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LIFE TABLE STUDY OF *Corcyra cephalonica* (STAINTON) IN STORED PEARL MILLET

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ABSTRACT

The studies on life table, age-specific distribution and life expectancy of rice moth, *Corcyra cephalonica* (Stainton) on pearl millet were carried out from June, 2022 to August, 2022 at the Regional Research Station Laboratory, Anand Agricultural University, Anand. Investigations on the fecundity life table and age-specific distribution of *C. cephalonica* revealed that the life expectancy of newly deposited eggs was only 12.30 days. The maximum duration of egg, larva and pupa was 4, 10 and 15 days, respectively. The pre-oviposition and oviposition periods were 1 and 4 days, respectively. The pre-pupation and pupation period were 8 and 6 days, respectively. The net reproductive rate (Ro) was 100.21, with the mean length of generation (Tc) 33.67 days. The values of the intrinsic rate of natural increase (rm) and finite rate of increase in number (λ) were computed to be 0.13 and 1.15 females per female per day, respectively. A study on age-specific distribution revealed that the contribution of the eggs and larvae to the population was quite high as compared to pupae and adults.

***Keywords*:** Rice moth, Bajra, life table, life cycle, reproductive potential

Introduction

The insect known as *Corcyra cephalonica* (Stainton), commonly referred to as the "Rice meal moth" or the "Flour moth," is a member of the Pyralidae family and falls under the Lepidoptera order (Stainton, 1866). It is a significant storage pest of pearl millet that is distributed across multiple regions, including Asia, Africa, North America, and Europe. Adult rice meal moths exhibit a grey coloration. Following mating, female moths typically deposit a range of 100 to 200 eggs in proximity to their food source. These eggs typically hatch within a span of 4 to 10 days. The larval stage involves the construction of a feeding tube gallery, composed of a silken structure and food particles, to facilitate nourishment and growth. Upon reaching full maturity, the larvae encase themselves in compact white cocoons for pupation. These pupae may be observed within storage pallets, sacks, or even within the food itself (Pandey, 2011). The rice moth is a significant pest that poses a serious threat to various stored food commodities, including cereals, pulses, oilseeds, millets and other food products. The current research on the life table of rice moths serves as a crucial tool for comprehending variations in the population of rice moths across various developmental stages throughout their life cycle. This study proves valuable in analyzing the mortality patterns within the insect population, aiding in the identification of key factors contributing to the highest mortality rates. The life table emerges as a significant analytical method for investigating the distribution, age determination, and mortality of organisms, allowing for the calculation of mortality rates for individual insects.

Materials and Methods

Rearing of *C. cephalonica*

Adult moths collected from the stock culture maintained at Biocontrol Research Laboratory, A.A.U, Anand were used for mass rearing of *C. cephalonica*. The broken seeds of pearl millet were used for mass rearing of the pest. The broken seeds were sterilised by heating at 55 ºC for four hours in an oven. The broken seeds of pearl millet were taken separately in wide-mouth cylindrical jars (diameter 10 cm, height 25 cm) up to three-fourths level. A few pairs of male and female moths were released in each jar for oviposition. The mouth of the jars was covered with two muslin cloths (black) tied with the help of rubber band. The jars were kept at an optimum temperature for the development of pest. A sufficient number of larvae and adults, thus obtained were used to study various aspects of *C. cephalonica* (Fig. 1).

Fig. 1: Mass rearing of rice moth, *C. cephalonica* in stored pearl millet

Separation of Sex

The sex of *C. cephalonica* adults were separated based on the male and female size. The male is generally small as compared to the female.

Construction of the Fecundity Life Table of *C. cephalonica* in Stored Pearl Millet

The investigation on the fecundity life table was carried out in the laboratory at a constant temperature (28 ± 1ºC) and relative humidity (60 ± 5%). To construct the life fecundity table, one hundred freshly laid eggs of *C. cephalonica* were collected carefully and placed in ten plastic containers (5.0 cm diameter × 5.5 cm height) in batches of 10 each. Observations on hatching, total larval development, formation of pupae and emergence of adults and fecundity of females were recorded daily. Age-specific mortality in different developmental stages, such as eggs, larvae, pupae and adults, was also recorded. To determine the age-specific fecundity, the total number of adults that emerged on the same day was kept separately in an oviposition cage for oviposition. The number of eggs laid on subsequent days on the pearl millet seeds was recorded. The observations on fecundity were continued till all the females died.

The column headings for the construction of life fecundity tables proposed by Howe (1958) and Atwal and Bains (1974) were used in this study. The same is as follows:

x = Pivotal age in days
l_x = Survival of female at age 'x'
m_x = Age schedule for female births at age 'x'

Net reproductive rate

The values of 'x', 'l_x' and 'm_x' were calculated from the data given in life tables. The total of products '$l_x m_x$' was the net reproductive rate (R_0) (Lotka, 1956). The 'R_0' was the rate of multiplication of the population in a generation is measured in terms of the number of females produced per generation. The number of times a population would multiply per generation was calculated by using the following formula:

$$R_0 = \Sigma\, l_x m_x$$

Mean duration of generation (T_C)

The approximate rate of generation time (T_C) (the mean age of the mothers in a cohort at the birth of female offspring) was calculated with the help of the following formula:

$$T_c = \frac{\Sigma\, x l_x m_x}{R_0}$$

Innate capacity for an increase in numbers (r_m)

The total number of individuals who survived and the mean number of female offspring born were recorded at each age interval. From these data, the arbitrary values of 'r_m' were derived by using the following formula.

$$T_c = \frac{\Sigma\, x l_x m_x}{R_0}$$

Where,
e = 2.71828
T_c = Mean generation time

The intrinsic rate of increase (r_m) was subsequently calculated from the arbitrary 'rm' by taking three trial values arbitrarily selected on either side of it differing in the second decimal place by establishing the following relationship (Atwal and Bains, 1974).

$$\sum e^{7-r_m x} . l_x m_x = e^7 = 1097$$

Such tables were constructed with the help of ‘x’ and ‘$l_x m_x$’ for each trial of ‘rm’. The values of $\Sigma e^{7-rmx}.l_x m_x$ were obtained from the trial and it was plotted against their arbitrary ‘rm’, which gave a straight line. The straight line was intersected by a vertical line drawn from the described values of $\Sigma e^{7-rmx}.l_x m_x$ = 1097. The point of the intersection gave a value of true ‘r_m’ accurate to four decimal points. The precise generation time (T) was then calculated by using the following formula:

$$T = \frac{log_e R_0}{r_m}$$

The finite rate of natural increase (λ)

The number of females per female per day, *i.e.*, the finite rate of increase, was determined as:

$$\lambda = antilog_e{}^{r_m}$$

From this data, the weekly multiplication of the population was calculated. Hypothetical F_2 females were also worked out with the formula $(R_o)^2$.

Stable age distribution

The stable age distribution (per cent distribution of various age groups) of the *C. cephalonica* was worked out with the knowledge of ‘r_m’ and the age-specific mortality of the immature and mature stages. The stable age distribution table was constructed by following the method of Andrewartha and Birch (1954) and Atwal and Bains (1974). The ‘L_x’ (life table age distribution) was calculated from the ‘l_x’ by using the following formula:

$$L_x = \frac{l_x + l_{(x+1)}}{2}$$

Per cent distribution of each age group were calculated by multiplying the L_x with $e^{-rm(x+1)}$. By putting together, the percentage under each stage, *viz.*, egg, larval, pupal and adult stages, the expected per cent distribution was worked out.

Life expectancy

Life expectancy was worked out by using columns x, l_x, d_x, $100q_x$, L_x, T_x and e_x.

Were,

x = Pivotal age (days)

l_x = Number of survivors at the beginning of the age interval out of 100

d_x = Number dying during ‘x’

$100q_x = \frac{l_x + l_{(x+1)}}{2}$, mortality rate per hundred alive at the beginning of age interval

$L_x = \frac{l_x + l_{(x+1)}}{2}$, Alive between x and x + 1

T_x = Number of an individual’s life days beyond ‘x’

$e_x = \frac{T_x}{l_x} \times 2$, Expectation of further life.

Results and Discussion

Fecundity Life Table

Life tables are analysed to determine which stage contributes the most to the life cycle of a pest. The life tables developed by Birch (1948) can be successfully used to determine the growth statistics and further applied to estimate the potential increase of insects reared on a host.

The results of the survival of different stages of *C. cephalonica* in stored pearl millet are summarised in Table 1. It is evident from the data that the maximum duration of egg, larva and pupa were observed at 4, 10 and 14 days, respectively and the number that survived at the egg stage was 91 individuals, larval stage was 80 individuals and adult stage emergence was 72 individuals (Fig. 2). There was 9% mortality during the egg stage.

The present findings are consistent with the results found by Allotey and Azalekor (2000), who reported 83% hatchability of eggs when it was reared on different food media like groundnut, bambara groundnut and cowpea. The researchers concluded that there was 16% mortality during the egg stage, which is more or less similar to the current finding result during the life table study. Dulera *et al.* (2015) observed that the maximum duration of egg, larva and pupa were 4, 15 and 29 days, respectively, on groundnut. Our present findings are more or less similar to earlier path-finding researchers, with slight variation due to different hosts and relative humidity.

The data presented in Table 2 indicated that the pivotal age pre-oviposition period was the 30th day. Females deposited the first batch of eggs on the 31st day. The maximum mean progeny production per day (mx) was observed on the 31st day of pivotal age to the tune of 67.5, which declined to 2.29 (mx) on the 47th day. The first female mortality was observed on the 2nd day (lx = 0.68) after the emergence of adult females and it increased slowly thereafter.

The oviposition period of *C. cephalonica* was 6 to 8 days on grains. It supports the work reported by

Haritha *et al.* (2000) who observed pre-oviposition and oviposition periods were 0.53 and 6.00 days on pods and kernels, respectively. Patel and Patel (2007) observed the oviposition period from 5.50 to 6.21 days on different host commodities. Similar results were also reported by Shailaja *et al.* (2009), that the pre-oviposition and post-oviposition periods of *C. cephalonica* on proso millet were 1.35 and 2.5 days, respectively. These observations are quite similar to the present finding research, but the approximate difference is occurring due to different types of hosts and environmental conditions.

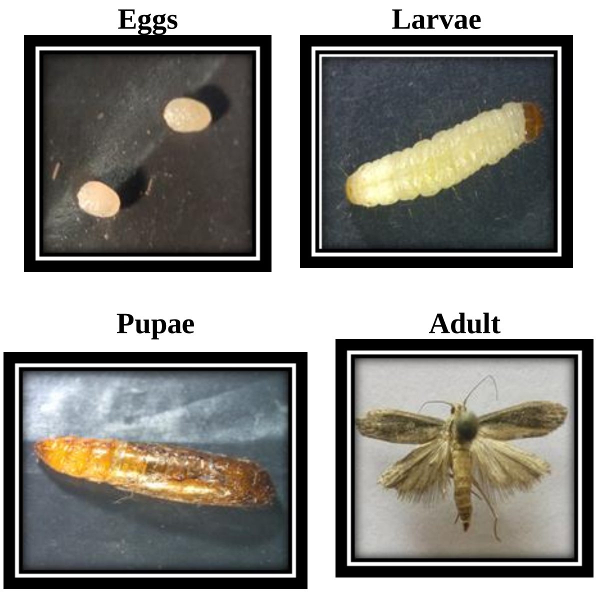

Fig. 2: Different developmental stages of *C. cephalonica*

Table 1: Survival of different developmental stages of *C. cephalonica* in stored pearl millet

No. of eggs	Number of individuals survived at different stages		
	Egg stage (0 to 4 days)	Larval stage (5 to 15 days)	Pupal stage (16 to 29 days)
10	8	7	6
10	9	8	8
10	10	9	8
10	9	8	7
10	9	9	9
10	9	8	7
10	9	8	7
10	10	8	7
10	10	9	8
10	8	6	5
100	**91**	**80**	**72**

The net reproductive rate (Ro) was worked out to 100.21 females per female with the mean length of generation time (Tc) was 33.67 days (Table 3). The intrinsic rate of natural increase in numbers (rm) was 0.13 females per female per day (Fig. 3) with a daily finite rate of increase (λ) of 1.15 females per female per day and the population would be able to multiply 2.65 times/week. The hypothetical F_2 females were worked out to be 10042.04. The multiplicity of the population is directly related to the reproductive ability of the insect. For effective control of population growth, a quantitative estimate of the biotic potential is imperative. Thus, the suitable statistic that aids in explaining the innate capacity for increase, or intrinsic rate of natural increase, is often useful for quantitatively explaining population increase.

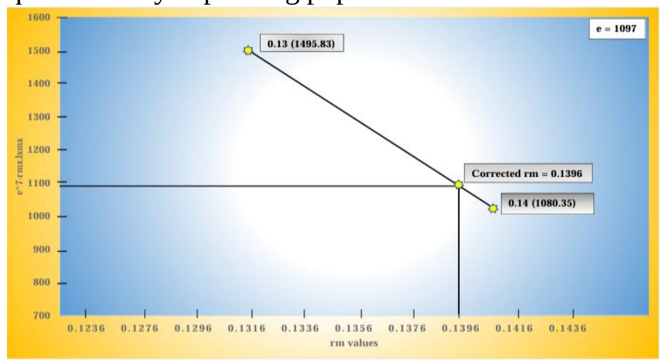

Fig. 3: Determination of the intrinsic rate of increase (rm) of *C. cephalonica* in stored pearl milllet

Present findings are more or less similar to the results of Ray et al. (1990), who reported that the net reproductive rate (Ro) was 149.81 with a mean generation length (Tc) of 63.01 days. The intrinsic rate of natural increase in numbers (rm) and finite rate of increase in numbers (λ) were 0.08 and 1.08 females per female per day, respectively. The population would be able to multiply 1.74 times per week. Similar results were also reported by Dulera *et al.* (2015) who studied that the net reproductive rate (Ro) was 100.31 with the mean length of generation (Tc) 32.25 days. The values of intrinsic rate of natural increase (rm) and the finite rate of increase in number (λ) were computed to be 0.14 and 2.75 females per female per day, respectively.

Teotia *et al.* (1975) observed the population growth of *C. cephalonica* on crushed jowar grains at 26.5°C temperature and 73% relative humidity. In abundant space and food, the population increased with an infinitesimal rate (innate capacity for increase) of 0.12 and a finite rate of 1.13 per day. The population multiplied 246.32 times between two successive generations and the mean time for completing a generation was 44.97 days. These research results generally match with the results of the present findings. Some differences may be occurring due to relative humidity and temperature, which are different in the researcher's work and the present research findings. Application of the life table, rate of increase and stable age distribution are almost as diverse as the other insects (Fakhari and Ansari, 2006). Such life tables may be analyzed to determine which stage, the life cycle of the insect, contributes the most of the population trend (Mandal *et al*., 2007).

In our findings, the stable age distribution of *C. cephalonica* was worked out by observing the age schedule of birth rate and death rate (mx and dx).

The data presented in Table 4 revealed that adults contributed 88.04% to the population, whereas eggs, larvae and pupae contributed 6.41, 4.60 and 0.93%, respectively. Thus, the table suggested that the maximum contribution towards the stable age distribution was made by the adult stage. More or less similar results were also reported by Dulera *et al.* (2015) who reported that adults contributed only 1.32% to the population, whereas eggs, larvae and pupae contributed 53.83, 37.15 and 7.68 % respectively. Thus, the table suggested that the maximum contribution towards the stable age distribution was made by the immature stages. These observations are quite similar to the present research but approximate differences are occurring due to different type of host and environmental conditions.

An attempt was made to work out life expectancy. The results summarized in Table 5 and depicted in Fig. 4 indicated that the life expectancy of newly deposited eggs was only 12.30 days. Further, it was observed that the mortality rate was comparatively high at the age of 45 to 50 days when the expectation of further life was reduced to 1.02 days from 12.30 days in the beginning. The recent findings strongly align with the observations made by Dulera *et al.* (2015), who noted that the life expectancy of newly deposited eggs was 12.22 days. The mortality rate was significantly higher around the age of 45 to 50 days, resulting in a considerable decrease in the remaining life expectancy from 12.22 days at the beginning to only 1.02 days.

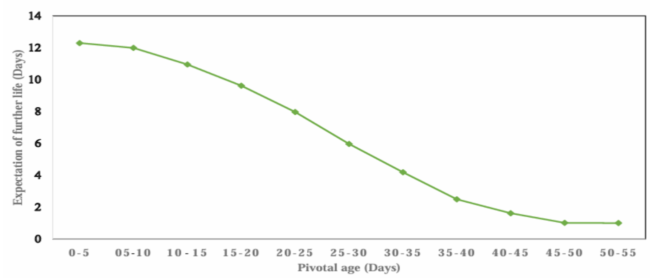

Fig. 4 : Life table for computing the life expectancy of *C. cephalonica* in stored pearl millet

Table 2: Life table (for female) and age-specific fecundity for *C. cephalonica* in stored pearl millet

Pivotal age in days 'x'	Survival of females at different age intervals 'lx'	Age schedule for female birth 'mx'	'lxmx'	'xlxmx'
0-29	0.72	-	-	Immature Stages
30	0.72	-	-	-
31	0.68	67.5	45.9	1422.9
32	0.66	-	-	-
33	0.63	27.22	17.14	565.62
34	0.6	12.08	7.24	246.16
35	0.56	13.75	7.7	269.5
36	0.53	6.31	3.34	120.24
37	0.49	10.22	5	185
38	0.43	8.65	3.71	140.98
39	0.4	3.67	1.46	56.94
40	0.37	7.07	2.75	110
41	0.34	3.22	1.09	44.69
42	0.3	5.95	1.78	74.76
43	0.24	5.16	1.23	52.89
44	0.21	2.74	0.57	25.08
45	0.18	2.56	0.46	20.7
46	0.14	4.27	0.59	27.14
47	0.11	2.29	0.25	11.75
48	0.09	-	-	-
			$R_0 = 100.21$	$\Sigma xlxmx = 3374.35$

Table 3: Mean length of generation, innate capacity of increase in numbers and finite rate of increase in numbers of *C. cephalonica* in stored pearl millet

Population growth statistics	Formulae	Calculated values
Net reproductive rate	$R_0 = \Sigma lxmx$	100.21
Mean length of generation	$T_c = \frac{\Sigma xlxmx}{Ro}$	33.67 Days
Innate capacity for an increase in number	$rm = \frac{Log_e Ro}{Tc}$	0.13 Females/female/day
Arbitrary rm	0.13 to 0.14	
Corrected rm	$\Sigma e^{7-rmx}.lxmx$	0.1396 Females/female/day
Corrected generation time	$T = \frac{Log_e Ro}{rm}$	33.00 Days
Finite rate of increase in number	Antilog e^{rm}	1.15 Females/female/day
Weekly multiplication of population	$(\lambda)^7$	2.65 Times
Hypothetical F_2 females	$(Ro)^2$	10042.04 Numbers

Table 4: Age-specific distribution of *C. cephalonica* in stored pearl millet

Pivotal age in days (x)	Lx	$e^{-rm(x+1)}$	Lx. $e^{-rm(x+1)}$	Percentage distribution
Egg stage				
0	1.00	0.8780	0.8780	1.75
1	1.00	0.7633	0.7633	1.52
2	0.96	0.6126	0.5880	1.17
3	0.93	0.5712	0.5312	1.06
4	0.91	0.4965	0.4518	0.90
				6.41
Larval stage				
5	0.91	0.4317	0.3928	0.78
6	0.91	0.3753	0.3415	0.68
7	0.91	0.3262	0.2968	0.59
8	0.91	0.2836	0.2580	0.51
9	0.89	0.2465	0.2193	0.43
10	0.87	0.2143	0.1907	0.37
11	0.87	0.1863	0.1620	0.32
12	0.87	0.1636	0.1423	0.28
13	0.84	0.1422	0.1194	0.23
14	0.83	0.1236	0.1025	0.20
15	0.80	0.1075	0.0860	0.17
				4.60
Pupal stage				
16	0.80	0.0934	0.0747	0.14
17	0.80	0.0812	0.0650	0.12
18	0.80	0.0706	0.0565	0.11
19	0.78	0.0614	0.0479	0.09
20	0.75	0.0533	0.0400	0.07
21	0.74	0.0464	0.0343	0.06
22	0.73	0.0403	0.0294	0.05
23	0.73	0.0350	0.0256	0.05
24	0.72	0.0305	0.0220	0.04
25	0.72	0.0265	0.0191	0.03
26	0.72	0.0230	0.0166	0.03
27	0.72	0.0200	0.0144	0.02
28	0.72	0.0174	0.0125	0.02
29	0.72	0.0151	0.0109	0.02
				0.93

Adult stage				
30	0.72	0.0131	0.0094	0.01
31	0.72	0.0114	0.0082	0.01
32	0.72	9.9518	7.1653	14.30
33	0.72	8.6516	6.2292	12.43
34	0.70	7.5214	5.2650	10.51
35	0.69	6.5388	4.5118	9.00
36	0.69	5.6845	3.9223	7.83
37	0.68	4.9915	3.3942	6.77
38	0.66	4.3394	2.8640	5.71
39	0.65	3.7725	2.4521	4.89
40	0.63	3.2797	2.0662	4.12
41	0.58	2.8512	1.6537	3.30
42	0.52	2.4787	1.2889	2.57
43	0.50	2.1549	1.0775	2.15
44	0.41	1.8734	0.7681	1.53
45	0.36	1.6286	0.5863	1.17
46	0.30	1.4158	0.4247	0.84
47	0.23	1.2309	0.2831	0.56
48	0.11	1.0701	0.1177	0.23
				88.04

Table 5: Life table for computing life expectancy of *C. cephalonica* in stored pearl millet

Pivotal age (days)	**Number of survivors to the beginning of age interval**	**Number of dying during 'X'**	**Mortality rate per hundred alive at beginning of age interval $\frac{(dx.100)}{lx}$**	**Alive between ge 'X' and 'X + 1 $\frac{(lx+(lx+1)}{2}$**	**No. of the individual's life days beyond 'X'**	**Expectation of further life in days ($\frac{Tx}{lx}$×2)**
(x)	**(lx)**	**(dx)**	**100 qx**	**(Lx)**	**(Tx)**	**(ex)**
0-5	100	13.00	13.00	93.50	615.09	12.30
5-10	87.00	7.00	8.05	83.50	521.59	11.99
10-15	80.00	5.00	6.25	77.50	438.09	10.95
15-20	75.00	3.00	4.00	73.50	360.59	9.62
20-25	72.00	0.00	0.00	72.00	287.09	7.97
25-30	72.00	3.00	4.17	70.50	215.09	5.97
30-35	69.00	6.00	8.70	66.00	144.59	4.19
35-40	63.00	27.00	42.86	49.50	78.59	2.49
40-45	36.00	25.00	69.44	23.50	29.09	1.62
45-50	11.00	10.91	99.18	5.55	5.59	1.02
50-55	0.09	0.09	100.00	0.05	0.05	1.00

Conclusion

The net reproductive rate (Ro) was 100.21 with the mean length of generation (Tc) 33.67 days. The values of intrinsic rate of natural increase (rm) and finite rate of increase in number (λ) were computed to be 0.13 and 1.15 females per female per day, respectively.

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