Original Research Article

Study on Biology of Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) on Maize, *Zea mays* L. in Manipur

ABSTRACT

Aim: To study the biology and morphometric parameters of different stages of fall armyworm, *Spodoptera frugiperda*.
Study design: Experimental study
Place and Duration of Study: PG laboratory, Department of Entomology, College of Agriculture, Iroisemba, CAU (Central Agricultural University), Imphal, June-August 2022.
Methodology: The egg masses collected from maize fields were transferred to sterilized petri plates containing maize leaves and reared under laboratory conditions (25±2°C, 70±10% RH). Duration and morphometric parameters of different stages of fall armyworm were recorded regularly.
Results: The mean incubation period of eggs was observed to be 1.90 days. The larval period of six instars were recorded to be 2-4, 2-5, 2-3, 2-3, 2-3, 2-3 and 3-6 days, respectively. The mean larval length of six instars were 1.91, 3.38, 6.15, 9.78, 18.60 and 32.30 mm, respectively. The mean larval width of six instars were 0.33, 0.74, 1.31, 2.26, 2.92 and 3.53 mm, respectively. The average larval weight of six instars were 0.0031, 0.0214, 0.0420, 0.0503, 0.0576 and 0.0652 gm, respectively. The total larval duration was observed to be 16.70 days. The male and female pupal period was found to be 7.60 and 7.10 days, respectively. The average male pupal length, width and weight were 14.79±0.18 mm, 4.54±0.14 mm and 0.17±0.01 gm, respectively. The average female pupal length, width and weight were 13.0-18.20 mm, 4.0-5.2 mm and 0.18±0.01 gm, respectively. The ovipositional period was found to be 1-6 days. Mean longevity of males and females were observed to be 8.70 and 9.00 days, respectively. The total life cycle of male and female lasted 34.90 and 35.60 days, respectively.
Conclusion: This study clearly provides basic information about the biology of this recently invaded pest. To prevent the potential devastating occurrence, compatible integrated pest management strategies are needed at the early stages of FAW infestation.

Keywords: *Maize; fall armyworm; Spodoptera frugiperda; biology; morphometric parameters*

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1. INTRODUCTION

Maize (*Zea Mays*) (Family: Poaceae), the American Indian word for corn, means literally "that which sustains life", originated in the Andean region of Central America. After rice and wheat, it is the third most important cereal grain in the world, providing nutrients for people and animals as well as being a major source of raw materials to produce starch, oil, and protein, alcoholic beverages, culinary sweets and more recently, fuel [1]. The USA and China are the major producers with 36% and 25% of the world's total production of maize, respectively. India, with an annual output of 31.65 million MT, is currently ranked sixth among the world's top ten maize producers [11]. Maize production is currently hampered by a number of biotic and abiotic problems. Although there are roughly 141 insect pests that impair the maize crop in varying degrees, just a dozen of them are~~is~~ serious enough to

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cause significant damage [12, 18]. Specifically, shoot fly, pink stem borer, and maize stalk borer are the insects of national importance. Besides these, recently introduced pest, *S. frugiperda* is a serious concern due to its notorious and polyphagous behavior, became an invasive challenge across the world.

Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a native pest of of America [13]. It has been reported for the first time in 2016 in Africa [10], causing the yield losses of maize estimated at 2.5 to 6 million US$ in 2017 [2]. Of late, FAW invaded the Indian subcontinent for the first time during mid 2018 infesting research fields of maize at the University of Agricultural and Horticultural Sciences, Shimoga, Karnataka [19] and spread quickly to many other states [21] including Northeast India which was first reported during late March 2019 in Lunglei district of Mizoram and West Tripura district of Tripura state. In Manipur, it was first detected on 7th May 2019 in Chandanpokpi village of Chandel district and subsequently reported from all the districts of Manipur [9].

FAW, a highly polyphagous pest, voraciously feeds on maize and survives on more than 350 crop plants [14]. The early instar larvae feed on the leaves by scraping and skeletonizing the upper epidermis, producing a translucent membrane resulting in papery patches and pinhole symptoms. Late instars cause substantial defoliation and produce a significant amount of faecal pellets in the whorls. During the reproductive stage, larvae damage tassels or bore inside the cob and eat away the kernels. Thus, the objective of this study was to present the baseline information on the biology of *S. frugiperda* which is helpful to formulate proper and effective pest management techniques. Keeping this in view, present study was conducted.

2. MATERIAL AND METHODS

2.1 Collection and mass multiplication of *S. frugiperda*

To study the biology of *S. frugiperda* on maize, initially egg masses were collected from maize fields of Andro Research Farm, CAU, Imphal, India. These egg masses were transferred to sterilized petri plates (with 70% ethanol and shade dried) containing young maize leaves which served as an immediate source of food for neonate larvae. After hatching, five neonate larvae were transferred to each petri plate containing young maize leaves. From the third instar, larvae were transferred individually to a sterilized petri plate due to cannibalistic behavior in mature larvae of fall armyworm and were kept in a rearing room at room temperature until pupation. Fresh maize leaves were given every day till the larvae entered the sixth instar stage. Pupae were separated based on distance from the genital opening to the anal slit [4] and kept in the same rearing room. One pair of pupae (male & female) were confined to each oviposition jar for mating. 5-8 day old maize plants were placed in an upright position inside the jar and the stem was wrapped with cotton in a small vial containing water to keep it upright. Cotton swab dipped in ten~~10~~ per cent honey solution was kept in the jar as food for adults. Transparent jars were covered with a fine muslin cloth and secured with a rubber band. The maize leaves and stems were replaced every day and inspected for egg batches. The portion of leaves bearing egg masses were removed carefully and transferred to petri plates with tender portion of maize leaf and used for further studies.

2.2 Statistical Analysis

Duration of different developmental stages of fall armyworm, i.e., egg, larva, pupa and adult were recorded regularly. Morphometric parameters such as length and width were also recorded by visually graphical method and weight by using electronic weighing balance. The

data collected on duration and size of different stages of insect were analyzed by calculating mean (n=10) and standard error.

3. RESULTS AND DISCUSSION

Results from the biology of *S. frugiperda* on maize revealed that the total life cycle of male and female lasted approximately 34.0 and 35.6 days, respectively. The duration and morphometric observations of different life stages of FAW were shown in Table 1 and 2, respectively.

3.1 Egg

Egg masses containing 35-335 eggs were laid by the female in a single layer or stacked up in two to three layers on under or upper surface of the maize leaf, at base of the plant and also in whorls. The eggs were dome shaped and covered with greyish white body scales of females. The eggs were pale yellow or creamy in colour at the time of oviposition which later turned brown to black just before hatching. The incubation period of the eggs under laboratory conditions ranged between 1-3 days with an average of 1.9±0.18 days [Table 1 and Fig.1(a)]. The present findings are in close agreement with the earlier research work of Dubale et al. [7], who observed the incubation period of 2.4 days. Incubation period of 2-3 days on maize was reported by Reddy et al. [16], Sharanabasappa et al. [19], Vishwakarma et al. [23] and Dileep Kumar and Murali Mohan [2022]. Reddy et al. [17] noticed that the average fecundity per female was 330 eggs with incubation period of 2-4 days on maize.

3.2 Larva

The larval stage of FAW completes in six instar stages. The young larvae were greenish in colour with black head whereas fully grown larvae were brownish in colour with a typical inverted 'Y' shape on head capsule [Fig. 2(a)] and four dark spots that form a square on the second to last segment [Fig. 2(b)].

3.2.1 First instar

The first instar larvae were very tiny and completely devoured the eggshells from which they hatched. Larvae had a comparatively large flattened circular black head and a whitish body covered with minute hairs. The duration of first instar larvae ranged from 2-4 days with a mean of 2.6±0.31 days [Table 1 and Fig. 1(c)]. Sharanabassapa et al. [19], Deepika Kalyan et al. [3], Reddy et al. [16] and Reddy et al. [17] reported the average first instar larval duration of *S. frugiperda* was 2.6±0.49, 2.80, 2.33±0.48 and 2.6±0.51 days, respectively which support the present findings. The mean length, width and weight of the first instar larvae were 1.91±0.12 mm ranging from 1.5-2.5 mm, 0.33±0.04 mm ranging from 0.2-0.5mm and 0.0031±0.0001 gm ranging from 0.0025-0.0038 gm, respectively (Table 2). Similarly, Deepika Kalyan et al. [3] observed the average length of 1.8±0.15 mm. Reddy et al. [17] observed the average length and width of 1.42±0.28 and 0.28±0.06 mm, respectively. Dinah Marri et al. [6] also studied the average length and weight of first instar larvae were 4.63 mm and 0.003 gm, respectively.

3.2.2 Second instar

The second instar larvae were amber coloured with a pale white to yellowish body and a brown tinge on the dorsum. At this stage, faint white dorsal and subdorsal lines started to appear on the body. The duration of the second instar larvae ranged from 2-5 days with a mean of 2.7±0.30 days [Table 1 and Fig. 1(d)]. The results are in accordance with the

findings of Deepika Kalyan et al. [3] and Reddy et al. [17] who observed the duration of second instar larvae was 2.5 and 2.7±0.48 days, respectively. The mean length, width and weight of the second instar larvae were 3.38±0.18mm ranging from 3.0-4.5mm, 0.74±0.05 mm ranging from 0.5-0.9 mm and 0.0214±0.0011 gm ranging from 0.0145-0.0256 gm, respectively (Table 2). The present findings are more or less similar with Deepika Kalyan et al. [3] who reported the mean length of 3.5±0.45 mm. Reddy et al. [17] observed the mean length and width of 3.32±0.48 and 0.69±0.04 mm, respectively. Dinah Marri et al. [6] observed the average weight of second instar larvae was 0.019 gm.

3.2.3 Third instar

The 3rd instar larvae showed an immense change in body colour. The larval body colour changed from light white to greenish brown. The larvae were light brown on the dorsal side and greenish on the ventral side. On the dorsal and sub-dorsal sides, the white lines were clearly visible and the black dots became more prominent. The duration of the third instar larvae ranged from 2.00-3.00 days with a mean of 2.10±0.10 days [Table 1 and Fig. 1(e)]. The present results showed similarity with the previous findings of Dubale et al. [7] who reported the average duration of 3rd instar larvae was 2.10±0.31 days with a range of 2-3 days. The mean length, width and weight of the third instar larvae were 6.15±0.34 mm ranging from 5-8 mm, 1.31±0.06 mm ranging from 1.0-1.5 mm and 0.0420±0.0008 gm ranging from 0.0376-0.0457 gm, respectively (Table 2). The present findings are similar with Reddy et al. [17] who observed an average length and width of 5.78±0.56 and 1.88±0.19 mm, respectively. Dinah Marri et al. [6] observed an average weight of 0.045 gm.

3.2.4 Fourth instar

The larval appearance changed noticeably from third to fourth instar. Their body colour ranged from olive to dark brown. Dorsal and sub dorsal white lines and inverted “Y” shape on head capsule became prominent. The duration of the fourth instar larvae ranged from 2-3 days with a mean of 2.3±0.15 days [Table 1 and Fig. 1(f)]. Sharanabasappa et al. [19], Deepika Kalyan et al. [3] and Reddy et al. [17] reported the average duration of fourth instar larvae as 2.00, 2.00 and 2.4 days, respectively. The mean length, width and weight of fourth instar larvae were 9.78±0.21 mm ranging from 9.0-11.0 mm, 2.26±0.07 mm ranging from 2.0-2.5 mm and 0.0503±0.0009 gm ranging from 0.0451-0.0546 gm, respectively (Table 2). More or less similar observations were recorded by Deepika Kalyan et al. [3] who reported an average length of 9.7±0.55 mm. Reddy et al. [17] observed an average length and width of 10.0±0.60 and 3.08±0.34 mm, respectively. Dinah Marri et al. [6] observed an average weight of 0.050 gm which supports the present findings.

3.2.5 Fifth instar

The fifth instar larvae were observed like those in their earlier instars, but larger in size. The larvae attained greyish brown colour on the dorsum and greenish colour on the ventral and sub-ventral sides. A distinctive pattern of four "dots" were observed on the eighth abdominal segment of larvae arranged in square manner and in trapezoidal manner on remaining abdominal segments. The duration of fifth instar larvae ranged from 2-3 days with a mean of 2.60±016 days [Table 1 and Fig. 1(g)]. The results showed similarity with the past findings of Sharanabassapa et al. [19], Deepika Kalyan et al. [3] reported an average duration of 2.8 days. The mean length, width and weight of the fifth instar larvae were 18.60±0.72 mm ranging from 15-22 mm, 2.92±0.03 mm width ranging from 2.8-3.0mm and 0.0576±0.0017 gm weight ranging from 0.0496- 0.0654 gm, respectively (Table 2). The present results are in line with the findings of Deepika Kalyan et al. [3] who reported an average length of

16.8±1.08 mm. Reddy et al. [17] observed an average length and width of 16.5±0.99 and 4.74±0.33 mm, respectively. Dinah Marri et al. [6] observed an average weight of 0.060 gm.

3.2.6 Sixth instar

During this stage, the larvae were stout, thicker, more bulged and slightly cylindrical in shape. The head of the larva was dark and bilobed in appearance, while the larval body was smooth with distinct segmentation. On the dorsum, the body was greyish-brown, and on the ventral and sub-ventral sides, it was greenish-speckled with reddish brown colour. The duration of the sixth instar larvae ranged from 3.00-6.00 days with a mean of 4.40±0.31 days [Table 1 and Fig. 1(h)]. The present findings are in close agreement with the earlier research work of Dubale et al. [7] having an average duration of 4.67±0.76 days. Reddy et al. [17] reported the mean duration of sixth larval instar was 5.1±0.87 days ranging from 4-6 days. The length, width and weight of the sixth instar larvae ranged from 28-39 mm, 3-4 mm and 0.0652±0.0012 gm, respectively having an average length of 32.3±1.23 mm, width of 3.53±0.13mm and weight of 0.0612-0.0722 gm (Table 2). Sonali Deole and Nandita Paul [22] reported the length and width of sixth instar larva were 32-35 and 6.01 mm, respectively. Dinnah Marri et al. [6] reported the larval weight of 0.067 gm which supports the present findings.

3.2.8 Total larval period

The total larval duration varied from 14 to 20 days with a mean duration of 16.70±1.33 days (Table 1). The result showed similarity with the previous findings of Dubale et al. [7] who observed the total larval period ranged from 14-18 days with mean of 16.07 days.

3.3 Pupa

During the prepupal stage, the fully grown larvae stopped feeding and changed to a vivid brown colour. The pupae were initially orange-brown in colour and later turned to dark reddish brown. Male and female pupae were separated based on distance from the genital opening to anal slot. The distance was more in female pupa when compared to the male [Fig. 1(j) and 1(k)]. The pupal period ranged from 6-8 days with a mean of 7.30±0.26 days. The male pupal period ranged from 7-8 days with a mean of 7.6±0.16 days whereas the female pupal period ranged from 6-8 days with an average of 7.10±0.28 days (Table 1). The present findings are in close agreement with Ramya and Maheswari [15] having 8-9 days of pupal period. Ashok et al. [1] reported the pupal period of 8.24 days on maize.

The male pupal length ranged from 14.0-16.0 mm with a mean of 14.79±0.18 mm, width ranged from 4.0-5.2 mm with a mean of 4.54±0.14 mm and weight ranging from 0.15-0.20 gm with a mean of 0.17±0.01 gm. The female pupal length ranged from 13.0-18.20 mm with a mean of 14.88±0.47 mm, width ranging from 4.0-5.2 mm with a mean of 4.54±0.14 mm and weight ranging from 0.16-0.22 gm with a mean of 0.18±0.01 gm (Table 2). Deepika Kalyan et al. [3] reported that the mean pupal length of *S. frugiperda* was 15.7±1.55 mm ranging from 14.0-19.0 mm. Reddy et al. [17] showed similarity by having an average length and width of 16.08±1.3 and 4.94±0.15 mm, respectively.

3.4 Adult

The adult is a small to medium sized moth where sexual dimorphism was clearly evident. Female forewings were less distinctly marked, ranging from a uniform greyish brown to a fine mottling of grey and brown [Fig. 1(m)], whereas male forewings were generally shaded in grey and brown colour with triangular white spots at the tip and near the centre [Fig. 1(l)].

Both sexes had iridescent silver white hind wings with a thin dark border. The oviposition period ranged from 1-6 days with a mean of 3.10±0.59 days (Table 1). The present results are in line with Reddy et al. [17] who recorded an average oviposition period of 3.02±0.78 days ranging from 3-4 days. The total life cycle of male and female ranged from 29-39 days with a mean of 34.90±1.07 days and 32-42 days with a mean of 35.60±0.96 days, respectively. The results are in close conformity with the earlier findings of Deepika Kalyan et al. [3] who reported an average life cycle of male and female was 36.15 and 40.11 days, respectively. Similarly, Sharanabasappa et al. [19] observed an average life cycle of male and female ranged from 32-43 and 33-46 days, respectively. Siddhapara et al. [20] reported the total life cycle of male and female was 34.50±1.80 and 37.20±2.52 days, respectively. The adult male and female longevity ranged from 4-13 days with a mean period of 8.70±0.94 days and 5-12 days with a mean period of 9.00±0.73 days, respectively. Reddy et al. [17] reported an average male longevity of 9.10 days and female longevity of 11.52 days. Similarly, Vishwakarma et al. [23] reported an average male longevity of 8.0 days and female longevity of 10.5 days. Sharanabasappa et al. [19] reported 8.2 and 10.8 days of longevity for male and female moth of *S. frugiperda,* respectively.

Table 1 Duration of different life stages of *Spodoptera furgiperda* (J. E. Smith) on maize

S. No.	Parameters	Mean ± SEm (days)	Range (days)
1.	Incubation period	1.90±0.18	1-3
2.	Larval period	16.70±1.33	14-20
	1st instar	2.60±0.31	2-4
	2nd instar	2.70±0.30	2-5
	3rd instar	2.10±0.10	2-3
	4th instar	2.30±0.15	2-3
	5th instar	2.60±0.16	2-3
	6th instar	4.40±0.31	3-6
3.	Pupal period	7.30±0.26	6-8
	Male pupa	7.60±0.16	7-8
	Female Pupa	7.10±0.28	6-8
4.	Oviposition period	3.10±0.59	1-6
5.	Male adult longevity	8.70±0.94	4-13
6.	Female adult longevity	9.00±0.73	5-12
7.	Total male life cycle	34.90±1.07	29-39
8.	Total female life cycle	35.60±0.96	32-42

*SEm= Standard error of mean

Table 2 Morphometric parameters in terms of length, width and weight of different life stages of *Spodoptera furgiperda* (J. E. Smith) on maize

S. No.	Stage	Length (mm)		Width (mm)		Weight (gm)	
		Mean ± SEm	Range	Mean ± SEm	Range	Mean ± SEm	Range
1.	Larva						
	1st instar	1.91±0.12	1.5-2.5	0.33±0.04	0.2-0.5	0.0031±0.0001	0.0025-0.0038
	2nd instar	3.38±0.18	3.0-4.5	0.74±0.05	0.5-0.9	0.0214±0.0011	0.0145-0.0256
	3rd instar	6.15±0.34	5.0-8.0	1.31±0.06	1.0-1.5	0.0420±0.0008	0.0376-0.0457
	4th instar	9.78±0.21	9.0-11.0	2.26±0.07	2.0-2.5	0.0503±0.0009	0.0451-0.0546
	5th instar	18.60±0.72	15.0-22.0	2.92±0.03	2.8-3.0	0.0576±0.0017	0.0496-0.0654
	6th instar	32.30±1.23	28.0-39.0	3.53±0.13	3.0-4.0	0.0652±0.0012	0.0612-0.0722
2.	Pupa						
	Male pupa	14.79±0.18	14.0-16.0	4.54±0.14	4.0-5.2	0.17±0.01	0.15-0.20
	Female pupa	14.88±0.47	13.0-18.20	4.02±0.10	3.5-4.8	0.18±0.01	0.16-0.22

**SEm= Standard error of mean*

1(a) Eggs

1(b) Neonate larvae

1(c) 1st instar larva

1(d) 2nd instar larva

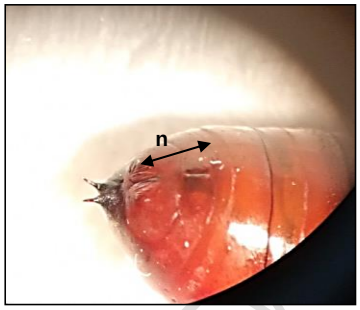
1(e) 3rd instar larva

1(f) 4th instar larva

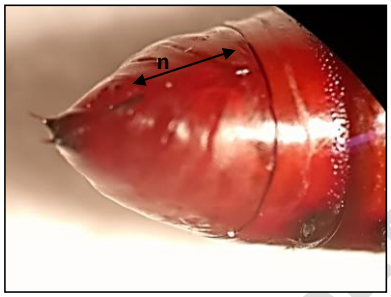
1(g) 5th instar larva

1(h) 6th instar larva

1(i) Pupae



1(k) Male pupa



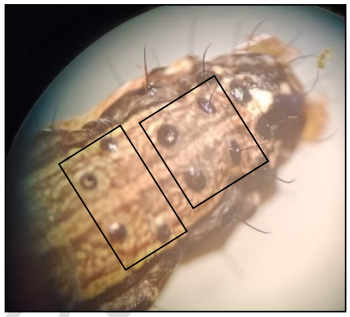
1(l) Female pupa

1(m) Male adult

1(n) Female adult

Fig. 1. Different life stages of *Spodoptera frugiperda* (J.E. Smith)
n = distance between anal slit and genitalia

2(a) larva with a typical inverted 'Y' shape on head capsule



2(b) larva with four black spots arranged in a square on 8th segment and trapezoid pattern in most dorsal segments

Fig. 2. Identification marks of *Spodoptera frugiperda* larva (J.E. Smith)

4. CONCLUSION

This study clearly provides basic information about the biology and external morphology of this recently invaded pest. This insect has become a major pest of maize, an important cereal grain in the world. To prevent this potential devastating occurrence, compatible integrated pest management strategies are needed at the early stages of FAW infestation. Knowledge of the biology of the FAW will play a vital role in this. When new strategies based on the biology of the FAW are used to manage it, the main focus must be on formulating a suitable and feasible IPM module for FAW and spreading awareness among the farmers about its life cycle, inspection and the right time of employing management practices.

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