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Life table evaluation of *Spodoptera frugiperda* on maize at room temperature

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Abstract
The life table of FAW was studied on maize at room temperature under laboratory conditions at Department of Entomology, Anbil Dharmalingam Agricultural College and Research Institute, Trichy. Pre-oviposition occurs from the 29th to the 31st day of pivotal age. The oviposition began on the 32nd day of pivotal age and continued it until 40th day. On the 36th day of pivotal age, females contributed the maximum progeny (mx = 577) in the life cycle. The average generation period (T) was 35.51 days, and the net reproductive potential (R_o) was 479.89 females. The number of hypothetical F2 females was found to be 230290.09. The egg stage contributed the maximum (52.20%), while larvae, pupae, and adults contributed 37.77, 2.15, and 0.21 percent, respectively, in a stable age distribution of FAW on maize.

Keywords: *Spodoptera frugiperda*, maize, biology, life table, laboratory

1. Introduction
The fall armyworm, *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) is an exotic polyphagous insect pest that originated in the Americas (Luginbill, 1928) [8]. Almost 100 plant species are affected by FAW, including maize, sorghum, rice, soybean, cotton, wheat, and sugarcane. In addition, Montezano *et al*. (2018) [12] published a study that listed 353 FAW larval host plant species from 76 plant families with the Poaceae family having the largest host taxa (106 taxa), followed by Asteraceae and Fabaceae (31 taxa each). According to a recent study, over 1300 species of invasive insect pests and pathogens have been introduced into 124 countries (Paini *et al.* 2016) [13].

It is crucial to have a comprehensive record of the insect's life history parameters, such as development, longevity, survivorship, and fecundity, as well as a complete life table on a host, in order to develop different measures of protection. The life table is an excellent tool for studying the dynamics of animal populations, particularly arthropod populations, because it can provide vital demographic parameters (Maia *et al.* 2000) [10]. The cohort life table provides the most detailed depiction of a population's survival, development, and reproduction, which are important variables in both theoretical and applied population ecology (Taghizadeh *et al.* 2008) [16]. The maize crop had been used for this present study.

2. Materials and Methods
2.1. Insect culture (Ashok *et al.* 2020) [4]
In the PG Laboratory of Anbil Dharmalingam Agricultural College and Research Institute, Trichy, a laboratory culture of FAW was maintained on maize leaves for two generations at a constant temperature of 27 ± 7 °C and 70% relative humidity. FAW egg masses were collected in the field and stored in round plastic containers (24.5 cm dia. x 19.5 cm ht.) with filter paper on the bottom. The emerging fall armyworm neonate larvae were allowed to feed on maize leaves that were kept over the trays. Every two days, the feed was changed. Filter paper was watered once every four hours with a pipette to keep the leaves turgid. Muslin material was used to cover the mouth of the container. Individual larvae were put to small plastic containers and covered with gadda cloth after the second instar due to FAW cannibalism. The feed was changed every day.

The pupae obtained were transported to the rearing cages. In sterile glass vials containing sterile absorbent cotton, a 10 per cent sugar solution (dissolved mixture of honey-10 g, sorbic acid-1 g, methyl paraben-1 g, sucrose-60 g, distilled water-100 ml) was provided and kept under 10 °C for further use. A little maize plant was cultivated in plastic cups and ten pairs of healthy adults were put into plastic containers (6 cm dia. x 8 cm ht.) for oviposition.

In 30 x 30 x 45 cm wire cages, newly emerged adults from the laboratory culture were kept for egg laying. Muslin cloth was used to wrap the sides of cages. To maintain the tender leaves of the host plant fresh and turgid, they were inserted into a conical flash containing fresh water and placed inside the cage for resting and oviposition of the adults.

2.2. Life table studies

Freshly laid 30 egg mass were placed in separate containers to create life tables. The larvae were put into plastic vials containing maize leaves after hatching. Every day, observations on hatching, larval development, pupa formation, successful adult emergence, and fecundity were made. Age-specific mortality was also recorded in several developmental stages such as eggs, larvae, pupae, and adults. Total number of adults emerged on the same day were confined in oviposition cage (30 x 30 x 30 cm.) for oviposition in order to evaluate age specific fecundity. The number of eggs collected / female was divided by two to determine the number of female births because the sex ratio was 1:1. (mx).

The following column headings were utilised in this work to generate the life fecundity tables proposed by Howe (1953) [6] and Atwal and Bains (1974) [4], viz, x = pivotal age in days, lx = female survival at age ‘X', and mx = age schedule for female births at age ‘X'.

2.2.1. Net reproductive rate (R0)

The values of x, lx, and mx were determined using information from life tables. The net reproduction rate (R**0**) is the sum of the products ‘lxmx' (Lokta, 1925) [7]. The rate of population multiplication in a generation, measured in females produced each generation, is known as the ‘R_o.' The following formula was used to compute the number of times a population would multiply per generation: $R_o = \Sigma$ lx mx

2.2.2. Mean duration of generation (Tc)

The following formula was used to compute the appropriate value of generation time (Tc), which is the mean age of the mothers in a cohort at the birth of female offspring, Tc = Σ lx mx / R_o.

2.2.3. Innate capacity for increase (rm)

At each age interval, the total number of individuals who survived and the mean number of female offspring births were recorded. The following formula was used to calculate the arbitrary value of rm (rc) based on these data: rm = loge R_o./Tc, Where Tc = Mean generation time, e = 2.71828. The intrinsic rate of rise (rm) was determined from the arbitrarily chosen ‘rm' by placing in the equation e^{7-rmx} lx mx (Atwal and Bains, 1974) [4] two trial values on either side of it differing in the second decimal place.

2.2.4. The finite rate of natural increase (λ)

The number of females per female per day, or the finite rate of increase, was calculated using the formula: λ = antilog erm. The population's weekly multiplication was determined using this information. The formula $(R_o)^2$ was also used to calculate the hypothetical F2 females.

2.2.5. Stable age distribution

On maize, the stable age distribution of FAW (percentage distribution of distinct age groups) was investigated with the knowledge of 'rm' and the age-related mortality of the immaturity and mature stage were also determined. Following the method of Andrewartha and Birch (1954) [2] and Atwal and Bains (1974) [4], a stable age distribution table was created. Using the following formula, the ‘Lx' (Life table age distribution) was calculated from the ‘lx' table:Lx = Life table age distribution = lx + (lx + 1)/2. The percent distribution of each age group (x) was derived by multiplying Lx by e^{-rm} (x + 1). The expected per cent distribution was found by measuring the percentages for each stage (egg, larval, pupal, and adult).

2.2.6. Life expectancy of FAW

Columns x, lx, dx, 100qx, Lx, Tx, and ex were used to calculate life expectancy, Where x = pivotal age (days); lx = population alive at the beginning of the age interval out of 100; dx = number of participants dying during ‘x'; 100qx = dx.100/lx, Mortality rate per hundred survivors at the start of the age interval; Lx = lx + (lx + 1)/2, Alive between x and x + 1; Tx = number of days an individual lived beyond ‘x’.Expectation of life, $ex = T_X$ / L_X × 2. The data was processed using a Microsoft Excel-based computer software.

3. Results and Discussion

3.1. Biology

The egg masses were green and spherical at the time of oviposition, turning pale brown to black before eclosion, and the egg stage lasted two to three days, with a mean of 3.41551 days, which is greater than the values reported by Ashok *et al.* (2020) [3] (Table 1). Larvae ranged in color from pale green to dark brown. Neonate larvae were pale green in color, with an inverted yellow-colored Y-shape marking on the head and four black dots grouped in a square on the last abdominal segment. A total of 250 to 609 eggs (433.67 ± 129.875) were laid on both surfaces of the leaf, often surrounded by a hair-like covering of scales (setae) from the female abdomen, however a female can produce up to 1000 eggs (CABI, 2017) [5].

When reared at 27 ± 1 ˚C, 75 ± 10% RH, and 14L:10D, the mean development time for larval instars 1 to 6 was 3.0, 2.47, 3.13, 2.07, 2.0, and 2.93 days, respectively. Previously, similar outcomes were obtained (Pitre and Hogg, 1983) [15]. The average duration of the pupal stage was 9.93 ± 1.486 days. Male and female adults lived an average of 11.6 ± 1.234 and 13.2 ± 0.883 days, respectively. Pre-oviposition, oviposition, and postoviposition periods ranged an average of 3.06 ± 1.032, 7.3 ± 1.112, and 2.13 ± 0.526 days, respectively. The observation showed longer periods of adult longevity when compare with the result of Montezano *et al.* (2018) [12]. The actual average of 77.67 ± 28.263 eggs/egg mass is lower than the figures reported by Marua and Virla (2004) [11].

Table 1: Biology of different life stages of FAW on maize

Particulars	Mean + SD	Range
Egg	3.4 + 1.551	2-4
I instar	3 + 0.765	2-3
II Instar	2.47 + 0.563	2-3
III	3.13 + 0.605	1-4
IV	2.07 + 0.527	1-3
V	2 +0.755	1-3
VI	2.93 + 0.883	2-5
Pupal period	9.93 +1.486	8-12
Adult period	12.13 +1.097	11-14
Male longevity	11.6 + 1.234	10-13
Female longevity	13.2 + 0.883	11-14
Preoviposition period	3.06 +1.032	2-5
Oviposition period	7.3 +1.112	5-9
Post oviposition	2.13 +0.526	1-3
No. of eggs/female	433.67 +129.875	250-609
No. of egg mass/female	3.53 +1.125	2-6
No. of eggs/egg mass	77.67 + 28.263	49-124

3.2. Life table

3.2.1. Stage-specific life table

From the egg to adult emergence, 40 individuals out of 160 eggs from a single egg mass survived (Table 2). The apparent mortality rate was highest (33.82 per cent) during the I instar stage, and lowest at the VI instar stage (2.22 per cent). The VI instar stage had the highest survival fraction (0.98), whereas the I instar stage had the lowest (0.662). The highest mortality to survival ratio (0.511) was recorded on I instar and the lowest on VI instar (0.02). Indispensable mortality (IM) was found to be highest in instar I (11.0) and lowest in instar VI (1.46). The highest generation mortality (K - Value) was observed at the I instar and the lowest (0.01) at the VI instar. When reared on maize at 27 ± 1˚C, 75 ± 20% RH and 14L: 10D, the sum of k values recorded for all developmental stages was 0.602. The findings were consistent with Acharya *et al*. (2007) [1], who investigated the lifecycle of *H. armigera* on cotton.

3.2.2. Age-specific lifetable

To determine the survival of females (lx) and age-specific fecundity, life fecundity tables were created (mx). The preoviposition phase ranged from the 29th to the 31st days of pivotal age, according to the life fecundity data (Tables 1 and 2). Females began depositing eggs on the 32nd day (mx=149) and stopped on the 40th day (mx= 11), with lx values of 0.24 and 0.07, respectively.

The first female mortality was seen on the second day after the emergence of adult, i.e., on the 33rd day of pivotal age (lx=0.23), and mortality increased slowly, as evidenced by a substantial decrease in lx values after the 33rd day of pivotal age. On the 36th day of pivotal age, the females generated the maximum progeny per day (mx = 577), which then decreased (mx=11) on the 40th day. The net reproductive rate (R_o) is 479.8855 no./female/lifetime, and the sum of x.lx.mx is 17041. 1.The mean length of generation was calculated using R_o and ∑x.lx.mx values. Patil *et al*. (2014) [14] found a similar pattern, with the pre-oviposition period ranging from 29 to 31 days of pivotal age and females contributing the maximum progeny (mx=577) on the 36th day of pivotal age.

3.2.3. Mean length of generation, innate capacity and finite rate of increase

The net reproductive rate (R_o) was 479.8855 no./female/lifetime, which is the ratio of total female birth in one generation. The average length of generation time (Tc) was 35.5107 days, according to the findings. With a daily finite rate of increase in number 1.1694 females/ female/ day and a population doubling time of 4.43 days, the intrinsic rate of natural increase in number (rm) was 0.156 females/ female/ day. Under the given conditions, the population of FAW would multiply 2.99 times per week. The population of hypothetical females in the F2 generation was found to be 230290.09.

3.2.4. Age-specific distribution

Eggs, larvae, pupae, and adults all contributed 52.20, 37.77, 2.15, and 0.21 per cent, respectively, according to a stable age distribution (Table 4). This means that the immature stages were the most important in maintaining the age distribution stability. Similar findings were made by Ashok *et al*. (2020) [3], who found that eggs, larvae, pupae, and adults of FAW contributed 55.75, 43.05, 1.04, and 0.16 per cent of the total contribution of FAW in maize, respectively.

3.2.5. Life expectancy

As development progressed, FAW life expectancy (ex) decreased steadily (Table 5). Newly placed eggs had a life expectancy (ex) of 15.81 days. The mortality rate (dx) gradually increased by a reduction in the lx values, and mortality was relatively high at the pivotal age of 10-15 days. The current findings support those of Maghodia and Koshiya (2008) [9], who found that *S. litura* eggs have a life expectancy of 17.34, 17.44, 16.39, 17.45, and 17.98 days on castor, tobacco, groundnut, cotton, and cabbage, respectively.

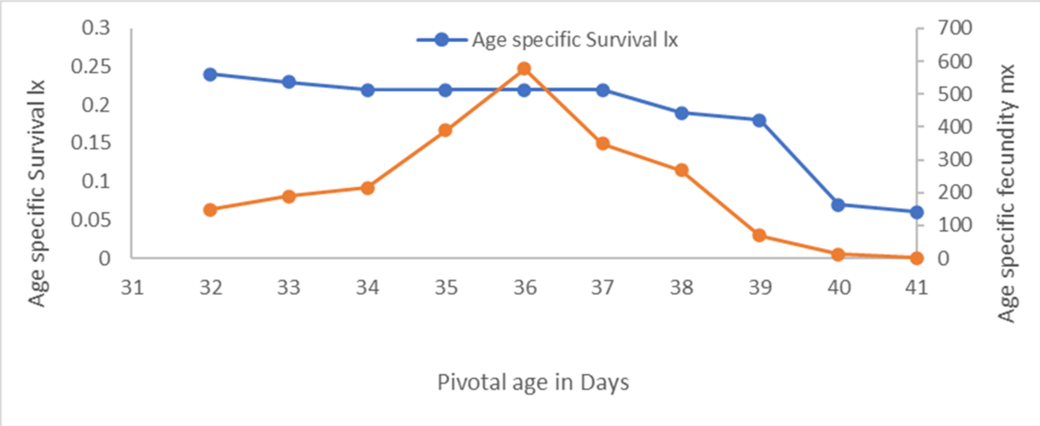

Fig 1: Age-specific survival (lx) and fecundity (mx) curve of FAW on maize

Table 2: Life table (for female) and age specific fecundity of FAW on maize

Pivotal age in days (x)	Different age interval (lx)	Female births (mx)	(lxmx)	(xlxmx)
0-28	immature stages			
29-31	pre-oviposition stage			
32	0.24	149	35.76	1144.32
33	0.23	188	43.24	1426.92
34	0.22	215	47.3374	1609.47
35	0.22	390	85.899	3006.47
36	0.22	577	126.94	4569.84
37	0.22	349	76.8064	2841.84
38	0.19	267	50.73	1927.74
39	0.18	69	12.402	483.678
40	0.07	11	0.7707	30.828
41	0.06	0	0	0
			479.8855	17041.1

Table 3: Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of FAW on maize

Net reproductive rate	R_0 =	479.8855 no./female/lifetime
Approximate generation time	Tc =	35.5107 days
Capacity for increase	rc = ($\log_e R_0$) /Tc	0.17385
Intrinsic rate of natural increase	rm =	0.156
Finite rate of increase	λ = e^rm	1.1694 no./day
Mean generation time	T = ($\log_e R_0$) /rm	39.45436 days
Population doubling time	t = 0.69315/rm	4.4298 days
Weekly multiplication of population	WM = e^7.rm	2.99
Hypothetical F2 females	$(R_0)^2$	230290.09

Table 4: Stage specific life table of FAW

Stages (x)	Survivors at beginning (lx)	Mortality (dx)	Survival proportion (%)	Apparent mortality (100qx)	Survival fraction (Sx)	Mortality rate	Mortality/ survival ratio (MSR)	Indispens-able mortality (IM)	log x	k values
Egg	160	100	24	15	0.85	0.15	0.176	8.55	2.204	0.07
L1	136	85	46	33.82	0.662	0.338	0.511	11	2.134	0.18
L2	90	56.25	15	16.67	0.833	0.167	0.2	9.6	1.954	0.079
L3	75	46.88	8	10.67	0.893	0.107	0.119	9.163	1.875	0.049
L4	67	41.88	7	10.45	0.896	0.104	0.117	7.076	1.826	0.048
L5	60	37.5	9	15	0.85	0.15	0.176	6.34	1.778	0.07
L6	51	31.88	1	11.76	0.980	0.0196	0.02	1.46	1.708	0.055
Prepupa	50	28.13	2	2.22	0.96	0.04	0.042	2.78	1.653	0.01
Pupa	44	27.5	5	9.09	0.896	0.104	0.116	4.1	1.643	0.041
Adult	40	25	0	0	0	0	0	0	1.602	0
										0.602

Table 5: Age specific distribution of FAW

Pivotal age in days x	Lx	x+1	- rm *(x+1)	e^- rm * (x+1)	Lx*e^- rm *(x+1)	% Distribution	
0	0.995	1	-0.1565	0.8552	0.8509	17.692	52.2044
1	0.98	2	-0.3129	0.7313	0.7167	14.9013	
2	0.895	3	-0.4694	0.6254	0.5597	11.6377	
3	0.815	4	-0.6259	0.5348	0.4358	9.0624	
4	0.81	5	-0.7824	0.4573	0.3704	7.7022	
5	0.805	6	-0.9388	0.3911	0.3148	6.546	37.7723
6	0.775	7	-1.0953	0.3344	0.2592	5.3892	
7	0.75	8	-1.2518	0.286	0.2145	4.4599	
8	0.735	9	-1.4083	0.2446	0.1798	3.7376	
9	0.713	10	-1.5647	0.2091	0.149	3.0984	
10	0.698	11	-1.7212	0.1789	0.1247	2.5938	
11	0.685	12	-1.8777	0.1529	0.1048	2.1783	
12	0.675	13	-2.0342	0.1308	0.0883	1.836	
13	0.67	14	-2.1906	0.1119	0.0749	1.5581	
14	0.67	15	-2.3471	0.0957	0.064	1.3325	
15	0.665	16	-2.5036	0.0818	0.0544	1.131	
16	0.655	17	-2.66	0.07	0.0458	0.9526	
17	0.66	18	-2.8165	0.0598	0.0395	0.8208	
18	0.645	19	-2.973	0.0512	0.033	0.686	
19	0.615	20	-3.1295	0.0437	0.027	0.5593	
20	0.585	21	-3.286	0.0374	0.0219	0.454	2.1531
21	0.545	22	-3.4424	0.032	0.0174	0.3625	
22	0.51	23	-3.5989	0.0274	0.014	0.2901	
23	0.485	24	-3.7553	0.0234	0.0113	0.2359	
24	0.47	25	-3.9118	0.02	0.0094	0.1955	
25	0.425	26	-4.0683	0.0171	0.0073	0.1512	
26	0.365	27	-4.2248	0.0146	0.0053	0.111	
27	0.325	28	-4.3812	0.0125	0.0041	0.0845	
28	0.28	29	-4.5377	0.011	0.003	0.0623	
29	0.23	30	-4.6942	0.0092	0.0021	0.0437	0.2060
30	0.2	31	-4.8507	0.0078	0.0016	0.0325	
31	0.17	32	-5.0071	0.0067	0.0011	0.0236	
32	0.15	33	-5.164	0.0057	0.0009	0.0178	
33	0.15	34	-5.32	0.0049	0.0007	0.0153	
34	0.14	35	-5.4766	0.0042	0.0006	0.0122	
35	0.13	36	-5.633	0.0036	0.0005	0.0097	
36	0.115	37	-5.7895	0.0031	0.0003	0.0073	
37	0.09	38	-5.946	0.0026	0.0002	0.0049	
38	0.08	39	-6.1024	0.0022	0.00017	0.0037	
39	0.075	40	-6.2589	0.0019	0.00014	0.003	
40	0.065	41	-6.4154	0.0016	0.0001	0.0022	
41	0.03	42	-6.5719	0.0014	0.00005	0.001	

Table 6: Life expectancy of FAW

Pivotal age in days (x)	Different age interval (lx)	No. of dying between x and x+1 (dx)	Rate of mortality (100qx)	Age structure (Lx)	No. of individual's life days beyond 'x' (Tx)	Mean expectation of life (ex)
0-5	0.9	0.03333	3.703333	0.827917	14.225	15.80556
5-10	0.755833	0.02	2.646086	0.718333	13.39708	17.72492
10-15	0.680833	0.0075	1.101591	0.66375	12.67875	18.6224
15-20	0.646667	0.01833	2.834536	0.584167	12.015	18.5799
20-25	0.521667	0.03667	7.029393	0.424167	11.43083	21.91214
25-30	0.326667	0.045	13.77551	0.245	11.00667	33.69388
30-35	0.163333	0.01333	8.161224	0.081667	10.76167	65.88776

4. Conclusion
For effective management of insect pests, the knowledge about the lifecycle and insect biology is required for crop phenology-based pest forecast model construction or in the refining existing models.

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