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Bionomics of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in maize

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Abstract

Investigations on bionomics of fall armyworm, *S. frugiperda* (J.E. Smith) infesting maize was carried out at PG Research Lab, Department of Entomology, College of Agriculture, JAU, Junagadh. For this experiment, duration and measurement of different stages of *S. frugiperda* viz., eggs, larva, pupa, adult and were studied. The life cycle of *S. frugiperda* revealed that the number of eggs laid by female was 327.4 ± 55.09 . As far as the hatching percent and the incubation period were concerned, 81.0 ± 5.91 percent and 2.43 ± 0.67 days were recorded. Mean period of larval instars i.e., first, second, third, fourth, fifth, sixth was 2.56 ± 0.49 , 2.30 ± 0.46 , 2.03 ± 0.60 , 2.00 ± 0.58 , 2.40 ± 0.61 , 4.63 ± 0.66 , respectively with a total larval period of 15.93 ± 1.48 days. Pre-oviposition, oviposition and post-oviposition periods were 4.2 ± 0.75 , 3.6 ± 0.49 and 4.4 ± 0.80 days, respectively. The period of pupal stage was 9.37 ± 0.91 days. Male and female adult longevity were 8.8 ± 1.17 and 11.6 ± 1.02 days, respectively. Total male and female adult life span were 37.6 ± 1.36 and 40.4 ± 1.62 days, respectively having 1:1.72 (Male: female) of sex ratio. The morphometric data viz., larval body length; pupal length and adult body length and wing span were measured.

Keywords: Life cycle, egg, larva, pupa, adult, duration and measurements

Introduction

Maize (*Zea mays* subsp. *mays*) also known as corn is a cereal crop first domesticated by indigenous peoples in Southern Mexico about 10,000 years ago. Maize provides 50-60 percent of daily human energy requirements. Maize is a good source of the vitamin B complex, thiamin, niacin, and pantothenic acid (B5) and also supplies dietary fiber and some essential minerals i.e. magnesium, zinc, phosphorus, copper, etc. (Bathla *et al.*, 2019) [6]. Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain. India produced 33.62 million tonnes in an area of 10.04 million hectares in 2021-22, whereas in *Kharif* 2022-23, maize production was 23.10 million tonnes in an area of 9.68 million hectares (Anon., 2022) [4]. In Gujarat, important districts growing maize are Dahod, Panchmahal, Vadodara, Kheda, Banaskatha, Bharuch, Anand and Dang. During 2020-21 in Gujarat, the *kharif* maize area, production and yield are 2867.05 ha., 4360.36 million tonnes, 1520.85 kg/ha yield respectively (Anon., 2020-21) [3]. The maize plant is attacked by 140 species of insect pests causing varying degrees of damage. However, only about a dozen are quite serious among these insect pests, only twelve species cause serious damage from sowing till storage (Arif *et al.*, 2019) [5]. The fall armyworm is an arthropod and larvae are the most damaging stage. Its scientific name is derived from Latin, which is *frugiperda* for last fruit, named because of the ability of species to destroy crops (Anon., 2017a). The fall armyworm moth lays eggs on the plant's foliage. The egg stage lasts for only 2-3 days in warmer weather. There are six "instars" in larval stage, whose entire duration is from 14-30 days. The first instar larvae are off-white to yellow with black head capsules and small black spots from which primary setae protrude. Larvae darken as they feed and appear greenish (Luginbill, 1928) [13].

Materials and Methods

The bionomics of *S. frugiperda* was studied at the PG Research Laboratory, Department of Entomology, College of Agriculture, JAU, Junagadh. *S. frugiperda* larvae collected from a maize field were reared in a galvanized tray with fresh maize leaves and whorls in a BOD

incubator (25 ± 1 °C, $70\pm 5\%$ Rh). Every day, sufficient fresh leaves and whorls were provided to *S. frugiperda* larvae after removing excreta and partially eaten leaves from the tray until the larvae changed to pre-pupal form. The top of the tray was covered with fine muslin cloth held in position by a rubber band. Before the formation of the pre-pupal stage, the Petri plate was filled with moist soil for pupation in the soil. The pupae formed in the soil were collected and transferred to another Petri plate for the emergence of the adults. A newly emerged male and female moth pair were confined in a glass jar with fresh maize leaves for resting and egg-laying. A small container with cotton swabs dipped in a five percent honey solution provided food. The jar was covered with muslin cloth and secured with a rubber band. Daily, fresh leaves were given, and eggs laid were collected for study. Observations included egg days, hatching percentage, larval days, pre-pupal and pupal days, pre-oviposition, oviposition and post-oviposition periods, fecundity, longevity of male and female, sex ratio, and total life span. Measurements of eggs, larval instars, pupa, and adults were taken with a vernier caliper.

Results and Discussion

Eggs

The eggs were typically laid in clusters of 267 to 395, either in a single layer or stacked in two to three layers. They were dome-shaped, covered with greyish-white scales from the female abdomen. Initially, the eggs were white to pale green, transitioning to brown or black just before hatching. The incubation period ranged from 2-4 days, with a mean of 2.43 ± 0.67 days (Table 1). Egg laying took place at night in the lab, and hatching occurred in the early morning after 2-3 days. Kranthi *et al.* (2021) [12] revealed that the incubation period of fall armyworm eggs was 2-3 days with a mean of 2.28 ± 0.075 days. The average length and width of eggs (Table 2) were 0.34 ± 0.03 mm and 0.29 ± 0.008 mm, respectively. These measurements align with Manjula *et al.* (2019) [14], who reported egg dimensions as 0.47 mm in length and 0.29 mm in width. Sharanabasappa *et al.* (2018) [18] observed a comparable incubation period of 2.50 ± 0.50 days on maize for fall armyworm, consistent with the present study.

Egg hatching percentage for *S. frugiperda* moths reared on maize averaged 81.0 ± 5.91 percent (Table 1), with a recorded range of 72% to 88%. These results align with Uma and Nagamandla (2018), who reported a similar hatching percentage of 81.50 ± 8.49 percent for *S. frugiperda* on artificial diets, supporting the findings of the present study.

Larva

First instar

The first instar larva of *S. frugiperda* exhibited a light greenish color with a prominent black head and minute hairs covering the body. The spiracles were observable in each instar. The duration of the first instar ranged from 2.00-3.00 days, with a mean of 2.56 ± 0.49 days (Table 1), consistent with findings by Sharanabassapa *et al.* (2018) [18] who reported an average duration of 2.60 ± 0.49 days. Navasero and Navasero (2020) [16] observed a yellowish first instar larva with a dark appearance due to a brownish-black setae and a black head. The development duration was 2.28 ± 0.45

days for males and 2.40 ± 0.49 days for females. The mean length and width of the first instar were 1.57 ± 0.19 mm and 0.31 ± 0.027 mm, respectively (Table 2), aligning with Reddy *et al.* (2021) [17] who reported a mean length of 1.42 ± 0.28 mm and width of 0.28 ± 0.06 mm for the first instar larva.

Second instar

In the second instar of *S. frugiperda* reared on maize, the size increased, and the head showed a slightly greenish-brown color, while the body exhibited a tinge of brown on the dorsum. Black spots, notably four arranged in a square pattern on the 8th abdominal segment and an inverted 'Y' on the head, were observed under a binocular microscope. The mean duration of the second instar was 2.30 ± 0.46 days (Table 1), with 2.00-3.00 days, in line with findings by Dubale *et al.* (2022) [8] who gave the mean period of 2.00 ± 0.00 and 2.33 ± 0.48 days. The mean length and width of the second instar larva were 1.57 ± 0.19 mm and 0.31 ± 0.027 mm, respectively (Table 2), contrasting with Reddy *et al.* (2021) [17], who reported a mean length of 3.32 ± 0.48 mm and a width of 0.69 ± 0.04 mm.

Third instar

In the third instar, *S. frugiperda* larvae displayed a greenish-orange color with a size larger than the second instar. The mean duration was 2.03 ± 0.60 days (Table 1), ranging from 1.00-3.00 days. Dubale *et al.* (2022) [8] recorded an average of 2.10 ± 0.31 days for the third instar. The mean length and width of the third instar larva were 5.98 ± 0.53 mm and 1.88 ± 0.23 mm, respectively (Table 2), aligning closely with Kalyan *et al.* (2020) [10], who reported an average length of 6.2 ± 0.30 mm.

Fourth instar

In the fourth instar, the larva exhibited a brownish head with white subdorsal and lateral lines. Notably, the 8th abdominal segment displayed a square pattern arrangement of black spots, while a trapezoidal pattern arrangement of black spots was visible on the 1st-7th and 9th segments. The fourth instar duration ranged from 1.00-3.00 days, with a mean of 2.00 ± 0.58 days (Table 1). Consistent with this, Reddy *et al.* (2021) [17] observed a range of 2.00 - 3.00 days with a mean of 2.4 ± 0.51 days. The mean length and width of the fourth instar larva were 9.94 ± 0.59 mm and 3.08 ± 0.33 mm, respectively (Table 2), closely aligning with Kalyan *et al.* (2020) [10], who reported an average length of 9.7 ± 0.55 mm.

Fifth instar

The larva in its fifth instar exhibited a light brown color on its back and a greenish hue on the lower and sub-ventral sides, a distinctive feature shared with the fourth instar larva. The duration of the fifth instar spanned from 2.00-3.00 days, with an average of 2.40 ± 0.61 days (Table 1). These results were in line with the earlier findings of Sharanabassapa *et al.* (2018) [18], who reported an average duration of 2.00 ± 0.00 days for the fifth instar larva of *S. frugiperda*. In terms of size, the mean length and width of the fifth instar larva were 16.28 ± 1.06 mm and 4.74 ± 0.49 mm, respectively (Table 2). Reddy *et al.* (2021) [17] corroborated these observations, revealing a mean length of 16.5 ± 0.99 mm and a width of 4.74 ± 0.33 mm.

Sixth instar

The sixth instar larva, the final stage, exhibited similarities with the fourth and fifth instars, characterized by a dull brown color on the dorsum and a greenish or reddish-brown color on the ventral and sub-ventral sides. The larva appeared thicker, more bulged, and slightly cylindrical, with a smooth body displaying clear and distinct segmentation. It grew larger with more prominent and darker spots compared to the fourth and fifth instar larvae. Cannibalism in *S. frugiperda* larvae was noted by Jason *et al.* (2001) [9], occurring commonly, especially at low food quantities and high rearing densities, irrespective of the larva's sex. The probability of cannibalism was influenced by the larval stage. The duration of the sixth instar larva ranged from 4.00-6.00 days, with a mean of 4.63 ± 0.66 days (Table 1), aligning closely with Sharanabassapa *et al.* (2018) [18], who previously reported it as 4.50 ± 0.50 days. Keerthi *et al.* (2021) [11] revealed the mean development time of the sixth larval instar was 5.08 ± 0.74 days when larva were reared on maize. Regarding size, the mean length and width of the sixth instar larva were 33.9 ± 1.55 mm and 5.89 ± 0.22 mm, respectively (Table 2). These findings were consistent with Deole and Paul (2018) [7], who reported lengths of 32-35 mm and a width of 6.01 mm.

Total larval period

The total larval duration ranged from 13-18 days, with a mean of 15.93 ± 1.48 days (Table 1). These results were consistent with Murua *et al.* (2008), who reported an average larval duration of 18.18 days for *S. frugiperda*. Reddy *et al.* (2021) [17] observed a variation from 14-21 days, with a mean duration of 18.0 ± 2.16 days.

Sex ratio

The sex ratio of male-female moth of *S. frugiperda* was 1:1.72. The present findings are in close Ahir *et al.* (2020) [1] studied the sex ratio of male:female was 1:1.30.

Pre-pupa and pupa

The full-grown larva ceased feeding, transitioning from a pale green to a bright brown color, releasing moisture and entering the pre-pupal stage. This stage lasted 1-2 days, averaging 1.33 ± 0.47 days (Table 1), consistent with Deole and Paul (2018) [7], who also observed 1-2 days pre-pupal period on maize. The reddish-brown pupa with cremasters exhibited sexual dimorphism, distinguished by the distance between the genital opening and anal entrance slots. Female pupae had a greater distance than male pupae. Pupation occurred within the soil, forming an earthen cocoon by binding soil particles with silk. The pupal period for *S. frugiperda* reared on maize averaged 9.37 ± 0.91 days, ranging from 8.00-11.00 days (Table 1), aligning with Reddy *et al.* (2021) [17], who reported a variation from 9 to 12 days with a mean duration of 9.9 ± 0.99 days. The average length and width of the pupa were 15.94 ± 1.27 mm and 4.93 ± 0.12 mm, respectively (Table 2). These measurements

closely resembled Reddy *et al.*'s (2021) [17] findings of an average length of 16.08 ± 1.3 mm and a width of 4.94 ± 0.15 mm.

Pre-oviposition, oviposition, postoviposition

The period before egg-laying (pre-oviposition) lasted 3-5 days, averaging 4.2 ± 0.75 days. Oviposition primarily took place at night, with females laying eggs in clusters three to four days after emerging. The actual egg-laying period (oviposition) ranged from 3-4 days, with a mean of 3.6 ± 0.49 days. Following oviposition, the post-oviposition period spanned from 3-5 days, with an average of 4.4 ± 0.80 days (Table 1). Reddy *et al.* (2021) [17] reported a pre-oviposition period ranging from 2-3 days, averaging 2.7 ± 0.48 days, while the oviposition period was 3-5 days, with a mean of 4.6 ± 0.70 days. The post-oviposition period ranged from 2-3 days, averaging 2.6 ± 0.52 days.

Adults

The adult moth was small to medium-sized, displaying clear sexual dimorphism. Male moths had forewings shaded in grey and brown, marked with triangular white spots, while females had less distinct markings ranging from uniform greyish brown to fine grey and brown mottling. Both sexes had iridescent silver-white hind wings with a narrow dark border. Female moths exhibited longer lifespans than males. Males lived for 7-10 days, averaging 8.8 ± 1.17 days, whereas females had a longevity range of 10-13 days, with a mean of 11.6 ± 1.02 days (Table 1). These findings were consistent with Dubale *et al.* (2022) [8], who reported a female adult survival period of 9.8 days (range: 9-11 days) and a male survival period of 8.7 days (range: 7-11 days). Siddhpara *et al.* (2021) [19] found that male and female adults lived for 7.90 ± 0.84 days and 10.60 ± 1.22 days, respectively.

Morphometric data analysis indicated that male moths were slightly larger than females. The mean body length of male moths was 15.42 ± 1.25 mm, while females measured 15.08 ± 1.58 mm (Tables 2). These findings aligned closely with Reddy *et al.* (2021) [17], who reported a mean body length of 15.20 ± 1.30 mm for males and 15.0 ± 1.58 mm for females. In terms of wing span, male moths had a measurement of 32.77 ± 2.08 mm, whereas females had a slightly smaller wing span of 32.15 ± 2.40 mm (Table 2). Reddy *et al.* (2021) [17] found similar results, with a wing span of 32.4 ± 2.07 mm for males and 31.8 ± 2.38 mm for females.

Total life span

The average life span of male *S. frugiperda* reared on maize was 37.6 ± 1.36 days, ranging from 36.00-39.00 days (Table 1). Similarly, the average life span of female moths was 40.4 ± 1.62 days, with a range of 38.00-42.00 days. These findings align with Sharanabasappa *et al.* (2018) [18], who reported a total life cycle duration of 37.50 ± 5.00 days and 40.50 ± 4.88 days for males and females.

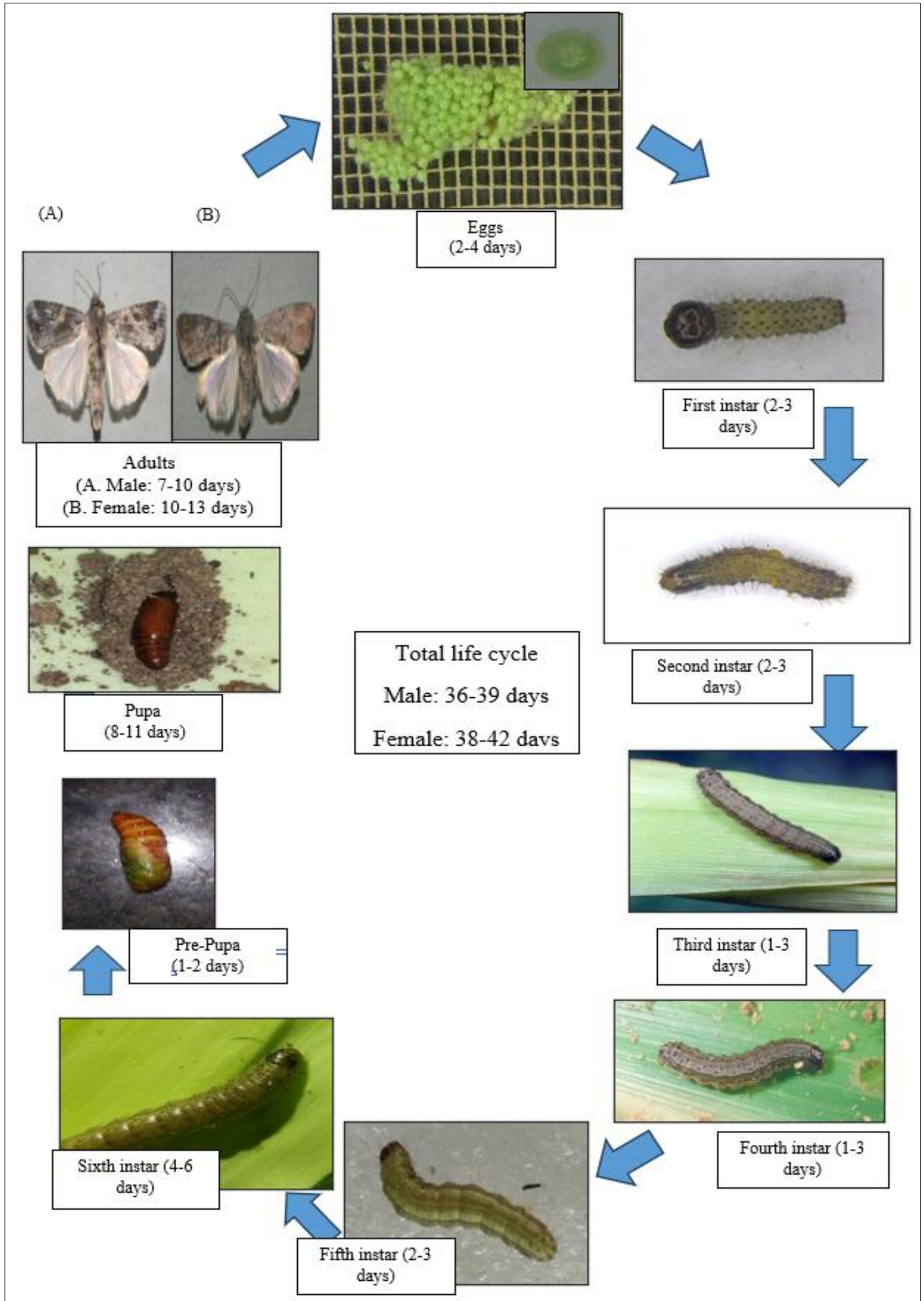


Fig 1: Life cycle of *S. frugiperda*
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Table 1: Bionomics of *S. frugiperda* under lab condition

Sr.no.	Stage of insect	No. observed	Range (days)	Mean \pm SD (days)
1.	Incubation period	30	2-4	2.43 \pm 0.67
2.	Larval period	30		
a.	I instar	30	2-3	2.56 \pm 0.49
b.	II instar	30	2-3	2.30 \pm 0.46
c.	III instar	30	1-3	2.03 \pm 0.60
d.	IV instar	30	1-3	2.00 \pm 0.58
e.	V instar	30	2-3	2.40 \pm 0.61
f.	VI instar	30	4-6	4.63 \pm 0.66
	Total larval period	30	13-18	15.93 \pm 1.48
3.	Pre pupal period	30	1-2	1.33 \pm 0.47
4.	Pupal period	30	8-11	9.37 \pm 0.91
5.	Adult longevity	10		
a.	Male	5	7-10	8.8 \pm 1.17
b.	Female	5	10-13	11.6 \pm 1.02
6.	Sex ratio	30		1:1.72
7.	Total life cycle	10		
a.	Male	5	36-39	37.6 \pm 1.36
b.	Female	5	38-42	40.4 \pm 1.62
8.	Pre oviposition period	5	3-5	4.2 \pm 0.75
9.	Oviposition period	5	3-4	3.6 \pm 0.49
10.	Post-oviposition	5	3-5	4.4 \pm 0.80
11.	Hatching percentage (%)	100	72-88	81.0 \pm 5.91
12.	Fecundity	5	267	263.2 \pm 55.09

Conclusion

Understanding the bionomics of the fall armyworm in maize is crucial for comprehending its life history and behaviors, aiding in the identification of its most susceptible stage and the development of effective management strategies. Research on the biology of the fall armyworm on maize uncovered key aspects of its life cycle. Female adults laid between 267-395 eggs, with an incubation period of 2.43 days. The total larval duration spanned 15.93 days, followed by a pupal period lasting 9.37 days. The pre-oviposition, oviposition, and post-oviposition periods were observed as 4.2, 3.6, and 4.4 days, respectively. The average longevity of males and females was noted as 8.8 and 11.6 days, respectively. The entire life cycle, from egg to adult, was completed in 37.6 days for males and 40.4 days for females. Additionally, morphometric data, including larval body length, pupal length, adult body length, and wing span, were meticulously measured.

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