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Life Table Analysis of Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera : Noctuidae) on Maize Crop

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ABSTRACT

Life table of *Spodoptera frugiperda* on maize was undertaken to study the different population growth statistics. The results on number of individuals survived during development revealed that there was 12.32% mortality during pupal stage. The number that survived from 100 eggs to adult emergence was 42 individuals. Females contributed highest number of progeny (m_x =2285) in the life cycle on the 40th day of pivotal age. The net reproductive potential (R_o) obtained was 470.66 females with the mean length of generation period (T_c) 33.46 days. The innate capacity for increase (rm) and finite rate of increase (λ) were found to be 0.183 and 1.201 females/day, respectively.

Keywords Innate capacity, Life fecundity table, Maize, Mortality, Pivotal age.

INTRODUCTION

Maize (*Zea mays* L.), which is a member of the Poaceae family, is one of the most important and well-known cereal crops, due to its high nutritional worth as a staple food (Abebe and Feyisa 2017). Because of its broad flexibility and high genetic yield potential, it is referred to as the "Queen of Cereals" globally (Jeyaraman *et al.* 2017). In area India ranks fourth while in production it ranks seventh in the world. Production of maize is currently below capacity. One of the main causes of the poor yields that the production of maize is currently experiencing is insect pests. *Spodoptera frugiperda* (J.E. Smith), also known as the fall armyworm (FAW), is an invasive species that significantly reduces the output of maize crops.

Life table is a most important analytical tool, under ecological study, which provides detailed information on population dynamics to generate simple but more informative statistics. It also provides a comprehensive detail of the survivorship, development and expectation of life. Life tables are one of the major tools in pest management as they reveal the most opportune period and vulnerable stages of the insect species. Looking to the above facts regarding practical utility of life table studies in managing the fall armyworm of maize crop, the present investigation conducted.

MATERIALS AND METHODS

The investigation into the life table of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) carried out at the laboratory of Department of Entomology,

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Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during the year 2022-23 under controlled laboratory conditions (25±2°C, 70±10% RH).

In order to maintain the culture of fall armyworm, the larval stages were collected from various maize fields, brought into the Laboratory of Department of Entomology and allowed to grow until they reached up to adulthood. Observations of egg development, larval growth, pupa formation, adult successful emergence and fecundity were recorded regularly. Age-specific mortality in various developmental stages, such as eggs, larvae, pupae and adults was noted and the proper causes of development failure were ascribed.

Stage-specific life table for fall armyworm

In order to create stage-specific life cycle, the lifecycle was divided into various developmental phases, including eggs, larval instars (I, II, III, IV and V), pupae and adults and was measure the development time and survival or mortality for each stage. The observations were recorded every day at 24 h intervals.

Preparation of stage-specific life table for fall armyworm

Data on stage-specific survival for eggs, larvae, pupae and adults were gathered from the age-specific survival and mortality life-table. The information obtained from such a table was applied to the computation of the various life metrics listed below.

Apparent mortality (100 q_x)

It gives the information on number dying as percentage of number entering that stage and was calculated by using formula :

Apparent mortality 100 $q_x = [d_x / l_x] \times 100$

Survival fraction (S_x)

Data obtained on apparent mortality was used for calculation of the stage specific survival fraction (S_x) of each stage by using equation :

S_x of particular stage = [l_x of subsequent stage] / [l_x of particular stage]

Mortality survivor ratio (MSR)

It is the increase in population that would have occurred if the mortality in the stage, in question had not occurred and was calculated as follows :

MSR of particular stage = [Mortality at particular stage] / [l_x of subsequent stage]

Indispensable mortality (IM)

This type of mortality would not be there in case the factor(s) causing it is/are not allowed operating. However, the subsequent mortality factors operate.

The equation is: IM = Number of adults emerged × MSR of particular stage

K values

It is the key (main) factor, which was calculated as the difference between the successive values for "Iog lx," is principally responsible for the change in population from one generation to the next. The "K" symbol represents the total generation mortality, which was estimated by adding the k-values of several developmental phases of insect (Southwood 1978).

$$K = k_E + k_{L1} + k_{L2} + k_{L3} + k_{L4} + k_{L5} + k_{L6} + k_{PP} + k_P$$

Where, k_E, k_{L1}, k_{L2}, k_{L3}, k_{L4}, k_{L5}, k_{L6}, k_{PP} and k_P are the k-values at egg, first instar, second instar, third instar, fourth instar, fifth instar, sixth instar, pre-pupal and pupal stages.

Age-specific life table of fall armyworm

In order to determine the age-specific fertility, the adults were caged for oviposition the same day they emerged. Every day, the leaf used for oviposition was changed and the number of eggs laid the next day was noted. Fecundity observations were made continuously, until all of the female moths died.

Preparation of age- specific life table

The number of alive and dead larvae out of hundred

were counted every day and the following assumptions and headings for the life fecundity tables as proposed by Howe (1953) were used in the documentation of age specific life table.

X= Pivotal age in days or age of the insect in days

l_x= Number of individuals survive at the beginning of each age interval × out of hundred (S_x/S_0)

d_x= Number of individuals die during the age interval × out of hundred (dnx/S_0)

m_x= Age schedule for female births at age 'x'

100 q_x= Per cent mortality, computing through following formula :

$$100\ q_x = (d_x/l_x) \times 100$$

e_x= Expectation of life or mean life remaining for individuals of age × life expectation was calculated by using the equation :

$$e_x=(T_x/L_x)\times 2$$

Here, L_x= Number of individuals alive between age x and x+1 and calculated by the equation :

$$L_x=l_x+(l_x+1)/2$$

T_x= Total number of individuals of x age units beyond the age x and obtained by the equation:

$$T_x= l_x+(l_x+1)+(l_x+2)\ldots\ldots\ldots\ldots +l_w$$

Where,

l_w= The last age interval.

RESULTS AND DISCUSSION

Stage-specific life table of fall armyworm on maize crop during year 2022-23

The results (Table 1) showed that the survival of life stages from egg to adult emergence was 46 individuals out of 100 eggs from a single egg mass. The maximum apparent mortality was recorded at egg stage due to infertility (21.00%) followed by I instar larval stage due to fungal infection (16.45%), II instar larval stage because of fungal infection (15.15%), pre-pupal stage due to unknown causes (6.12%), III instar larval stage due to disease (5.35%), pupal stage due to malformed pupae (4.34%) and minimum mortality was recorded at V instar larval stage due to incomplete moulting (1.96%). The highest survival fraction (Sx) was recorded at V and VI instar larval stage (0.980), while the minimum survival fraction (Sx) was recorded at egg stage (0.790). The findings relating mortality survival ratio showed that the egg stage had the highest value (0.265), while the V and VI instar larval stage had the lowest value (0.020). The maximum indispensable mortality (IM) was recorded during the egg stage (11.16), whereas the minimal indispensable mortality (MI) was recorded at the V instar larval stage (0.840). Maximum generation mortality (k – values) was recorded at egg stage (0.103) and the minimum generation mortality (k – values) of VI instar larvae stage was recorded (0.008) (Fig. 1). However, the sum of k – values (K value) obtained for all the developmental phases was recorded as 0.377, indicating that there will be no increase in population in following generation.

Similar results with the present studies were documented by Yin *et al.* (2020), who reported highest mortality, was occurred in the egg stage (64%) on maize. Similarly, they also found that the apparent mortality and mortality survival ratio was found highest at egg stage (31%) and lowest at larval stage (0%) on maize, respectively.

The findings related to k-value were consistent

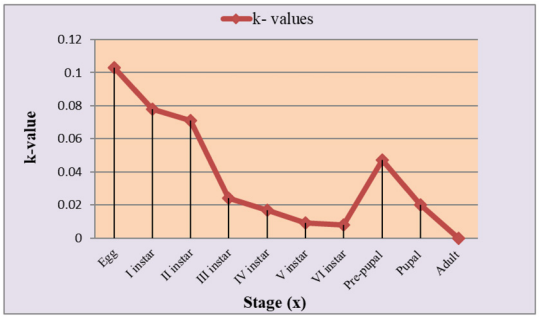

Fig 1. k-values of fall armyworm at different life stages on maize crop.

Table 1. Stage specific life table of fall armyworm, *S. frugiperda* on maize crop during year 2022-2023.

Stages x	No. surviving at the beginning of each stage (l_x)	No. dying in each stage (d_x)	Apparent mortality (100 q_x)	Survival fraction (S_x)	Mortality/ survivor ratio of the stage (MSR)	Indispensable mortality (IM)	Log l_x	k- values
Egg	100	21	21.00	0.790	0.265	11.16	2.000	0.103
I instar	79	13	16.45	0.835	0.196	8.272	1.897	0.078
II instar	66	10	15.15	0.848	0.178	7.500	1.819	0.071
III instar	56	03	5.357	0.946	0.056	2.377	1.748	0.024
IV instar	53	02	3.773	0.962	0.039	1.647	1.724	0.017
V instar	51	01	1.960	0.980	0.020	0.840	1.707	0.009
VI instar	50	01	2.000	0.980	0.020	0.857	1.698	0.008
Pre-pupal	49	05	6.122	0.897	0.113	4.772	1.690	0.047
Pupal	44	02	4.347	0.954	0.047	2.000	1.643	0.020
Adult	42	-	-	-	-	-	1.623	-
								K value =0.377

with Priyanka *et al.* (2021), who found the similar trend that the highest generation mortality (k-value) was observed at I instar larval stage, while the lowest at V instar larval stage, when reared on maize at 27 ± 1°C, 75 ± 20% RH and 14L: 10D and the sum of k values recorded for all developmental stages was 0.602.

Age-specific life table of fall armyworm on maize crop during year 2022-23

The results related to the study of age-specific life table of fall armyworm on maize crop during year 2022-23 revealed that it required maximum of 36-40 days to complete the life cycle. It was also found that the fall army worm reached up to the adult stage at age of 36-40 days and out of 100 only 64 adult moths reached the adulthood. The mortality of fall armyworm was recorded maximum (10) during initial 00-05 days, while minimum (01) during 16-20, 21-25 and 26-30 days. The mortality per cent was relatively higher (12.32%) at the age of 31-35 days of pivotal age due to malformed pupae, however the lowest mortality per cent (1.19%) came in the age interval 16-20 due to incomplete moulting. The life expectancy (ex) of fall armyworm declined gradually with the advancement of the developmental stages (Fig. 2). It was reported highest in age interval 0-5 days which came out to be 12.88 days, while found lowest in age interval 36-40 days which came as 2.00 days (Table 2).

Table 2. Age-specific life table of fall armyworm, *S. frugiperda* on maize crop during year 2022-2023.

Pivotal age in days (x)	No. of surviving to the begining of age interval (l_x)	Individual dying between x and x+1 (d_x)	% mortality (100 q_x)	Alive between age 'x' and 'x+1' (L_x)	No. of individuals life days beyond 'x' (T_x)	Expectation of life (e_x)
00-05	01	0.10	10.0	0.95	6.44	12.88
06-10	0.90	0.04	4.44	0.88	5.49	12.20
11-15	0.86	0.02	2.32	0.85	4.61	10.72
16-20	0.84	0.01	1.19	0.83	3.76	8.95
21-25	0.83	0.01	1.20	0.82	2.92	7.04
26-30	0.82	0.01	1.21	0.77	2.10	5.12
31-35	0.73	0.09	12.32	0.69	1.32	3.63
36-40	0.64	00	00	0.64	0.64	2.00

Table 3. Age-specific fecundity of fall armyworm, *S. frugiperda* on maize crop during year 2022-2023.

Pivotal age in days (x)	Survival of female at age interval (l_x)	Female birth at age (m_x)	$l_x.m_x$	$x.l_x.m_x$
0-27	-	-	-	-
28	0.24	-	0.24	6.72
29	0.24	-	0.24	6.96
30	0.24	158.0	37.92	1137.6
31	0.24	193.0	46.32	1435.92
32	0.24	213.0	51.12	1635.84
33	0.22	381.0	83.82	2766.06
34	0.22	418.0	91.96	3126.64
35	0.20	557.0	111.4	3899.00
36	0.16	207.0	33.12	1192.32
37	0.10	103.0	10.3	381.10
38	0.08	46.0	3.68	139.84
39	0.06	9.00	0.54	21.06
40	0.03	00	00	00
		Σmx= 2285	Σlx.mx= 470.66	Σx.lxmx= 15749.06

Observations were recorded earlier by Priyanka *et al.* (2021), where the highest life expectancy (e_x) of fall armyworm was reported in age interval 0-5 days which came out to be 15.81 days, while found lowest in age interval 45-50 days which came as 1.00 days. Similarly, Sunil *et al.* (2019) also observed the highest life expectancy (e_x) of *S. litura* as 14.04 days for age interval 0-5 days. As development progressed, the life expectancy (e_x) of fall armyworm decreased gradually. Similar results were observed earlier by Gedia *et al.* (2008), where the contribution of eggs, larvae, pupae and adults of *S. litura* were 52.0, 46.4, 1.30 and 0.30%, respectively on groundnut.

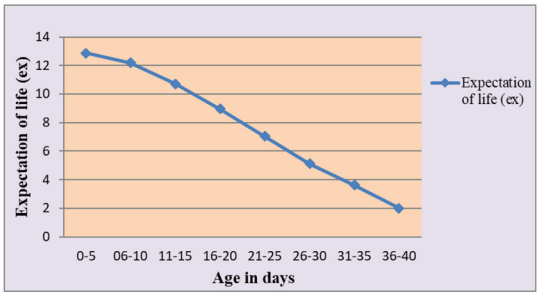

Fig 2. Life expectancy of fall armyworm at different age intervals on maize crop.

Table 4. Population and reproduction parameters of fall armyworm, *S. frugiperda* on maize crop during year 2022-2023.

Sl. No.	Parameters	Formula	Calculated value
1	Net reproductive rate (R_o)	$R_o = \Sigma l_x.m_x$	470.66
2	Mean length of generation/Approximate generation time (T_c)	$T_c = \Sigma_x.l_x\, mx/R_o$	33.46
3	Intrinsic rate of natural increase (r_m)	$r_m = \log e\, R_o / T_c$	0.183
4	Finite rate of increase (λ)	$\lambda = \text{antilog}_e\, r_m$	1.201
5	Potential fecundity (Pf)	$Pf = \Sigma m_x$	2285
6	Hypothetical F_2 female	$(R_o)^2$	221520.83

Age-specific fecundity of fall armyworm on maize crop during year 2022-23

The data recorded during the year 2022-23 was indicated that pre-oviposition period ranged from 27th to 29th day of pivotal age. Female deposited the first batch of eggs on 30th day (m_x=158) and it continued up to 39th day (m_x=9.0) with l_x values being 0.24 and 0.06, respectively (Table 3). The first female mortality was observed on the 6th day after the emergence of adult i.e., on the 33rd day of pivotal age (l_x=0.22) and mortality increased gradually, specified by a gradual decrease in the l_x values after 33rd day of pivotal age. The females contributed maximum mean progeny production per day (m_x=557) on 35th day of pivotal age, which declined (m_x=9.0) on the 39th day. Summation of $l_x.m_x$ and summation of $x.l_x.m_x$ was recorded as 470.66 and 15749.06, respectively.

In one generation, the ratio of total female birth was recorded as 470.66, and represented as the net reproductive rate (R_o). The mean length of generation time (T_c) was recorded as 33.46 days. The daily finite rate of increase in number was found to be 1.201 females per female per day, while the intrinsic rate of natural increase in number (rm) was reported to be 0.183 females per female per day. The estimated number of hypothetical females in the F_2 generation was reported as 221520.83, with a potential fecundity of 2285 eggs per female (Table 4).

Priyanka *et al.* (2021) found a similar pattern, with the pre-oviposition period ranging from 29th to 31st days of pivotal age and female contributed maximum progeny (m_x=577) in the lifecycle on the 36th day of pivotal age.

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