The Pharma Innovation Journal 2022; SP-11(6): 2872-2875

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(6): 2872-2875

www.thepharmajournal.com
Received: 23-03-2022
Accepted: 29-04-2022

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Life table of ladybird beetle, *Cheilomenes sexmaculata* (Fabricius) on cotton aphid

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Abstract
A study was carried out to construct the life table of ladybird beetle, *Cheilomenes sexmaculata* at Department of Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during the year 2019-20. On the basis of the observation made for the life table studies of *C. sexmaculata* reared on cotton aphid. *Aphis gossypii,* the net reproductive rate (R_0) 129.47 was obtained with a mean length of generation (T) 26.81 days. The intrinsic rate of natural increase in numbers (r_m) was 0.1871 females per female per day and the population would be able to multiply 3.7034 times per week. The hypothetical F_2 females were worked out to be 16,763.69. The life expectancy of *C. sexmaculata* declined gradually with the advancement of development. The life expectancy of newly deposited eggs was 10.70 days.

Keywords: Ladybird beetle, *Cheilomenes sexmaculata, Aphis gossypii,* life table

Introduction

Biological control is the most economical, eco-friendly and effective approach involving the utilization of natural enemies such as predators, parasitoids and pathogens. It has long been recognized as core component of Integrated Pest Managemnt and has assumed significance. The predaceous coccinellids under the order coleoptera and family coccinellidae are linked to biological control more than any other taxa of predatory organisms. It is one of the important predators of aphids, mealybugs, scale insects, whiteflies, thrips, leafhoppers, mites and other small soft-bodied insect pests (Omkar and Pervez, 2000) [12]. *Cheilomenes sexmaculata* (Fabricius) is a species of ladybird beetle. It was described by Johan Christian Fabricius in 1781. It is well known as a predator of aphids and other small insects. High value of the life history parameters *viz.*; developmental rate, immature survival, fecundity, egg viability, reproductive rate and conversion of efficiency of ingested food it has the intrinsic advantages over two coexisting coccinella species (Omkar *et al.*, 2005) [11]. Ladybird beetle has a significant potential of commercialization and use against a variety of pests in combination with other integrated pest management tactics. Various works has been in progress on a very large-scale use of *C. sexmaculata* in different countries leading to development of large-scale mass production technology (Pirsanna, 2012). Life table analysis is a standard ecological method to estimate demographic parameters related to population dynamics (Legaspi, 2004) [10]. Life table gives the most comprehensive explanation of the survivorship, development, and reproduction of a population. By correlating studies on the predation rate and life table and by considering variations due to age, stage, and sex into account, the growth, stage variability, reproduction, and the predation rate can be effectively characterized (Chi and Yang, 2003) [6]. Thus, more effective use of these natural enemies in biological control of pests and to insight the knowledge on above mentioned aspects the present study was carried out.

Materials and Methodology

Initial culture of predatory coccinellid was collected from different field crops and maintained on aphids, *Aphis gossypii* (Glower). The field collected adults were confined in a plastic jar (20.0×10.0 cm) covered with black muslin cloth and tightened with rubber band. The adults were provided with suitable number of aphids as food. Initially counted numbers of 15 to 20 aphids were provided, but with the gradual development of larvae the numbers of aphids were increased proportionally. Eggs laid by the female coccinellids on leaves or periphery of the jar was collected after 2 to 3 days, by gently brushing with a soft camel hair brush and were kept in plastic vials of 5.0 × 4.0 cm size, with paper pieces to minimize cannibalism among emerging grubs. Initially the newly hatched grubs were reared in groups for two days in plastic jar and then reared individually in plastic vials. Nymphs of aphids (up to 100) were provided daily to each individual in plastic vials to the predatory grubs until pupation. The adults emerged out from pupae were collected individually with the help of plastic tube and transferred to an aluminum cage of size 15.0 × 15.0 × 15.0 cm for mating. Newly emerged adults were provided with host (prey) as described earlier. The culture of the predator maintained was used for further study of different parameters.

For constructing the life table, the culture of *C. sexmaculata* was maintained for two consecutive generations at constant temperature of 25 ± 1 °C using B.O.D. incubator as mentioned under methodology. Freshly laid 100 eggs were collected from the cage with the help of wet camel hair brush and placed in 10 Petri dishes in batches of 10 each. The eggs were placed on the slides in one row to facilitate observations on hatching. Fresh food was provided daily in the morning. Observations on hatching, total larval development, formation of pupae, emergence of adults and fecundity of females were recorded daily. Age specific mortality in different developmental stages such as eggs, larvae, pupae and adults were recorded. With a view to determine the age specific fecundity, total number of adults emerged on the same day were kept separately in oviposition cage for egg laying. Numbers of eggs laid on subsequent days were recorded. The observations on fecundity were continued till all the females died. The female birth was calculated according to the sex ratio. Life tables were constructed according to the methods of Birch (1948) [5], Howe (1953) [9] and Atwal and Bains (1974) [4]. Stable age distribution was worked out by observing the population schedule of birth rate and death rate (m_x and l_x) when grown in limited space. Life expectancy was computed by using the method suggested by Deevey (1947) [7] and Atwal and Bains (1974) [4]. The male and female was separated by observing the physical properties since, female tends to be larger than the males and in males, the distal margin of seventh abdominal sternite was concave in shape, while in female they were convex. Male ladybird beetles display lighter pigmentation of their labrum and prosternum, while females had darker pigmentation (Doston, 2018) [8].

Results and Discussion

The studies on life table, age specific distribution and life expectancy of *C. sexmaculata* on *A. gossypii* were carried out at Department of Agricultural Entomology, Anand Agricultural University, Anand at a constant temperature of 25 ± 1 ^{0}C during the month of November, 2019 to February, 2020. The results obtained are presented herewith. An attempt was made to work out the number of individuals survived during development. The data (Table 1) indicated that there was very less mortality during egg stage. The numbers that survived from 100 eggs to adult emergence was 98 individuals. The maximum duration of egg stage, larval stage, pre pupal stage and pupal stage were recorded as 2, 9, 2 and 4 days, respectively.

Life fecundity table was constructed to determine the survival of female (l_x) and age specific fecundity (m_x). Close interpretation of the data (Tables 2 and 3 depicted in Fig. 1) indicated that pre-oviposition period was between 18th and 21st days of pivotal age. Female started laying eggs after 22th day and ceased after 35th day with l_x values being 0.82 and 0.01, respectively. The females contributed the highest number of progeny (m_x = 28.82) on 27th day of pivotal age, which decreased day by day. The net reproductive rate (R_0) of 129.47 (Table 4.3) was obtained with mean length of generation (T) at 26.81 days. The intrinsic rate of natural increase in numbers (r_m) was 0.1871 females per female per day and the population would be able to multiply 3.7034 times a week. The hypothetical F_2 females were worked out to be 16,763.69. No similar records are found for these observations, and hence comparisons are lacking. Although, Zhao *et al.* (2015) [13] observed more or less similar results for *C. sexmaculata* on *A. craccivora* a few differences that are observed may be due to the difference in the host aphid species. Abbas *et al.* (2020) [1] observed that intrinsic rate of increase (r_m) and mean length of generation time (T_c) of the life table of *Menochilus sexmaculatus* (Fabricius) against different aphid species. The results recorded on *Myzus persicae* Sulzer and *Lipaphis erysimi* Kaltenbach were somewhat similar to that found on present investigation. The net reproductive rate (R_0) recorded on host *A. nerii* Fonscolombe was nearer to that observed on *A. gossypii* in present investigation.

The contribution of each developmental stage and the stable age distribution were also calculated (Table 4). The data showed that adults contributed only 2.7081 per cent to the population of stable age and that of eggs, larvae, pre-pupal and pupae was 44.81, 45.95, 3.053 and 3.471 %, respectively. These observations lack comparisons, since no similar observations pertaining to stable age distributions parameters were available. The life expectancy data (Table 5) clearly indicated that life expectancy of *C. sexmaculata* declined gradually with the advancement of development. The life expectancy of newly deposited eggs was 10.70 days. The expectancy of further life was 5.92 days at the time of adult emergence. The life expectancy of *A. nerii* and *M. persicae* recorded by Abbas *et al.* (2020) [1] which is somewhat similar to the present findings of investigations.

Table 1: Survival of different life stages of *C. sexmaculata*

Sr. No.	No. of eggs	Number of individuals survived			
		Egg stage (0–2 days)	Larval stage (3–11 days)	Pre-pupal stage (12-13 days)	Pupal stage (14–17 days)
1	10	10	10	10	10
2	10	10	9	9	9
3	10	10	9	9	8
4	10	10	9	9	9
5	10	9	8	8	7
6	10	10	10	10	9
7	10	10	8	8	8
8	10	10	9	9	9
9	10	9	6	6	6
10	10	10	10	10	10
Total	100	98	88	88	85

Table 2: Age specific fecundity of *C. sexmaculata* (for female)

Pivotal age in days (x)	Survival of female at different age interval (l_x)	Age schedule for female births (m_x)	$l_x m_x$	$xl_x m_x$
0-17	**Immature stages**			
18-21	**Pre-oviposition period**			
22	0.82	4.76	3.90	85.89
23	0.82	9.91	8.13	186.96
24	0.81	15.90	12.88	309.14
25	0.75	21.73	16.30	407.40
26	0.75	24.99	18.74	487.29
27	0.70	28.82	20.17	544.61
28	0.69	22.70	15.66	438.48
29	0.60	22.08	13.25	384.12
30	0.55	19.53	10.74	322.29
31	0.41	15.05	6.17	191.34
32	0.30	8.83	2.65	84.73
33	0.14	5.62	0.79	25.96
34	0.04	2.33	0.09	3.16
35	0.01	0.41	0.00	0.14
			$\Sigma l_x m_x$ 129.47	$\Sigma xl_x m_x$ 3471.52

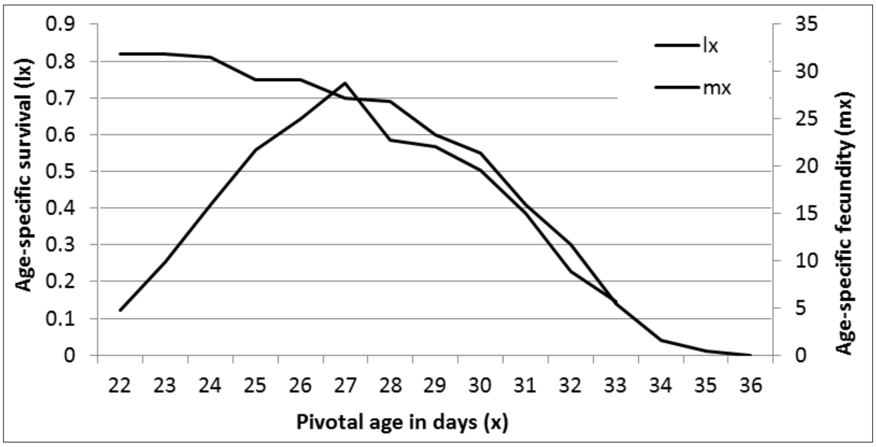

Fig 1: Age-specific survival and fecundity of *C. sexmaculata* reared on *A. gossypii*

Table 3: Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *C. sexmaculata*

Sr. No.	Population growth statistics	Formula	Calculated values
1	Net reproductive rate	$R_0 = \Sigma l_x m_x$	129.47
2	Mean length of generation (days)	$r_m = \frac{\log_e R_0}{T_c}$	26.81
3	Innate capacity for increase in numbers (Females/female/day)	$T_c = \frac{\sum x l_x m_x}{R_0}$	0.1814
4	Arbitrary 'r_m' (r_c) = 0.18 and 0.19	-	-
5	Corrected 'r_m' (Females/female/day)	$\sum e^{7-r_m x} . l_x m_x$	0.1871
6	Corrected generation time (days)	$T= \frac{log_e R_0}{r_m}$	26.00
7	Finite rate of increase in numbers (Females/female/day)	$\lambda = \text{antilog}_e{}^{r_m}$	1.2057
8	Weekly multiplication of population (times)	$(\lambda)^7$	3.7034
9	Hypothetical F_2 females	$(R_0)^2$	16763.69

Table 4: Percentage contribution of various stages to the stable age-distribution of *C. sexmaculata*

Hosts	Percentage contribution of various stages				
	Eggs	Larvae	Pre-pupae	Pupae	Adults
A. gossypii	44.81	45.95	3.05	3.47	2.71

Table 5: Life table for computing life expectancy of *C. sexmaculata*

Pivotal age in days	Number surviving to the beginning of age interval	Number dying during 'x'	Mortality rate per hundred alive at beginning of age interval $\frac{d_x \times 100}{l_x}$	Alive between age 'x' and 'x + 1' $\frac{l_x + l_{(x+1)}}{2}$	No. of the individual's life days beyond 'x'	Expectation of further life $\frac{T_x}{l_x} \times 2$
(x)	**(l_x)**	**(d_x)**	**(100 q_x)**	**(L_x)**	**(T_x)**	**(e_x)**
0-5	100	4	4.00	98	535.00	10.70
5-10	96	8	8.33	92	437.00	9.10
10-15	88	1	1.14	87.5	345.00	7.84
15-20	87	3	3.45	85.5	257.50	5.92
20-25	84	9	10.71	79.5	172.00	4.09
25-30	75	20	26.67	65	92.50	2.47
30-35	55	55	100.00	27.5	27.50	1.00

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