close agreement with Jaba *et al.* (2020)^[9] who recorded an average pupal length and breadth were 16.89 and 4.73 mm, respectively.

Sexual dimorphism was clearly observed in adults. In males, the forewings were shaded grey and brown with reniform indistinct spot, faintly outlined in black, with a small V-shaped mark; light brown orbicular spot, somewhat oval and oblique in shape and white patch at the apical margin of the wing. The forewings of females were less distinctly marked, varying from uniform greyish-brown to finely mottled grey and brown patterns and without white patch near the apical margin of the wing as seen in males. In both sex, the hind wings were iridescent silver-white with a narrow dark border. The body length of male and female adults were measured as 17.27 ± 1.46 and 14.23 ± 1.72 mm. These findings are in close agreement with Chaudhary *et al.* (2023)^[5] who noted that the length of male moths ranged from 13 to 21 mm with an average of 16.62 ± 1.66 mm and female moths ranged from 13 to 19 mm with an average of 14.76 ± 1.58 mm. whereas wing expanse were 31.68 ± 0.94 and 32.28 ± 0.27 mm, respectively.

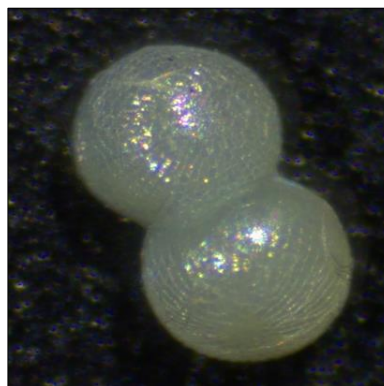
Table 1: Biology of fall armyworm, *S. frugiperda* on sorghum leaves under laboratory conditions

Sr. No.	Life stage	Min.	Max.	Average $\pm$ SD
1	Egg period			
	Incubation period (Days)	2	4	2.38 ± 0.60
2	Hatching (%)	73.86	89.13	78.96 ± 4.52
3	Larval period (Days)			
	1 st instar	1	3	1.98 ± 0.51
	2 nd instar	2	3	2.18 ± 0.39
	3 rd instar	1	3	2.34 ± 0.69

	4 th instar	2	4	2.28 ± 0.54
	5 th instar	2	4	2.74 ± 0.78
	6 th instar	3	5	3.70 ± 0.61
	Total larval period (Days)	12	19	15.22 ± 1.43
4	Pre-pupal period (Days)	1	2	1.32 ± 0.47
5	Pupal period (Days)	8	10	8.92 ± 0.70
6	Pre-oviposition period (Days)	3	5	3.44 ± 0.65
7	Oviposition period (Days)	2	4	2.84 ± 0.69
8	Post-oviposition period (Days)	3	5	3.76 ± 0.78
9	Sex ratio (Male: Female)	1:1.27		
10	Adult longevity			
	Male (Days)	7	9	8.04 ± 0.84
	Female (Days)	8	11	10.00 ± 0.82
	Fecundity (No. of eggs/female)	832	1428	1216.88 ± 152.98
11	Total life span			
	Male (Days)	30	38	35.08 ± 1.98
	Female (Days)	32	40	37.56 ± 2.24
12	Temperature (°C)	25.85	31.25	28.15 ± 1.44
13	Relative humidity (%)	59.41	95.23	78.11 ± 10.17

Table 2: Measurement of different life stages of fall armyworm, *S. frugiperda* under laboratory conditions

Sr. No.	Life stage	Particulars	Min. (mm)	Max. (mm)	Average ± SD (mm)
1.	Egg	Length	0.39	0.51	0.44 ± 0.04
		Breadth	0.36	0.53	0.42 ± 0.04
2.	Larva				
	1 st instar	Length	1.02	1.18	1.09 ± 0.04
		Breadth	0.15	0.26	0.22 ± 0.03
	2 nd instar	Length	3.08	4.05	3.72 ± 0.22
		Breadth	0.37	0.64	0.54 ± 0.07
	3 rd instar	Length	5.13	7.26	6.58 ± 0.53
		Breadth	0.61	1.02	0.87 ± 0.08
	4 th instar	Length	11.84	16.15	12.84 ± 0.92
		Breadth	0.86	1.36	1.16 ± 0.15
	5 th instar	Length	18.60	29.18	22.55 ± 2.19
		Breadth	1.38	2.78	2.35 ± 0.38
	6 th instar	Length	26.47	35.83	30.33 ± 2.04
		Breadth	1.73	4.17	3.14 ± 0.64
3.	Pupa	Length	15.05	20.47	17.08 ± 1.28
		Breadth	4.71	5.09	4.87 ± 0.13
4.	Adult				
	Male	Length	14.18	19.95	17.27 ± 1.46
		Wing expanse	29.80	33.53	31.68 ± 0.94
	Female	Length	11.74	20.18	14.23 ± 1.72
		Wing expanse	31.77	32.72	32.28 ± 0.27

**Photo 1:** Egg mass on muslin cloth**Photo 2:** View of eggs



(A)



(B)



(C)



(D)



(E)



(F)

Photo 3: Larvae of *S. frugiperda* (A): First, (B): Second, (c): Third, (D): Fourth, (E): Fifth and (F): Sixth instar

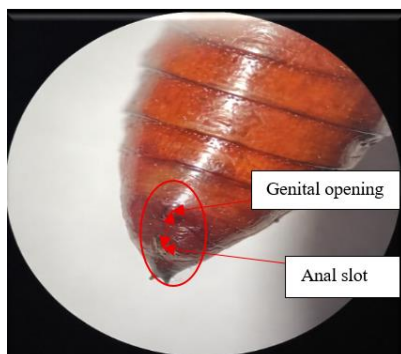


Photo 4: Male pupa of *S. frugiperda*

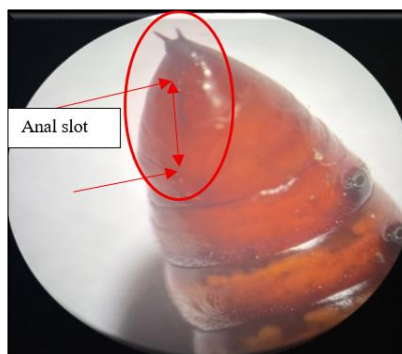


Photo 5: Female pupa of *S. frugiperda*



Photo 6: Male adult of *S. frugiperda*



Photo 7: Female adult of *S. frugiperda*

Conclusion: It can be concluded that the morphological description of fall armyworm, *S. frugiperda* would be useful for proper identification of various stages viz., egg, larva, pupa and adult. A female adult laid an average of 1216.88 ± 152.98 eggs per female. The incubation period, larval period and pupal period were an average of 2.38 ± 0.60 , 15.22 ± 1.43 and 8.92 ± 0.70 days, respectively. The adult period of male and female were an average of 8.04 ± 0.84 and 10.00 ± 0.82 days, respectively. The total life span of male and female were an average of 35.08 ± 1.98 and 37.56 ± 2.24 days, respectively. The sex ratio (male: female) was 1:1.27. This information would be useful for planning of integrated management strategy of fall armyworm under field conditions.

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