Biology and Life Table of Fall Armyworm *Spodoptera frugiperda* (J.E. Smith) on Maize at Laboratory Conditions in Nepal

Binu Bhat[1] and Ajaya Shree Ratna Bajracharya[1]*

National Entomology Research Center
Nepal Agricultural Research Council
Khumaltar, Lalitpur

***CORRESPONDING AUTHOR:**

Ajaya Shree Ratna Bajracharya
Email: ajayabajracharya@yahoo.com

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ABSTRACT

The biology and life table of *Spodoptera frugiperda* (J.E. Smith) was studied at 27±2 ^{o}C temperature and 75±10% relative humidity at a Laboratory in the National Entomology Research Center, Lalitpur, Nepal from June to October, 2021.The main purpose of the study is to determine life cycle and to prepare stage specific life table of the insect on the preferred host maize. The mean incubation, larval and pupal periods were found to be 2.79, 14.04 and 9.49 days, respectively. The adult longevity of male and female moths was recorded at 15.39 days and 16.16 days. Pre-oviposition, oviposition and post-oviposition periods of female moths were 3.27 days, 5.39 days and 6.85 days with the fecundity of 1712 eggs per gravid female. The width of head capsules of the first, second, third, fourth and fifth larval instars was observed to be 0.31 mm, 0.51 mm, 0.81 mm, 1.30 mm and 1.95 mm, respectively. The highest apparent mortality (13.39) and indispensable mortality (10.02) were recorded in the insect's egg stage. Among larval instars, the maximum apparent mortality (7.1) and indispensable mortality (4.72) were recorded in the first instar.

Keywords: Apparent mortality, FAW, Head capsule, Oviposition, *S. frugiperda*

1. INTRODUCTION

The fall army worm (FAW) *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is a destructive pest which causes serious threat to agriculture. It is a polyphagous pest, as it has very wide host range, more than 80 crop species have been recorded as host whereas, and maize is a preferred host (Prasanna *et al.* 2018). In absence of control measure, it caused maize yield loss up to 20.6 m tons per annum in 12 African maize producing countries in the year 2017 (Day *et al.* 2017). *S. frugiperda* larvae damage the maize crop starting from seedling stage to cob formation stage. After hatching, first instar larvae feed on green part of leaf and leaves a transparent layer of the epidermis. Later growing larvae feed on leaves making holes of different shapes. Late instar larvae especially the third and fourth instar cause severe damage to leaves by making big holes. They enter into the whorl of plant and damage the entire plant by consuming the whorl. The *S. frugiperda* attacks all stages of maize crop from vegetative to generative phage, but the level of damage is higher in vegetative phase than the generative phase (Prasanna *et al.* 2018). In maize crop, *S. frugiperda* reduced the yield causing losses up to 40% in Honduras, 72% in Argentina and in the range of 21-53% in Africa (Rwomushana *et al.* 2018).

The fall armyworm is native to the Americas and was confined to American continents till 2015 (Luginbill 1928). In 2016, the insect was reported from Africa (Goergen *et al.* 2016). This pest was reported for the first time in Asia from Shivamogga district of Karnataka, India in May 2018 (Sharanabasappa *et al.* 2018a), and it was recorded for the first time in Nepal from Gaindakot of Nawalpur district on 9th May 2019 (Bajracharya *et al.* 2019).

After introduction of the pest in Nepal it is necessary to study life cycle, biology of the pest on preferred host which is important for the development of effective IPM technology of the pest. Life table study is the powerful and necessary tools for understanding the growth, survival rate, survival duration, rate of increase of population. It is necessary to understand the population dynamics of a pest species on preferred crop for the development of management technology. Considering the facts, the present studies were conducted on the life cycle, biology and life table of *S. frugiperda* under laboratory conditions.

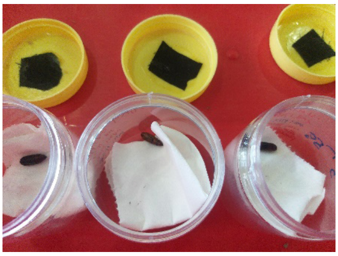
2. MATERIALS AND METHODS

Studies were conducted at the National Entomology Research Centre (NERC) of Nepal Agriculture Research Council (NARC), Khumaltar, Lalitpur from June to October, 2021. The GPS co-ordinates of the location is N 27°39’03.74”, E 085°19’38.59” and the altitude is 1,308 m above mean sea level. Temperature of laboratory during experimental period was maintained at 27±2 °C whereas, humidity was maintained at 75±10%.

2.1 Culture of *S. frugiperda*

Larvae of *S. frugiperda* were collected from the infested maize fields at Gaindakot in Nawalpur district (N27°42’16.67”, E84°22’50.61”). The larvae were identified as fall armyworm from its dorsal pinacula on eight abdominal segment which were larger and arranged in square pattern (Bajracharya *et al.* 2019). The hand picking was done from the maize fields with typical fall armyworm damage symptoms of papery window and ragged holes on leaves. Collected larvae were reared into adults for maintaining insect culture in laboratory of NERC (Fig. 1). The larvae were reared in rectangular, transparent, plastic boxes with dimensions of 22.7 cm x 16.3 cm x 9.0 cm of length, breadth and height, respectively. Window of 10 cm x 5 cm dimensions was made on lid of boxes for air supply, these windows were covered with black muslin cloth. The larvae were allowed to grow and feed on maize leaves until larvae attained prepupal stage when larvae stop feeding and become inactive. Old leaves were removed daily and fresh leaves were provided. Pupae were collected and kept in separate plastic box until adult emergence. Emerged adults were paired and kept into round plastic box of 250 mL capacity covering mouth of box with black muslin cloth. A small hole was made on one side of the box to provide 10% honey solution soaked in cotton ball as adult food. The rearing of the insect was performed throughout the study period for supply of required stage of the insect.


(a)


(b)


(c)

Fig. 1. Insect rearing and culture maintenance in laboratory (a) Larva (b) Pupa (c) Adult

2.2 Life cycle and biology of *S. frugiperda*

The life cycle of *S. frugiperda* was studied on maize (variety Rampur composite) leaves as food medium. Adults emerged on the same day were paired and kept in a round plastic box for mating and mouth of the box was covered with black muslin cloth. The eggs laid on the black muslin cloth were collected and left until hatching. After hatching individual larva was kept separately in transparent plastic box of 250 mL capacity and larval observation from 60 replications was recorded. Fresh maize leaves were provided every day to larvae at an interval of 24 hour after removing remaining of old leaves. Larval exuviae were observed to determine the molting during transfer of larvae from old leaves to fresh maize leaves. Whole process was performed under stereo- microscope (Bestscope BS340T). After attaining to the pupal stage insects were collected with puparium and kept in plastic boxes separately for hatching. After emergence adults were transferred to transparent plastic boxes. Sex differentiation was made on the basis of external morphology of adult moths described by Bajracharya *et al.* (2019) and single pair was kept separately in each box for mating. Small cotton balls were soaked with 10% honey solution and provided as adult food through a small circular hole made on the side of plastic box.

The observation recorded on biology study of *S. frugiperda* were the egg period, larval period with duration of each instar, pupal period, adult emergence with sex ratio and adult longevity of male and female moths. Similarly, pre-oviposition, oviposition and post oviposition duration were also recorded along with fecundity of gravid female moth. Data obtained from observation were entered in Microsoft Excel and mean values, ranges, and standard error of means was calculated using computer software GenStat discovery edition 4.

2.3 Stage-specific life table of *S. frugiperda*

To prepare stage specific life tables of *S. frugiperda*, the development time and mortality of different developments stages; eggs, larval instars (I, II, III, IV, V and VI), pupae and adults were recorded. One pair of adult male and female paired and one bunch of fresh eggs laid at the same time was collected for the experiment. Undamaged 115 eggs from the collected bunch were kept for hatching. The number of larvae emerged from hatched eggs were recorded. After hatching, the first instar larvae were kept individually in separate transparent plastic box and observation were recorded daily at an interval of 24 hours. Maize leaves were provided as food for larvae and fresh leaf was provided daily. During observation mortality of each stage, instar period and developmental periods of stages were calculated and recorded to construct the stage specific life table of the insect. During observation dead larvae and pupae were removed. Total emerged adults from pupae were also counted.

In stage-specific life table apparent mortality, survival fraction, mortality survival ratio, indispensable mortality and k-values were calculated. From these assumptions various life parameters were calculated in stage specific life table. Stage specific life table was constructed with apparent mortality, survival fraction, mortality survival ratio, indispensable mortality and k- values (Southwood & Henderson 1976; Ali & Rizvi 2010; Ashok *et al.* 2020).

Apparent mortality (100qx): It is the measured mortality, expressed as percentage of numbers dying at particular stage to the numbers living at beginning of that stage. It is calculated as

100qx = [dx/lx]X100

Whereas,

x = stage of insect

dx = mortality during stage x

lx = numbers surviving at beginning of stage x

Survival fraction (sx): stage specific survival fraction of particular stage is a ratio of number of living insects at the beginning of the subsequent stage to the number of living insects at the beginning of the particular stage.

sx of particular stage = (lx of subsequent stage)/ (lx of particular stage)

Mortality-survivor ratio (MSR): It is measurement which shows increase in population that would have occurred if the mortality factor of that stage had been absent. It is calculated as,

MSR of particular stage = (mortality in particular stage) / (lx of subsequent stage)

Indispensable mortality (IM): It is a part of generation mortality which would not occur when factors causing mortality at particular stage is removed. However subsequent mortality factors allowed to operate. It is calculated as,

IM= (Number of adults emerged) x (MSR of particular stage)

K-values: It is also a measurement of mortality factor, which is responsible for increase and decrease of number of insects from one stage to successive stages. It is calculated as difference between "log lx" of successive life stages. Total generation mortality is expressed as K and it is derived by adding k values of all developmental stages of the insect

K= kg+ kL1+kL2+kL3+kL4+kL5+kL6+kP

Where, kg, kL1, kL2, kL3, kL4, kL5, kL6, and kP are the k- values at egg, first instar, second instar, third instar, fourth instar, fifth instar, and pupal stages of *S. frugiperda*.

3. RESULTS AND DISCUSSION

3.1 Life Cycle of *S. frugiperda*

Life cycle of *S. frugiperda* consists of four development stages viz. egg, larva, pupa and adult (Fig. 2). Adults of *S. frugiperda* generally laid eggs on the black muslin cloth covering mouth of the plastic box in laboratory condition. Eggs were laid in group with overlapping two or three layers covered with abdominal hairs of female moth (Fig. 2a). Egg masses were creamy white and greenish at the time of oviposition, later become pale brown or black prior to hatching. Incubation period was recorded as 2.79±0.056 days (Table 1). The duration of egg stage ranged between 2-3 days. Similar egg period of *S. frugiperda* was reported by previous workers (Ashok *et al.* 2020; Sharanabasappa *et al.* 2018b). However, Kalyan *et al.* (2020) reported longer egg period (3-4 days) of *S. frugiperda* while studying life cycle under laboratory condition at 25±2 ^{o}C temperature.

In larval stage five molting occurred and passed through six instars. The first instars larvae were whitish which later changed into greenish with black head. Colour of fully grown larvae varied from brown, greenish, pinkish with granulated texture all over the body surface. Grown up larvae which is 3.7 cm long were characterized by the ecdysial line on the head forming 'V' shape which continues with middorsal stripe of prothoracic shield forming inverted 'Y' shaped whitish marking. Black spots on 8^{th} and 9^{th} abdominal segments were larger than the other abdominal segments. Black spots on 8^{th} abdominal segment were arranged in square shaped and trapezoid on 9^{th} abdominal segment (Fig. 2b).

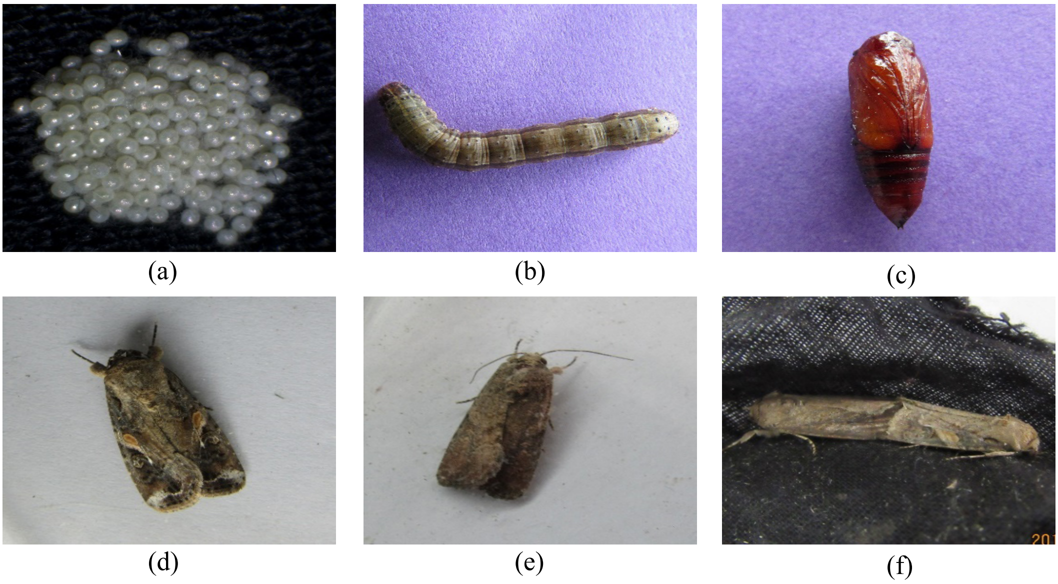


Fig. 2. Different developmental stages of *S. frugiperda* (a) Eggs (b) Larvae (c) Pupa (d) Male moth (e) Female moth and (f) Mating of adult moths

Mean larval development period in the present study was 14.04 days which ranged between 13-19 days (Table 1). Similar larval development duration of 13-19 days with a mean of 16.46 days was reported by Kalyan *et al.* (2020). Similarly, Sharanabasappa *et al.* (2018b) reported mean larval period 15.9 days which ranged between 14-19 days. Whereas, Ashok *et al.* (2020) reported larval period of 10-19 days.

Pupa were brown in colour with two spines in cremaster (Fig. 2 c). The mean duration for pupal development time was found 9.49±0.069 days (Table 1). The total duration for pupal development ranged between 9-10 days. Similar pupal period was reported by various previous workers; Ashok *et al.* (2020) reported mean pupal period of 8.24 days which ranged between 7-10 days. Kalyan *et al.* (2020) found pupal period as 8.96 days ranging between 7-11 days. Sharanabasappa *et al.* (2018b) reported longer pupal period of 10.50 days ranging between 9-12 days.

The mean adult longevity recorded was 15.39±0.789 days and 16.16±0.860 days for male and female moths, respectively (Table1). The female moths lived longer than males, similar findings were reported by previous workers. Average longevity of male and female moths was found 10.67 days and 13 days by Kalyan *et al.* (2020). Similarly, Ashoka *et al.* (2020) reported male and female adult longevity as 11.10 days and 12.60 days, respectively. Whereas, Sharanbasappa *et al.* (2018b) reported shorter adult longevity of 8.20 days for male and 10.80 days for female.

Table 1. Average duration of different developmental stages and egg production of *S.frugiperda* on maize leaves in laboratory conditions.

Developmental stage	Mean (days)*	Range (days)
Egg period	2.79 ±0.056	2-3
I Instar	2.08±0.037	2-3
II Instar	2.06±0.023	2-3
III Instar	1.74±0.067	1-3
IV Instar	1.77±0.058	1-2
V Instar	2.08±0.059	1-4
VI Instar	4.32±0.084	3-6

Pupal period	9.49±0.069	9-10
Total larval period	14.04±0.117	13-19
Total development period	26.32±0.420	24-31
Male longevity	15.39±0.789	8-24
Female longevity	16.16±0.860	8-28
Preoviposition period	3.27±0.212	2-6
Oviposition period	5.39±0.319	3-10
Postoviposition period	6.85±0.896	1-17
No of eggs/female	1712±316	716-2125

*Values presented as Mean ± SEM (Standard Error of Mean)

Mean duration of pre-oviposition, oviposition and post-oviposition periods in female moths were 3.27±0.212 days, 5.39±0.319 days and 6.85±0.896 days, respectively. Ashok *et al.* (2020) reported similar pre-oviposition, oviposition and post-oviposition period of 3.90 days, 6.10 days and 2.60 days, respectively. Similarly, Kalyan *et al.* (2020) reported 3.47 days, 2.96 days and 6.13 days of pre-oviposition, oviposition and post-oviposition periods. Sharanbasappa *et al.* (2018b) reported shorter average preoviposition, oviposition and post oviposition as 3.60 days, 2.80 days and 4.30 days, respectively.

3.2 Head Capsule of *S. frugiperda*

In the life cycle of *S. frugiperda*, it passed through six larval instars with five molting. Average width of head capsule of different larval molts of *S. frugiperda* reared at 27±2 °C temperature and 75% average relative humidity in National Entomology Research Center is given in Table 2. The width of head capsule of first, second, third, fourth and fifth molts were 0.31 mm, 0.51 mm, 0.81 mm, 1.3mm and 1.9 mm, respectively.

Table 2. Mean head capsule width of various larval instars of *S. frugiperda* in laboratory conditions.

Larval molts	Width (mm)*	Range (mm)
First instar	0.31±0.0018	0.25-0.35
Second instar	0.51±0.0036	0.44-0.58
Third instar	0.81±0.0053	0.74-0.88
Fourth instar	1.30±0.0093	1.11-1.58
Fifth instar	1.95±0.0092	1.72-2.09

*Values presented as Mean ± SEM (Standard Error of Mean)

3.3 Stage-specific Life Table of *S. frugiperda*

After passing through different development stages 62 adult emerged from a single egg mass containing 115 eggs (Table 3). At egg stage, the apparent mortality was recorded the maximum (13.9%). While comparing the apparent mortality between different larval instars, the highest apparent mortality was recorded in the first instar (7.1%) while minimum apparent mortality in the fifth instar (1.2%). Ashok *et al.* (2020) also found highest apparent mortality in the first instar larvae (20.00) and minimum in sixth instar ((1.79). Considering survival fraction (sx) was found maximum in the fifth instar (0.99) followed by the fourth (0.98), third (0.97) and second (0.96) instar. Whereas, survival fraction (sx) in the sixth and first instar larvae were 0.95 and 0.93, respectively. The survival fraction (sx) of the egg, prepupa and pupal stage were, 0.86, 0.94 and 0.85, respectively.

Table 3. Stage -specific lifetable of *S. frugiperda*

Stages (x)	Survivors at beginning (lx)	Mortality (dx)	Survival proportion (%)	Apparent mortality (100qx)	Survival fraction (sx)	Mortality/ survival ratio (MSR)	Indis pensable mortality (IM)	log lx	k values
Egg	115	16	100	13.9	0.86	0.2	10.02	2.06	0.07
L1	99	7	86.1	7.1	0.93	0.1	4.72	1.99	0.03
L2	92	4	80	4.3	0.96	0	2.82	1.96	0.02
L3	88	3	76.5	3.4	0.97	0	2.19	1.94	0.01
L4	85	2	73.9	2.4	0.98	0	1.49	1.93	0.01
L5	83	1	72.2	1.2	0.99	0	0.76	1.92	0.01
L6	82	4	71.3	4.9	0.95	0.1	3.18	1.91	0.02
Pre pupa	78	5	67.8	6.4	0.94	0.1	4.25	1.89	0.03
Pupa	73	11	63.5	15.1	0.85	0.2	11	1.86	0.07
Adult	62	0	0	0	0	0	0	1.79	0
K-value									0.27

Mortality due to specific factor called indispensable mortality (IM), which was found to be maximum in pupal stage (11.00) followed by egg stage (10.02). Whereas, among larval instars maximum indispensable mortality was recorded in the first instar (4.72) and minimum in the fifth instar (0.76). Kalyan *et al.* (2020) also reported the highest indispensable mortality in the first instar larvae and the lowest in the sixth instar. Early larval instars are more delicate than the later instars, could be a reason behind higher mortality in early instars. Similarly, the highest generation mortality (k-values) among the larval instars was recorded in the first instar (0.3) followed by the second and sixth VI instars (0.02). Whereas, generation mortality in the third, fourth and fifth instars were recorded 0.01. The sum of k values obtained for all developmental stages was 0.27 when reared on maize at 27±2 ^{o}C and 75% relative humidity.

Life cycle and life table study will help in understanding the development of *S. frugiperda.* Information on the duration of each development stage in life cycle study and life table helps in evaluating the survival and mortality of each stage, which helps in developing the integrated management strategy of the pest.

4. CONCLUSION

In the present study we got clear knowledge on life cycle of *S. frugiperda* with average developmental period from egg to adult was 26.32 days which ranged between 24-31 days. Adult male moth can survive for 8-24 days and female moth can survive for 8-28 days depositing eggs on host plant. So, during maize crop duration, there could be 3-4 overlapping generations of *S. frugiperda.* As *S. frugiperda* can damage both vegetative and reproductive part of the maize plant, it is necessary to manage *S. frugiperda* throughout the crop development period until harvest. As life table study showed higher mortality during the egg and early larval stages, management of the insect need to be more targeted to these stages of *S. frugiperda.*

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