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Life-table and intrinsic rate of increase of seed beetle (*Caryedon serratus*) on groundnut at different temperatures

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ABSTRACT

The age-specific survival and fecundity rates of groundnut seed beetle (*Caryedon serratus* Olivier) at different temperatures (25, 30, 35 and 40°C) in the laboratory on groundnut (*Arachis hypogaea* L.) were studied to estimate the dependence of the intrinsic rate of increase on temperature. Results indicated that the fecundity, survival rates and developmental time of *C. serratus* were different at different temperatures. The fecundity of *C. serratus* reared at 25°C was highest and decreased with the increase in temperature. Net reproductive rate and mean length of generation also decreased with the increase in temperature. Net reproductive rate varied from 159.07 viable eggs/female at 25°C to 101.94 eggs/female at 40°C and mean generation time varied from 166.52 days at 25°C to 59.31 days at 40°C. The intrinsic rate of increase (r_m), the innate capacity for increase (r_c), and finite rate of increase (λ) increased with increase in temperature from 25 to 40°C. Intrinsic rate of increase (r_m), varied from 0.0316 females/female/day at 25°C to 0.0784 females/female/day at 40°C. The intrinsic rate of natural increase (r_m) at 40°C was 2.48 times higher than that at 25°C. The shorter generation time and higher intrinsic rate of increase shortened the population doubling time of *C. serratus* to 8.96 days at 40°C compared to 21.94 days at 25°C.

Key words: *Caryedon serratus*, Groundnut, Intrinsic rate of increase, Life-table, Temperature

All forms of post-harvest groundnut are damaged by seed beetle (*Caryedon serratus* Olivier) (Coleoptera: Bruchidae), which is the only primary pest of stored groundnut causing both quantitative and qualitative losses. The larvae of *C. serratus* bore into the seeds via small holes and feed on the embryo and the endosperm, and final instar grub comes out for pupation through exit holes. Kumari *et al.* (2002) reported that the extent of damage on 'TMV2' groundnut (*Arachis hypogaea* L.) by seed beetle was 77.1% in pods, 67.8% in kernels and weight loss in pods and kernels was 55.1 and 52.3%, respectively. Life-table study is one of the useful numerical aids in studying population (Greenberg *et al*. 2001).

In many insects, the mortality rate is characteristic of the stage and is not uniform for all development stages. The mortality rates of early and late stages are often higher than those of the intermediate stages (Medeiros *et al.* 2000). Knowledge on the number of immature stage and the mortality factors affecting each stage may assist in the timing of pest management programme (Edward George 2000). The standard estimator for the growth rate of insect population is the intrinsic rate of increase (r_m), which describes the maximum rate of increase at any time interval under optimum conditions. The intrinsic rate of increase is the true measure of the reproductive potential of an organism (Chaudhari and Nikam 2001). The rate of multiplication of a population per generation is described by the net reproductive rate (R_0), which is dependent on the intrinsic rate of increase (Sedlacek *et al*. 1986).

Life-table is a useful tool to determine bio-potential and provides a format for recording and accounting all population changes in the life-cycle of species. Although there are rare data on the fecundity and life-table parameters of *C. serratus*, Prasad *et al.* (2008) reported that females lay maximum number of eggs and have shorter mean length of generation when reared on tamarind compared to groundnut and Bengalgram. Temperature is the most important abiotic factor affecting development and reproduction. Temperature influences both population growth and mortality therefore, knowledge of the effects of temperature on the biological parameters is essential to investigate population dynamics of *C. serratus* on groundnut. Life table parameters need to

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be determined in the laboratory, which usually involve rearing them under constant conditions, despite the fact that insects are subjected to more complex and fluctuating conditions in their natural environments. Intrinsic rate of increase is of especial interest because it integrates the effect of mortality and fertility in a single value. Limited information is available on the bio-potential and intrinsic rate of increase of *C. serratus* at different temperatures. Therefore, an attempt was made to study the life-table of *C. serratus* reared on groundnut at four different temperatures to understand the effect of different temperatures on the intrinsic rate of increase of *C. serratus* and also used as a basis for understanding the population dynamics for pest management programme.

MATERIALS AND METHODS

Laboratory experiments were conducted at Directorate of Groundnut Research, Junagadh, Gujarat during 2007 and 2008. Groundnut seed beetle, *C. serratus* was collected from the infested groundnut pods at local market/go-downs and reared on 'GG 20' groundnut (*Arachis hypogaea* L.) in the laboratory at ambient temperature. Fresh one kg of groundnut kernels of 'GG 20' were weighed and kept in plastic jar. Twenty five pairs of freshly emerged adults were released into the jar and covered with muslin cloth, secured with rubber band. After two days, kernels with single egg were removed from the jar and used for the estimation the life table parameters. Four separate sets were arranged in biological oxygen demand incubator set at different temperatures such as 25, 30, 35 and 40°C at 70% relative humidity. One hundred kernels containing single eggs were placed in ten plastic Petri-plate (4 cm) in batches of 10 each.

The newly hatched larvae were allowed till pupation and emergence. Mortality from hatching to emergence of adults was recorded daily. Fecundity of the female was noted daily from emergence to death. To know the sex ratio the eggs deposited were hatched and the larvae reared on groundnut kernel at respective temperature till emergence. Sex ratio (1:1) of the adults emerged was calculated. Considering the ratio of females to males (1 M:1 F) and the fecundity, the number of female births/female was calculated. Using the data on survival, fecundity and life span, life-table was constructed according to the method of Birch (1948) and Southwood (1978).

Life-table was calculated using data from the study described above. The death and survival rates (*x* and *lx*) observed each day were recorded for all immature stages and adult stages. The probability of surviving from birth to age X (*lx*) for every immature stage and adult stage were also calculated.

The intrinsic rate of increase (r_m) was calculated by using the equation $\Sigma e^{x} m^{x} lx mx X = 1$, where. 'e' is the base of the natural logarithms, 'x' is the age of the individuals in days, '*lx*' is the number of individuals alive at age 'X' as the proportion of *lx* and '*mx*' is the mean number of female progeny per female of age 'X'. The sum of the products '*lxmx*' is the net reproductive rate (*Ro*). The rate of multiplication of population for each generation was measured in terms of females produced per generation (Srinivasaperummal and Samuthiravelu 1992). The precise value of cohort generation was calculated as follows:

$$Tc = \frac{\sum lxmxX}{Ro}$$

The arbitrary value of innate capacity for increase 'r_c' was calculated from the equation

$$r_c = \frac{Log_e\ Ro}{Tc}$$

This is an appropriate 'r_m' value. The values of the negative exponent of e^{rm} x ascertained from this experiment often lay outside the range. For this reason, both sides of the equation were multiplied by a factor of $\Sigma e^{7\text{-}rm}\ X^{lx\text{-}mx} = 1096.6$.

The precise generation time (T) was calculated from the equation:

$$T = \frac{Log_e\ Ro}{r_m}$$

The finite rate of increase (λ) was calculated as antilog e^{rm}. The weekly multiplication of population was calculated as $(e^{rm})^7$. The doubling time (DT) defined as the time required for the population to double its size was calculated as log 2/ log λ.

The per cent distribution of each age group (*x*) was 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.

RESULTS AND DISCUSSION

Results indicated that the survival and the period for the different stages of *C. serratus* were different at different temperatures (Table 1). The egg stage lasted for two days at 40°C whereas it took 11 days at 25°C. The duration of larval stage decreased as the temperature increased. It was completed on 37 day at 40°C while it took 94 days at 25°C. The pupal stage lasted up to 160, 99, 58 and 55th day after oviposition at 25, 30, 35 and 40°C respectively. Per cent survival of the egg was 96, 97, 96 and 98, the per cent survival of larvae was 85, 83, 60, and 86, and the per cent survival of pupa was 80, 80, 57 and 78, at 25, 30, 35 and 40°C, respectively. On the whole, on groundnut *C. serratus* requires 160 days to emerge as adults when reared at 25°C, whereas, at 30, 35 and 40°C the duration was 99, 58 and 55 days, respectively. Development time and longevity were significantly decreased with increase in temperature.

Temperature affected fecundity of *C. serratus* at different temperatures. The life fecundity data indicated that the female

started laying of eggs after 0–11 day of pivotal age at 25°C, whereas at 40°C it was 0–2 day of pivotal age. The fecundity of *C. serratus* reared at 25°C was higher than reared at higher temperatures (Table 2). Net reproductive rate and mean length of generation decreased with the increase in temperature. Net reproductive rate varied from 159.07 viable eggs per female at 25°C to 101.94 viable eggs per female at 40°C and mean generation time varied from 166.52 days at 25°C to 59.31 days at 40°C. The mean length of generation (T), was 166.52, 105.51, 63.27 and 59.31 days at 25, 30, 35 and 40°C respectively. Innate capacity for increase and finite rate of increase (λ) increased as the temperature increased. Innate capacity for increase ranged from 0.0304 to 0.0780 females/female/day and finite rate of increase (λ) ranged from 1.0321 to 1.0805 females/female/day at 25 and 40°C, respectively (Table 2). Similarly, Patel and Koshiya (1994) reported that the innate capacity of increase of 0.0764 females/female/day and finite rate of increase 1.0794 females/female/day for *C. serratus.*

The intrinsic rate of increase (r_m), increased with increase in temperature from 25 to 40°C. Intrinsic rate of increase was lowest at 25°C (0.0316 females/female/day) and highest at 40°C (0.0784 females/female/day). The intrinsic rate of natural increase is an important population parameter used to measure the population growth potential of a species under specified conditions. The intrinsic rate of natural increase (r_m) at 40°C was 2.48 times higher than that at 25°C. The intrinsic rate of increase is the true measure of the reproductive potential of an organism (Chaudhari and Nikam 2001). The intrinsic rate of increase is a good indicator of the temperature at which the growth of a population is most favorable because it reflects the overall effect of temperature on the development, reproduction and survival characteristics of population. The intrinsic rate of increase summarizes the physiological qualities of an animal relation to capacity to increase (Andrewarth and Birch 1954).

Table 1 Survival of different developmental stages of *C. serratus* at different temperatures

No. of eggs	Number survived											
	25°C			30°C			35°C			40°C		
	Egg stage (0–11 days)	Larval stage (12–94 days)	Pupal stage (95–160 days)	Egg stage (0–6 days)	Larval stage (7–53 days)	Pupal stage (54–99 days)	Egg stage (0–6 days)	Larval stage (7–42 days)	Pupal stage (43–58 days)	Egg stage (0–2 days)	Larval stage (3–37 days)	Pupal stage (38–55 days)
10	9	9	7	10	10	10	10	6	5	10	9	9
10	9	8	8	7	6	6	9	6	6	10	10	9
10	9	8	8	10	9	8	9	6	6	10	10	9
10	9	8	8	10	10	10	9	8	8	10	8	6
10	10	10	10	10	7	6	9	5	4	9	6	6
10	10	5	5	10	6	5	9	5	5	10	10	10
10	10	10	10	10	9	9	9	7	7	10	8	8
10	10	8	8	10	7	7	9	8	8	10	10	7
10	10	9	8	10	9	9	9	4	4	9	7	6
10	10	10	8	10	10	10	9	5	4	10	8	8
100	96	85	80	97	83	80	96	60	57	98	86	78

Table 2 Mean length of generation, innate capacity of increase and intrinsic rate of increase of *C. serratus* at different temperatures

Population growth parameter	Calculated values			
	25°C	30°C	35°C	40°C
Net reproductive rate (*Ro*)	159.07	135.56	105.48	101.94
Mean length of generation (*Tc*)	166.52 days	105.51 days	63.27 days	59.31 days
Innate capacity for increase in number (r_c)	0.0304 females/female/day	0.0465 females/female/day	0.0651 females/female/day	0.0780 females/female/day
Corrected 'r_m' (Intrinsic rate of increase)	0.0316 females/female/day	0.0472 females/female/day	0.0662 females/female/day	0.0784 females/female/day
Corrected generation time (T)	160.42 days	104.01days	62.21 days	59.75 days
Finite rate of increase in number (λ)	1.0321 females/female/day	1.0483 females/female/day	1.0684 females/female/day	1.0805 females/female/day
Weekly multiplication of population (λ7)	1.247	1.3915	1.5895	1.7191
Doubling time (Log 2/Log λ)	21.94 days	14.69 days	10. 47 days	8.96 days
Hypothetical F2 females (Ro2)	25302.20	18377.42	3775.53	10391.76

Table 3 Age-specific distribution of *C. serratus* at different temperatures

Stage	25°C		30°C		35°C		40°C	
	Pivotal age	Per cent contribution	Pivotal age	Per cent contribution	Pivotal age	Per cent contribution	Pivotal age	Per cent contribution
Egg	0–11	32.59	0–6	29.61	0–6	42.68	0–2	19.35
Larva	12–94	63.35	7–53	63.55	7–42	54.42	3–37	66.42
Pupa	95–160	3.82	54–99	6.05	43–58	2.44	38–55	3.10
Adult	161–188	0.28	100–117	0.78	59–67	0.43	56–69	2.47

The population reared at 40°C had the highest intrinsic rate of increase (0.0784 females/female/day), at which the doubling time, mean generation time and development period became minimal compared with populations reared at other temperatures. The doubling time decreased from 21.94 to 8.96 days as the temperature increased from 25 to 40°C. The higher temperature not only accelerates the metabolic processes and hasten the larval development but also shorten the mean generation time.

At all temperatures tested the innate capacity of increase (r_c) was slightly less than the true intrinsic rate of increase (r_m) indicating that the population was tending towards overlapping generation (Southwood 1978).

Moreover, on reaching the stable age distribution, the population of *C. serratus*, at the various stages of egg, larva, pupa and adult, accounted for 32.56, 63.35, 3.82 and 0.28% respectively at 25°C, 29.61, 63.55, 6.05 and 0.78% respectively at 30°C, 42.68, 54.42, 2.44 and 0.43% respectively at 35°C and 19.35, 66.42, 3.10 and 2.47%, respectively at 40°C (Table 3). At all the different temperatures studied the maximum contribution towards stable age distribution was made by immature stages. The adult distribution which was significantly contributed to next generation was slightly higher at 40°C (2.41%) compared to other temperatures studied.

The computation of life expectancy (Fig 1) clearly showed that the life expectancy of newly deposited eggs was more on at 25°C (68.0 days). The mortality rate was comparatively higher at the age of 80 to 85, 25 to 30, 25 to 30 and 45 to 50 days where the expectancy of further life was reduced to 5.43, 6.45, 18.28 and 6.2 days at 25, 30, 35 and 40°C, respectively. The computation of life table expectancy data clearly indicated that the life expectancy of *C. serratus* at different temperatures declined gradually with the advancement of age and temperature.

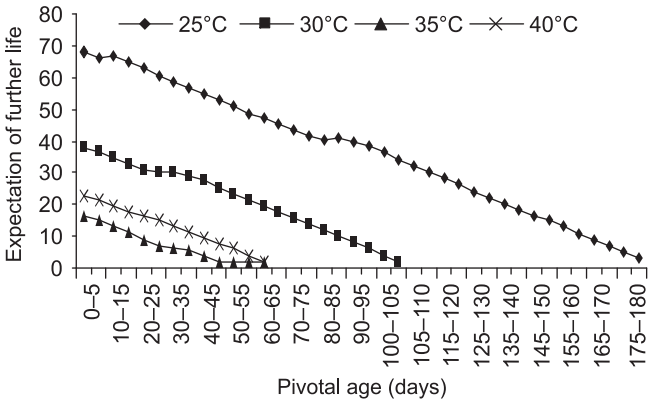

Fig 1 Life expectancy of *C. serratus* at different temperatures

The ultimate aim of development of the life-table of insects under laboratory conditions is to decide the expected life span of particular insect with its reproductive potential in a specific set of weather conditions with abundance of space and food supply. Temperature is a key abiotic factor that regulates the insect population dynamics, rate of development, reproduction, mortality, survival and seasonal abundance of *C. serratus* in groundnut storage. Although insects are not subjected to constant temperatures in nature, controlled laboratory studies can provide valuable insight into the population dynamics of stored grain pests.

The present study clearly showed that different temperatures influence population growth rate, fecundity, developmental time, mortality, longevity, and intrinsic rate of increase of *C. serratus* on groundnut. We conclude that *C. serratus* has greatest pest potential on groundnut when stored under warmer conditions when temperatures are most favourable for faster development particularly in Saurashtra region of Gujarat and the growth parameters described in the present study could be used to predict population density and evaluate control measures.

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