



Life-history and life-table parameters of fall armyworm (*Spodoptera frugiperda*) for maize (*Zea mays*) in tropical Indian condition

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Maize (*Zea mays* L.) is affected by various biotic and abiotic stresses in India. Among biotic factors, in addition to stem borers, outbreak of an invasive pest, fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) observed in India in 2018 by Sharanabasappa and Kalleshwaraswamy (2018). This important whorl feeder and yield limiting pest has spread to major maize producing states of India (Rakshit *et al.* 2019). It was first reported outside Americas in Central and West African countries in 2016 and later on spread to almost all sub-Saharan African countries. FAW is highly polyphagous, migratory with wide host range (>350 plant species) with strong preference for maize. The larvae feed on different parts of the plant and cause serious damage resulting in yield reduction of 14.3–22.7% at the early whorl stage (Harrison 1984). Thorough knowledge on life history traits, population dynamics and mortality factors are essential for the development of integrated pest management strategies in India. Therefore, detailed research on life cycle and life-table parameters for FAW was carried out on maize under laboratory conditions at Winter Nursery Centre, ICAR-IIMR, Hyderabad.

The biological aspects included morphometrics and life cycle of fall armyworm reared on maize under laboratory conditions were studied at 26–31°C and 50–65% relative humidity during August–September, 2018 to January–February, 2019 i.e. 34th to 6th standard weeks (SDW). Morphometrics of the life stages of fall armyworm like diameter of eggs, length and width of head capsule, larval body, pre-pupa and pupa were measured with ocular

micrometer after calibrating with stage micrometer. Measurement of length of pre-pupa, pupa, length of fore wing and hind wing, wing span, body length were recorded with the help of standard scale. The developmental period of FAW was studied separately on baby corn by rearing on multi-well tissue culture plates from 34th to 6th standard weeks (SDW) for a period of six months. Observations were taken separately for egg, larval, pupal periods and also on adult longevity.

For life table studies, 100 eggs were taken as cohort and the newly hatched larvae were transferred to Petri dishes by using a fine camel hairbrush and reared as a group up to second instar. The third, fourth, fifth and sixth instars were reared individually in multi-well tissue culture plates. Newly emerged adults were paired in oviposition cage and transferred daily to a new container. Eggs laid by each female at different ages were collected and counted. Stage and age specific fecundity table was constructed. Population growth attributes and life expectancy of FAW were computed as per standard procedure.

Life stages measurement of FAW: The females laid eggs in masses on upper/lower leaf surface with each mass contained 50–150 eggs. The dome shaped egg had flattened base which curved upward to broadly rounded point at the apex. Freshly laid eggs were pale green in colour, which later changed to golden yellow and turned black prior to larval emergence. The egg diameter was 0.087–0.104 mm (Table 1). The first instar larva was creamy white to yellow in colour with a black head broader than the body and head was 0.07–0.10 mm in length and 0.10–0.11 mm in width. The first instar larvae were 0.56–0.76 mm in length, 0.10–0.14 mm in width and 0.14–0.15 mg in weight. The second instar larva was darker in colour with head capsule varied from 0.11–0.17 mm in length and 0.15–0.19 mm in width. The third instar larva's dorsal body surface became brownish and started forming three dorsal and lateral white lines. Head capsule of third instar larva contains white inverted "Y" line and the length varied from 0.17–0.21 mm, while the width ranged from 0.19–0.30 mm. The second and third instar larvae were 0.4–0.6 and 1.0–1.5 cm in length,

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Table 1 Morphometrics of immature stages of fall armyworm reared on maize (n=10).

Stage	Head capsule length (mm)			Head capsule width (mm)			Body length (First instar in mm, 2-6 instar and pupa in cm)			Width (mm)			Weight (mg)		
	Min	Max	Mean ±SEm	Min	Max	Mean± SEm	Min	Max	Mean± SEm	Min	Max	Mean ±SEm	Min	Max	Mean± SEm
Egg (Diameter)	0.087	0.104	0.095±0.003	-	-	-	-	-	-	-	-	-	-	-	-
First instar	0.07	0.10	0.09±0.001	0.10	0.11	0.11±0.001	0.56	0.76	0.64±0.01	0.10	0.14	0.12±0.001	0.14	0.15	0.15±0.006
Second instar	0.11	0.17	0.14±0.001	0.15	0.19	0.17±0.001	0.40	0.60	0.5±0.02	0.17	0.19	0.17±0.001	2.31	3.70	2.88±0.11
Third instar	0.17	0.21	0.19± 0.01	0.19	0.30	0.25±0.00	1.00	1.50	1.24±0.05	0.30	0.39	0.34±0.01	20.13	24.37	22.20±0.28
Fourth instar	0.26	0.34	0.32±0.01	0.46	0.56	0.51±0.00	2.00	2.40	2.22±0.05	0.63	0.82	0.72±0.02	81.56	133.97	100.18±3.19
Fifth instar	0.43	0.47	0.45±0.001	0.52	0.59	0.55±0.00	2.50	2.70	2.6±0.02	0.25	0.40	0.34±0.01	170.32	190.63	183.12±1.72
Sixth instar	0.45	0.52	0.47±0.00	0.52	0.60	0.56±0.00	2.70	2.90	2.8±0.03	0.73	0.87	0.83±0.01	200.21	234.21	217.58±5.47
Pre-Pupa	-	-	-	-	-	-	1.20	1.50	1.36±0.03	0.69	0.87	0.77±0.02	122.10	243.10	177.06±0.01
Pupa	-	-	-	-	-	-	1.50	1.60	1.55±0.05	0.85	0.87	0.86±0.01	124.19	146.24	136.18±2.12

0.17–0.19 and 0.30–0.39 mm in width and 2.31–3.70 and 20.13–24.37 mg in weight respectively. The change in instar was confirmed with presence of eclosed head capsule.

In fourth to sixth instar larvae’s head was reddish brown with brownish black or greenish dorsal body surface and three white dorsal lines and light lateral lines. Dark elevated spots were present on the dorsal surfaces which had spines. The head capsule of fourth, fifth and sixth instar larva was 0.26–0.34, 0.43–0.47 and 0.45–0.52 mm in length and 0.46–0.56, 0.52–0.59 and 0.52–0.60 mm in width, respectively. The fourth, fifth and sixth instar larvae were 2.0–2.4, 2.5–5.7 and 2.7–2.9 cm in length, 0.63–0.82, 0.25–0.40 and 0.73–0.87 mm in breadth and 81.56–133.97, 170.32–190.63 and 200.21–234.21 mg in weight, respectively. Larva had a distinct pattern of four large spots in square pattern on 8th abdominal segment and two spots in trapezoidal shape on 9th abdominal segment which were evident from third instar (Fig 1).

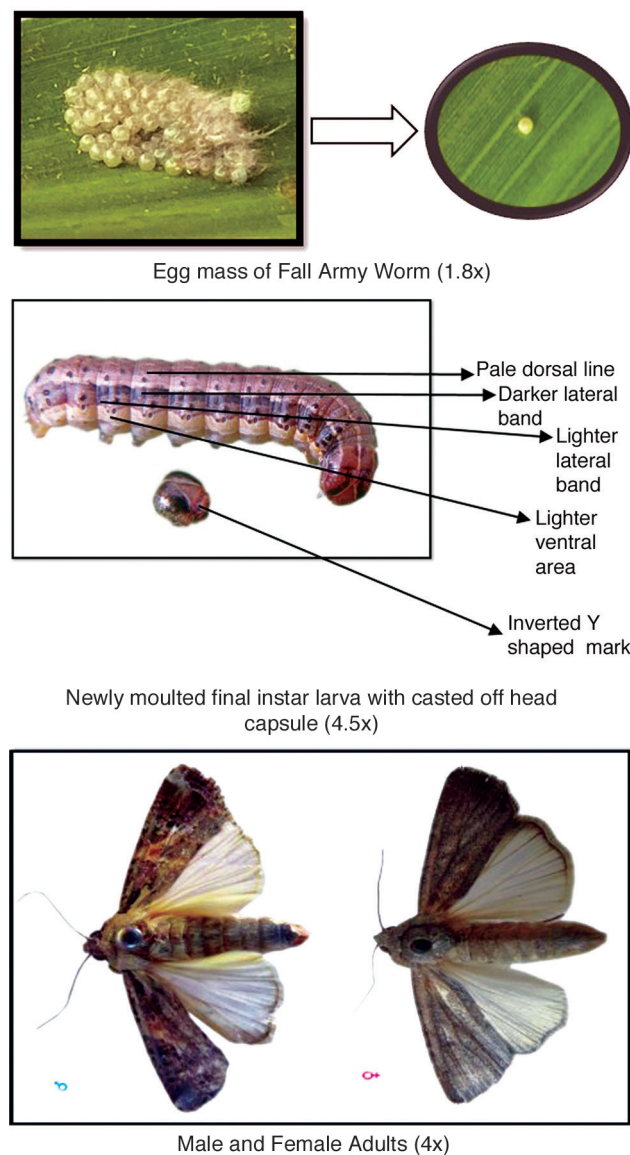


Fig 1 Various stages of the fall armyworm life cycle.

Table 2 Life cycle and life-table of fall armyworm reared on maize.

Life cycle (days)	Standard weeks						Mean				
	34 to 38	38 to 42	42 to 46	46 to 50	50 to 2	2 to 6					
Egg	4.67±0.33	5.33±0.33	5.67±0.33	4.30±0.32	4.30±0.32	3.33±0.32	4.60±0.23				
Larva	14.33±0.33	14.33±0.33	15.67±0.66	17.60±0.66	17.60±0.32	13.66±0.32	15.53±0.31				
Pupa	7.33±0.33	7.33±0.33	7.67±0.33	8.00±0.0	8.30±1.32	7.33±0.32	7.66±0.31				
<i>Adult longevity (days)</i>											
Male moth	3.67±0.33	3.67±0.33	3.67±0.33	4.60±0.32	6.30±0.87	5.0±0.57	4.49±0.32				
Female moth	4.67±0.33	5.67±0.88	5.67±0.88	5.30±0.32	5.30±0.32	6.0±0.57	5.44±0.39				
Total Life cycle (days) - Male	30±0.0	30.67±0.88	32.67±0.88	34.66±0.66	36.66±1.45	29.33±0.32	32.33±0.49				
Female	31±0.57	32.67±1.45	34.66±1.66	35.33±0.87	35.66±1.66	30.30±0.87	33.27±0.84				
Temp. range (°C)	31.0-33.2	30.0-33.0	29.4-32.9	25.5 -30.0	23.8-26.6	28.2-30.4					
Relative Humidity (%)	43-60	43-59	40-66	35-57	35-53	35-56					
<i>Life table</i>				<i>Life expectancy</i>							
Pivotal age in days (x)	Survival of female (l _x)	Female birth age schedule (m _x)	(l _x m _x)	(x.l _x m _x)							
0-26	Immature stages	-	-	-							
27	Preoviposition	-	-	-	X	I _x	d _x	100 _{qx}	L _x	T _x	E _x
28	0.38	29	11.02	286.5	0-5	100	23	23.0	100.5	415.5	8.26
29	0.38	33	12.54	338.6	5-10	77	10	13.0	77.5	315.0	8.12
30	0.38	100.5	38.19	1069.3	10-15	67	4	6.0	67.5	237.5	7.03
31	0.34	62.7	21.32	639.5	15-20	63	11	17.5	63.5	170.0	5.35
32	0.25	36.4	9.10	282.1	20-25	52	14	26.9	52.5	106.5	4.05
33	0.15	26.9	4.035	129.1	25-30	38	23	60.5	38.5	54.0	2.80
34	0	0	-	-	30-35	15	0	0	15.5	15.5	2.00
-	-	-	Ro	Σx.l _x m _x	-	-	-	-	-	-	-
			=Σl _x m _x	2903.1							
			96.20								

The pre-pupa was similar to last larval instar with changed reddish brown colour. Pre-pupa and pupa measured 1.2–1.5 and 1.5–1.6 cm in length, 0.69–0.87 and 0.85–0.87 mm in width, 122.10–243.10 and 124.19–146.24 mg in weight respectively. According to Leuck and Perkins (1972), pupal weight is an important indicator for insect fitness and thus the present pupal weight obtained in this study indicated that maize is a suitable host for FAW. The fore wings of male moth were mottled dark grey with fawn coloured spot towards the centre and distinct white patch near the dorsal tip. The fore wings of females were less distinctly marked ranging from uniform greyish brown to a fine mottling of grey and brown (Fig 1). In male moths, the length of fore wing ranged from 1.2–1.4 and 1.2–1.5 cm with expanse of 2.8–3.2 and 2.8–3.1 cm, body length varied from 1.4–1.7 and 1.3–1.6 cm with body weight of 52–85 and 36–87 mg, respectively. The length of fore wing of female ranged from 1.2–1.5 cm, wing expanse measured from 2.8–3.1 cm, body length varied from 1.3–1.6 cm and

weight ranged from 36–87 mg.

Development of FAW: The egg, larval and pupal period of FAW varied from 3.33±0.32 to 5.67±0.33, 13.66±0.32 to 17.60±0.32 and 7.33±0.33 to 8.30±1.32 days, respectively (Table 2). The longevity of male and female varied from 3.67±0.33 to 6.30±0.87 and 4.67±0.33 to 6.0±0.57 days, respectively. The total life cycle for male and female varied from 29.33±0.32 to 36.66±1.45 and 30.30±0.87 to 35.66±1.66 days, respectively. Sharanabasappa *et al.* (2018) also reported 32–43 days life cycle of FAW in Karnataka. Hatching occurred in just 2–3 days during 2nd–6th SDW. During 50 to 2 SDW, the larval duration was longest (23.8–26.6°C and 35–53% RH) while it was shortest during 34 to 42 and 2 to 6 SDW (28.2–33.2°C and 35–60% RH). The present study indicated that temperature had profound effect on larval development. The average longevity of male and female adults was 4.49 and 5.44 days respectively.

Stage specific life table of FAW: At egg stage, the apparent mortality was 16% and amongst larval instars,

highest mortality was at first (8.33%) while lowest in fifth (1.56%) instar. The apparent mortality at pre-pupal and pupal stages remained maximum at 10.34 and 26.92%, respectively. At egg stage the survival fraction was 0.8400. Among larval instars, survival fraction remained highest at fifth (0.9843) and lowest at first instar (0.9166). The survival fractions at pre-pupal and pupal stages were 0.8965 and 0.7307, respectively.

At egg stage, the mortality-survivor ratio (MSR) was 0.1904. Among larval instars, maximum MSR (0.0909) was observed at first instar while minimum in fifth instar (0.0158). The respective MSR values were 0.1153 and 0.3684 at pre-pupal and pupal stages. The k-value obtained at egg stage was 0.0758. Among larval instars, highest k-value revealed during first instar (0.0378) and lowest at fifth instar (0.0068). At pre-pupal and pupal stages, k-values obtained were 0.0474 and 0.1363 respectively. The pre-oviposition period was observed on 27th day of pivotal age. Female deposited eggs between 28th day and 33rd day with l_x values being 0.38 and 0.15, respectively. The female had highest number of progeny ($m_x = 100.5$) in the life cycle on the 30th day of pivotal age and decreased further.

Population growth attributes of fall armyworm: The net reproductive rate of FAW was 96.203 females/day while intrinsic rate of natural increase was 0.1513 females/day. The present results are in agreement with Southwood and Henderson (2000). The mean time required to complete one generation was 30.17 days and population doubling time was 4.58 days while the corrected generation time was 30.18 days. The finite rate of increase in number (λ) was 1.1633 female offspring/female/day and thus FAW population would be able to multiply 2.8829 times/week. The hypothetical F_2 females were worked out as 9255.01. The life-expectancy of newly deposited eggs was 8.26 while the mortality rate was comparatively high at pivotal age of 0–5 and 25–30 days. Results from the life-table indicated that the life-expectancy of FAW declined gradually with development advancement.

SUMMARY

Fall armyworm (*Spodoptera frugiperda* (J. E. Smith)) is an invasive pest reported in 2018 from India which principally attacks maize during vegetative and reproductive stages. Investigations were carried out to understand biology of the pest in new tropical and sub-tropical environment for devising effective management strategies in maize. The biological aspects included morphometrics and life cycle of fall armyworm reared on maize under laboratory conditions at 26–31°C and 50–65% relative humidity during August–September, 2018 to January–February, 2019 i.e. 34th to 6th standard weeks (SDW). Life table parameters including stage specific and age specific fecundity, population growth attributes and life expectancy of fall armyworm were computed. The diameter of eggs, length and width of body and their head capsules of different larval instars, pre-pupa, pupa, male and female adults were also measured.

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