Life table and population parameters of *Paracoccus marginatus* at varying temperatures on cotton

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Abstract

The effect of temperature on the life history traits of Paracoccus marginatus *was carried out at 20, 25 and 30°C on cotton. The data revealed that* P. marginatus *took maximum of 41.3 days to complete one generation at 20°C followed by 28.5 and 26.5 days at 25°C and 30°C, respectively. Adult longevity was higher at 20°C, but declined at 25 and 30°C. Doubling time was lowest at 30°C (3.55 days) and higher at 20 and 25°C (9.06 and 4.19 days, respectively). Generation time decreased as temperature increased towards an optimal temperature. As temperature increased, survivorship (lx) declined more quickly, but fecundity (mx) peaked earlier. At 30°C, the net fecundity was highest resulting in the highest intrinsic rate of increase. The results indicated that ability of* P. marginatus *to develop, survive and reproduce successfully between 20 and 30°C suggests that it can establish in areas within this temperature range.*

Keywords: *Paracoccus marginatus,* life table, population parameters, temperature

Introduction

In ecological studies, life table is a most important analytical tool, which provides detailed information of population dynamics to generate simple but more informative statistics. It also gives a comprehensive description of the survivorship, development and expectation of life (Ali and Rizvi, 2007). Therefore, knowledge on the effects of temperature on the biological parameters is essential to investigate population dynamics. The collection of data on life-table at different temperatures provides crucial information required for pest management in varying environmental conditions (Amarasekare *et al*., 2008).

Mealy bugs, which were considered to be minor pests in many crops, have acquired the status of major pests during the last few years, especially in cotton, vegetables and fruits. Widespread incidence of mealy bug in almost all cotton growing regions in India was reported by Nagrare *et al*., (2009). Mealy bug, *Paracoccus marginatus* (Williams and Granara de Willink) (Hemiptera: Pseudococcidae) is a soft bodied sap sucking insect pest. List of agricultural and horticultural crops damaged by this invasive pest is growing at an alarming rate (Thangamalar *et al*., 2010). The large populations of this insect are attributed by short developmental cycle and high fecundity. Both nymphs and adults suck the sap by inserting stylets into the epidermis of the leaves, flowers, squares, bolls and tender stem resulting in chlorosis, stunting of growth, leaf deformation or crinkling, early leaf drop and death of plants. With the increasing importance of mealy bug control, worldwide, there is need to know the population dynamics. Temperature is a key abiotic factor that regulates insect population dynamics, developmental rates, and seasonal occurrence (Schowalter, 2000, Amarasekare, 2007, Francis *et al*., 2012). Intrinsic rate of increase, upper and lower developmental thresholds, fecundity and survivorship schedules are essential for describing temperature effects on population dynamics. Therefore, in the present investigation, life table of *P. marginatus* was determined at varying temperatures.

Materials and methods

Field collected adult females of *P. marginatus* were kept in separate Petri dishes (90 x 10 mm) and placed in the BOD incubator. A blotting paper was spread over the inner surface of Petri dishes for egg laying. Fresh leaves of cotton plant were provided as food. The eggs laid by females were counted and transferred in other Petri dishes with the help of soft camel hair brush and allowed to hatch at room temperature. For the construction of life tables of *P. marginatus* at varying temperatures, eggs were also placed in BOD incubator at 20±1°C, 25±1°C and 30±1°C with 65±5 % RH and 12L:12D. Hatching percentage was recorded from each cohort and subsequently adjusted, so that life-table commenced with 500 eggs in a cohort. Thereafter, each individual was examined daily to monitor its development, fecundity and survivorship. During the reproductive period, newborn nymphs were counted daily and then removed. Cotton leaves were replaced after every 3 days throughout the study period.

Life table construction

Life table was then constructed using the following parameters (Table 1). Observations on number of alive and dead out of five hundred newly hatched neonates were recorded daily.

The net reproductive rate, Ro (the number of times a population would multiply each generation), was calculated using the methods described in Southwood (1978). Population growth statistics, including the intrinsic rate of increase (r_m) computed by trial and error method (Birch, 1948), net reproductive rate (Ro), and mean generation time (GT) were calculated for populations at different temperatures using the formulae.

Results and discussion

The data on age specific life-table at varying temperatures revealed that the *P. marginatus* required maximum 41.3 days to complete the entire generation at 20°C followed by 28.5 days at 25°C and 26.5 days at 30°C. Summary of life table statistics of *P. marginatus* are presented in Table 2.

Life expectancy (ex)

At all temperatures, life expectancy reached a maximum during the 1st instar, peaks were at the age of 9, 6 and 5 days at 20, 25 and 30°C respectively. In all the temperatures, an increase in life expectancy was registered after egg hatching and before the 2nd nymphal instar. Then, a constant decline with a regular slope for the rest of nymphal instars

Table 1. Parameters used for construction of life table

X	The pivotal age for the age class in units of time (days)	
l_x	The number of surviving individual at the beginning of age class x	
L_x	The number of individual alive between age x and x+1	x +1 (x + 1)/ 2
100qx	Percent apparent mortality	100 qx=(dx/lx)X100 dx = Number dying during the age intervall x = Number surviving at the beginning of each interval
T_x	Total number of individuals of age x units beyond the age x	Tx = lx + (lx + 1) + (lx +)………………..+ lw. lw means last age interval.
e_x	Life expectancy for individual of age x	ex = Tx / l x
m_x	Age specific fecundity, the number of living females born per female in each class interval	
Ro	Net reproductive rate, equal to the sum of the l_x m_x or	$Ro = \sum lx\, mx$
T_c	Cohort generation time (in days)	$Tc = \sum X\, lx\, mx / \sum lx\, mx$
r_c	Innate capacity for increase	$r_c = \ln R_o / T_c$
r_m	The intrinsic rate of natural increase or the corrected innate capacity for increase	$\sum e^{7 - r_m x l_x m_x} = 1$
T	The corrected generation time	$T = \ln R_o / r_m$
λ	The finite rate of increase, number of female offspring per female per day	$\lambda = e^{rm}\, e^{rm}$
DT	Doubling time, the number of days required by a population to double	DT = ln2/ r_m

and adult stage was observed; thereafter it dropped linearly until arriving zero at 43, 32 and 30 days of age at 20, 25 and 30°C respectively (Fig.1).

Survival

In Fig. 2, specific mortality is expressed as lx, *i.e.*, survival, the probability of being alive at age x. The survival rate decreased with increase in the development stage. In any temperature, during the adult stage, it continued declining showing a fairly age-specific mortality, until reaching zero. Kumar *et al*., (2013) reported that the mortality rate was high for the first instar crawlers, which declined sharply in subsequent instars in *Phenacoccus solenopsis*. The initial increase observed at all temperatures could be interpreted as the result of having overcome the largest mortality risks of first stages of life cycle, as egg hatching and first moulting similar to report of Mastoi *et al*., (2014). *P. marginatus* took less time to develop and had higher survival rates at 30ºC than at 20 and 25°C (Amarasekare *et al*., 2008).

Fecundity life table (mx)

At 20°C and 25°C, reproductive peaks were at 40, 29 days of age respectively. At 30°C, reproductive peaks were at 27 days of age. One of the important factors that affect population growth is starting time for egg deposition. Females at 30, 25 and 20°C started to lay eggs on the 25th, 27th, and 40th day, respectively (Tables 3-5). Early egg deposition is important parameter for population growth. In general, cohorts reared at low temperature, started reproduction and reached the age of maximum reproduction later. Individual and total females laid less egg at lower temperature. Consequently they had a lower reproductive output than those kept at 25°C and 30°C. Longest developmental time was reported at low temperature (Hameed *et al*., 2012; Ali *et al*., 2012). Reproductive period of *Maconellicoccus hirsutus* was the longest at 20°C compared with those at 25 and 30°C (Chong *et al*., 2008). Age of maximum reproduction was significantly lower at

Table 2. Population and reproductive parameters of *P. marginatus*

Parameter	*P. marginatus* 20°C	25°C	30°C
Gross reproduction rate (GRR) (female eggs/female)	252	474	497
Net reproductive rate (Ro) (female eggs/female)	23.6	110.3	176.1
Mean length of generation (Tc) (days)	41.4	28.6	26.6
Innate capacity for natural increase (r_c) (No. of females/female /day)	0.0764	0.1647	0.1945
True intrinsic rate of increase (r_m) (No. of females/female /day)	0.0765	0.1652	0.1952
True generation time (T) (days)	41.3	28.5	26.5
Finite rate of increase (λ) (females /day)	1.08	1.18	1.2155
Doubling time (DT) (days)	9.06	4.19	3.55
Annual rate of increase	1.33×10^{12}	1.54×10^{26}	9.09×10^{30}

Table 3. Trial and error method for calculation of intrinsic rate of natural increase (rm) of *P. marginatus* on cotton at 25 °C

Pivotal age in days	Proportion of individuals still alive at age x (l_x)	Mean of offspring produced / individual in age interval x (m_x)	$l_x m_x$	$Xl_x m_x$	0.1651 e^{7-rmx}	0.1651 $e^{7-rmx}.lxmx$	0.1652 e^{7-rmx}	0.1652 $e^{7-rmx}.lxmx$	0.1653 e^{7-rmx}	0.1653 $e^{7-rmx}.lxmx$
0-26	0.24	-	-	-	-	-	-	-	-	-
27	0.237	95	22.5	608.2	12.7	286.3	12.7	285.5	12.6	284.8
28	0.234	125	29.3	820	10.8	315.5	10.7	314.7	10.7	313.8
29	0.231	142	32.9	953.0	9.1	300.2	9.1	299.3	9.1	298.5
30	0.228	112	25.6	768	7.7	198.3	7.7	197.7	7.7	197.1
$\sum_{27}^{30} e^{7-rmx}.lxmx$		474	110.3	3149.3		1100.3		1097.2		1094.1

30°C. Average number of eggs/female/day and of eggs for female on its lifetime was lower at 20°C. Total number of eggs produced for the cohort was higher at 30°C. The highest fecundity of *P. marginatus* was at 25°C producing an average of 300 eggs and at lower temperatures produced offspring for a significantly longer period than at higher temperatures reported by Amarasekare *et al*., (2008).

Reproductive value

The Net Reproductive Rate (Ro) on the three temperatures was varied. It was higher at 30°C. Greater values were registered at 40, 29 and 27 days of age at 20°C, 25°C and 30°C, respectively. Thereafter, these values declined until the end of the generation. *P. marginatus* reared at 30°C developed faster than at 20°C and 25°C and produced more offspring. Intrinsic rate of natural increase was significantly lower at 20°C, but it could be due to the high instantaneous death rate at this temperature. Finite rate of increase was very similar to the observed; these two increase rates provide estimates of the growth potential of *P. marginatus* population. The intrinsic capacity for increase (*r*m), the net reproductive rate (*R*o), and the finite rate of increase (λ) reached the maximum values at 30°C, which were 0.195, 176.08, and 1.215, respectively. Their minimum values were observed at 20°C, which were 0.0765, 23.62 and 1.08, respectively (Tables 3-5). The *R*o value at 25°C ranked the second. The intrinsic rate of natural increase (rm) 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 a population. The capacity for increase was slightly less than the intrinsic rate of

Table 4. Trial and error method for calculation of intrinsic rate of natural increases (rm) of *P. marginatus* on cotton at 20°C

Pivotal age in days	Proportion of individuals still alive at age x (l_x)	Mean of offspring produced / individual in age interval x (m_x)	$l_x m_x$	$Xl_x m_x$	0.0764		0.0765		0.0766	
					$_e7\text{-}r_mX$	$_e7\text{-}r_mXl_xm_x$	$7\text{-}r_mX$	$7\text{-}r_mXl_xm_x$	$7\text{-}r_mX$	$_e7\text{-}r_mXl_xm_x$
0-39	0.098				-	-	-	-	-	-
40	0.096	72	6.9	276.4	51.6	356.8	51.4	355.4	51.2	353.9
41	0.096	65	6.2	255.8	47.8	298.4	47.6	297.2	47.4	296.0
42	0.092	61	5.6	235.7	44.3	248.7	44.1	247.6	43.9	246.6
43	0.09	54	4.9	208.9	41.1	199.5	40.9	198.7	40.7	197.8
$\sum_{40}^{43} {}_e7\text{-}r_mXl_xm_x$		252	23.6	977.0		1103.4		1098.9		1094.3

Table 5. Trial and error method for calculation of intrinsic rate of natural increases (rm) of *P. marginatus* on cotton at 30°C

Pivotal age in days	Proportion of individuals still alive at age x (l_x)	Mean of offspring produced / individual in age interval x (m_x)	$l_x m_x$	$Xl_x m_x$	0.1952		0.1953		0.1954	
					e^{7-rmx}	$e^{7-rmx}.lxmx$	e^{7-rmx}	$e^{7-rmx}.lxmx$	e^{7-rmx}	$e^{7-rmx}.lxmx$
0-24	0.358	-	-	-	-	-	-	-	-	-
25	0.355	98	34.9	871.4	8.3	290.4	8.3	289.7	8.3	288.9
26	0.355	133	47.3	1229.9	6.9	324.2	6.8	323.4	6.8	322.5
27	0.353	142	50.1	1353.8	5.6	282.7	5.6	281.9	5.6	281.2
28	0.353	124	43.8	1225.9	4.6	203.1	4.6	202.5	4.6	201.9
$\sum_{25}^{28} e^{7-rmx}.lxmx$		497	176.0	4680.9		1100.4		1097.4		1094.6

increase indicating that the population was tending towards overlapping generation.

Gross fecundity (the total number of offsprings that a female could produce if lived to her absolute age) was also higher at 30ºC and 25ºC than at 20ºC, because of its higher number of eggs/female/day. Net reproductive rate was significantly higher at 30°C suggesting that this is the optimal temperature for rearing this species. Doubling time was lowest at 30ºC (3.55 days) and higher at 20ºC and 25ºC (9.06 and 4.19 days, respectively). Generation time varied between 41.3 (at 20°C) and 28.47 (at 25ºC) and 26.49 at 30°C (Table 1). But the later is significantly lower, showing that at 30°C the actual mean length of a generation in terms of population dynamics is very short. Generation time decreased as temperature increased towards an optimal temperature, similar to the reports of Aheer *et al*., (2009); Hameed *et al*., (2012).

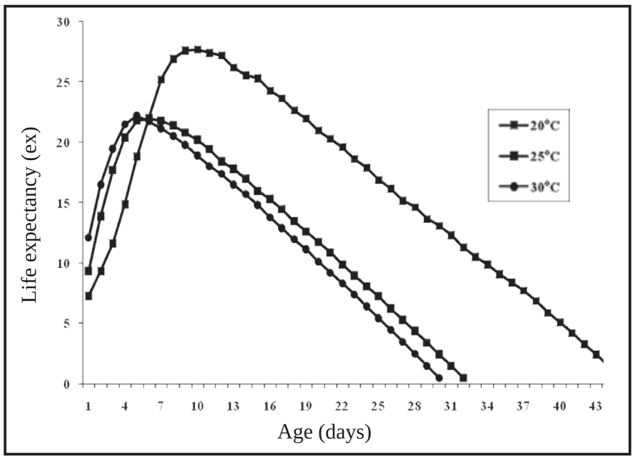

Figure 1. Life expectancy of *P. marginatus* on cotton at different temperatures

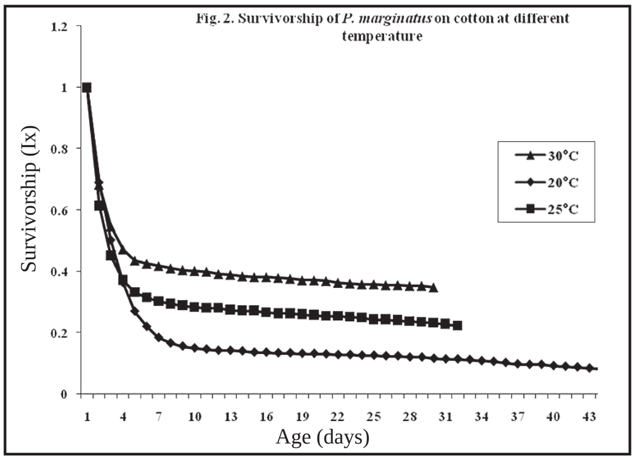

Figure 2. Survivorship of *P. marginatus* on cotton at different temperatures

Our experiments showed that temperature affected the survival, development, longevity and fecundity of *P. marginatus*. It is difficult, however, to know how well parameters estimated under the laboratory conditions at constant temperatures could be applied in the field (Omer *et al.,* 1996) because under natural conditions, insects are never exposed to constant temperatures (Infante, 2000). Nevertheless, laboratory studies at different temperatures can provide useful information on the development, survival, and reproduction of insects (Wang *et al.,* 1997) that is essential to developing an effective IPM program.

Information from current study may be helpful in managing the susceptible stages of cotton mealy bug at different temperatures. It is evident from this that the development of *P. marginatus* is dependent on temperature. The population growth indicates that it can achieve high density levels during the warm season. Prolonged development time of *P. marginatus* at low temperatures may increase their exposure to natural enemies and insecticides. Maximum fecundity at high temperature suggests the suitability of condition for population build up. Hence in this condition, careful inspection of crop is needed. Laboratory studies at different temperatures can provide useful information on the development, survival, and reproduction of insects that is essential to developing an effective IPM program.

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