
Laboratory Studies on the Development and Life Table Parameters of *Planococcus citri* (Risso) (Hemiptera, Pseudococcidae) at Different Temperatures

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Abstract: The development and life table parameters of *Planococcus citri* (Risso) were investigated at various temperatures ranging from 20 to 30 °C. The total duration of development of female mealybug was 28.2 day at 20 °C, 20.8 day at 25 °C, and 20.05 day at 30°C. The total life cycles of *P. citri* females were 63.20, 51.10, and 41.55 days at 20, 25, and 30°C, respectively. The highest number of egg laying by female of *P. citri* was recorded at 30°C with an average of 340.1 eggs, while the average numbers of egg laying were 62.1 and 276.8 eggs per female at 20, and 25°C, respectively. The total life cycles of *P. citri* males were 43.2, 30.4, and 23.95 days at 20, 25, and 30°C, respectively. The total number of daughters per female (R_0) obtained at 20°C was 62.61 compared with 136.88, 380.00 and 339.62 daughters at 25, 27 and 30 °C, respectively. The generation time (G_t) values of *P. citri* were 64.45, 50, 46.35 and 44.88 day for insect reared at 20, 25, 27 and 30°C, respectively. While intrinsic rate of natural increase (r_m) values were 0.064, 0.09, 0.128 and 0.129 for insect reared at 20, 25, 27 and 30 °C, respectively. The values of total days for population to double (D_t) decreased gradually with increasing degree of temperature. These findings showed citrus mealybug performances to be highly affected by temperature.

Keywords: citrus mealy bug, *Planococcus citri*, development, life table parameters.

1. INTRODUCTION

Mealybugs had piercing-sucking mouthparts that remove plant fluids and serious infestations can lead to premature leaf drop, reduced plant vigor, and the formation of honeydew, which is an excellent growing medium for black sooty mold fungi (Serrano et al., 2001). The citrus mealy bug, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) attacks many host plants including all orchard trees in Egypt (Ahmed and Abd-Rabou, 2010). The reproductive ability of its female is temperature dependent (Copeland et al., 1985). Age specific life and fertility tables have been effective tools for analyzing and realizing the impact of an external effect on the growth, survival, reproduction and intrinsic rate of increase of an insect population (Wittmeyer and Coudron, 2001). The biology of citrus mealybug has been studied on different host plants, including citrus, coffee, pumpkin, and coleus (Malleshaiah et al., 2000; Laflin and Parrella, 2004; Hogendorp et al., 2006). Life table is an important method to calculate the biological data using mathematical equations to predict the rate of population growth.

In the recent decade, the trend of increased build up of various mealybug species in crop plants and in the wild plant is observed mainly due to certain abiotic changes in climate and environment. During the last few years mealybugs, which were considered to be minor pests in many crops have acquired the status of major pests especially in cotton, vegetables and fruits (Tanwar et al., 2007).

However, the temperature-dependent responses of citrus mealybug were not studied over a wide range of constant temperatures. Thus, the main objective of this study was to determine the effect of selected different constant temperatures on the major biological parameters of the citrus mealybug, *Planococcus citri* such as survival, development, reproduction, and population growth and running these biological data in a computer program to estimate the life table parameters.

2. MATERIALS AND METHODS

2.1. Rearing of the Citrus Mealybug

The stock culture of citrus mealy bug used in this study was originally collected from Alexandria Agricultural Experimental station, from infested ornamental plants. The mealybug colony was kept under laboratory conditions of $25 \pm 2^\circ\text{C}$, 60-70% RH on pumpkin fruits.

2.2. Mass Rearing

Red potatoes (*Solanum tuberosum* L.) var. Kara was used as a host plant for rearing of Citrus mealybugs. The tubers were allowed to sprout and were used in rearing a colony of *P. citri*. Potatoes were soaked in a 1% solution of bleach (Clorox; The Clorox Co., Oakland, CA; 6% sodium hypochlorite) for 15 min and rinsed with water, air-dried, and placed in bags made from black cotton cloth to encourage sprouting according to Yang and Sadof (1995). Bags were kept inside dark cages at $27 \pm 2^\circ\text{C}$ and 65-75 % RH. Every week, newly sprouted potatoes were added to the stock culture of *P. citri* to maintain the colony.

2.3. Biology of Citrus Mealy Bug

For studying the biology of mealybug, *P. citri*, females were confined in plastic cups (10 cm high and 11 cm diameter) provided with kara potato. A circular hole was made in the lid of each plastic cups covered with muslin for ventilation. these cups were kept in wooden cage, (30 × 30 × 30 cm) covered with muslin except one side has a slave for examination for one generation under laboratory conditions ($25 \pm 2^\circ\text{C}$ and RH 65- 75 %).

Eggs were taken from the isolated adult females immediately after deposition and placed on potato tubers confined in plastic cups 4cm high and 11cm diameters until hatching and observed daily under a stereoscopic microscope. Crawlers were observed daily, and transferred to fresh potato tubers in other plastic cups using fine hair brush. Dead and stuck nymphs were recorded and removed from the plastic cups. Larval growth and moults were recorded daily. The number of days from hatching to last moult for female nymphs was also recorded.

These groups of nymphs were examined daily until death of the adult females and the following observations were recorded. The development time (days) from the first instar (crawler) of mealybug to the onset of oviposition was recorded for each of the three nymphal instars under three tested degrees of temperature (20, 25, and 30°C) by checking for exuvia which were visible through the loose waxy filaments. The nymphs for each replicate were observed daily under a dissecting microscope at a magnification of 10 x.

Survival rate of each instar was recorded by counting the number of individuals that had successfully molted to the next instar. The overall survival rate from egg to adult female or male at each temperature treatment was determined by the number of adult females (or males) divided by the total number of eggs. The life span of adult females was simply measured from adult eclosion until death. Maturity recorded as the sum of the pre-oviposition, and post-oviposition time.

The colony which maintained as mentioned above was monitored daily to ascertain when female citrus mealybugs began to oviposit. The onset of oviposition was determined by the presence of a clearly visible white tuft of wax beneath the female abdomen. Twenty preovipositing females were randomly assigned at each temperature degree for egg counting. Females collected from the colony and placed into plastic cups containing potato tuber as an oviposition site. After the females start laying eggs, eggs were collected daily and counted to determine the fecundity of each female.

The experiments were completely randomized design. Mean of the response variable was calculated and used in subsequent analyses in all experiments. One-way analysis of variance (ANOVA) was performed according to Steel and Torrei (1980). Means were compared using least significant difference (LSD) test.

2.4. Life Table Parameters

The main purpose of life table parameters leads to predict the rate of population growth of *Planococcus citri*.

A certain number of eggs were taken from the isolated adult female's immediately after deposition and placed on potato tubers confined in plastic cups 4cm high and 11cm diameters until hatching. 20 virgin females were isolated soon after the third moult and observed daily to record the daily survival

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rate (L_x). The laid eggs were calculated daily and removed from beneath adult females. The duration periods of immature stages of 1st, 2nd and 3rd instar were calculated. Daily adult numbers observation from the first day of female eclosion until complete females death, daily survival rate (L_x) and female fecundity (m_x) were calculated according to equation of life tables to predict the growth rate of the population under laboratory conditions of temperatures under $20 \pm 2^\circ\text{C}$, $25 \pm 2^\circ\text{C}$, $27 \pm 2^\circ\text{C}$ and $30 \pm 2^\circ\text{C}$.

From the fertility and survival schedules, several population growth parameters including the net reproductive rate (R_0), finite rate of increase (λ), mean generation time (T), doubling time (DT), and intrinsic rate of natural increase (rm) were calculated using the formulas suggested by Carey (2001), where x is the age of individuals in days, l_x is the age-specific survival, and m_x is the age-specific number of female offspring.

3. RESULTS AND DISCUSSION

3.1. Temperature Effect on the Development of the Citrus Mealybug Females

The effect of three degrees of temperature (20, 25, and 30°C) on the female development stages of *P. citri* is presented in Table (1). Citrus mealybug females successfully developed into adults at temperatures ranging from 20 to 30°C .

The duration of nymphal instars under the temperature of 20°C recorded 12.5, 11.89 and 10.0 days for first-, second- and third-instar nymphs of *P. citri* females, respectively. The preoviposition period, oviposition period, and postoviposition period were 12.2, 15.2, and 0.8 days, respectively. Data in Table (1) shows that the average of longevity of females of citrus mealy bug reared under 20°C was 28.2 days, while the total development time from egg to end life of females of citrus mealy bug reared under 20°C was 63.20 days.

Under the temperature of 25°C the duration of immature stages recorded 10.15 9.8 and 9.95 days for first-, second- and third-instar nymphs of *P. citri* females, respectively. The preoviposition period, oviposition period, and postoviposition period were 10.10, 9.20, and 1.5 days, respectively. Data in Table (1) shows that the average of longevity of adult females of citrus mealy bug reared under 25°C was 20.8 days, while the total development time was 51.10 days for females of citrus mealy bug reared under 25°C .

Under the temperature of 30°C the longest stadium for female nymphs was the third nymphal instar (8.3 days) while that of first and second instars were 6.1 and 7.1 days, respectively. The preoviposition period, oviposition period, and postoviposition period were 8.15, 9.65, and 2.25 days, respectively. Data in Table (1) shows that the average of females longevity of citrus mealy bug reared under 30°C was 20.05 days and the total development time was 41.55 days.

Table1. Duration of nymphal and adult stages of females of *planococcus citri* reared on potato tubers under different temperature

Temperature ($^\circ\text{C}$)	Duration (day, mean \pm S.D.)							Total life cycle
	Nymphal periods			Adult female				
	1 st instar	2 nd instar	3 rd instar	Pre oviposition period	Oviposition period	Post oviposition period	Longevity (adult)	
20	12.5 ^a \pm 1.64	11.89 ^a \pm 2.32	10.00 ^a \pm 1.50	12.20 \pm 0.92	15.20 \pm 2.53	0.80 \pm 0.92	28.2	63.20 \pm 4.54
25	9.85 ^b \pm 0.81	10.15 ^b \pm 2.89	9.95 ^a \pm 2.52	10.10 \pm 1.91	9.20 \pm 2.53	1.50 \pm 1.35	20.8	51.10 \pm 3.21
30	6.10 ^c \pm 1.37	7.10 ^c \pm 1.94	8.30 ^b \pm 1.72	8.15 \pm 1.73	9.65 \pm 3.05	2.25 \pm 1.16	20.05	41.55 \pm 4.07
L. S.D _{0.05}	0.836	1.505	1.230	-	-	-	-	-

Mean values followed by different letters in the same columns are significantly different ($P < 0.05$, SNK, after one-way ANOVA).

Table (1) shows the female longevity of *P. citri* when reared under 20, 25, and 30°C . Female longevity was the longest at 20°C where the female *P. citri* survived for 28.2 day after adult eclosion. The female longevities are 20.8 days and 20.05 days at 20 and 25°C respectively. Our findings agree

with the results of Chong *et al.* (2008) that female longevity of *M. hirsutus* was the longest at 20°C since the female survived for 28.2 d after adult eclosion. The longevities of females were similar at 25 °C (21.2 day), 27 °C (19.9 day), and 30°C (19.5 day). However, no significant difference in adult longevity of males and females of the mealybug, *Paracoccus marginatus* reared on different hosts. Mean longevity of adult males and females kept at 25 °C was 2.3 day and 21.2 day, respectively (Amarasekare *et al.*, 2008). Adult longevity of the citrus mealybug, *P. citri* at three different constant temperatures (18, 24 and 30°C) on citrus was 17.3, 13.1 and 11.7 days, respectively (Ahmed and Abd-Rabou, 2010).

Our results are in full agreement with results of Ahmed and Abd-Rabou (2010) who found that mean durations of the first instar of *P. citri* were 8.5, 6.0 and 3.4 days at 18, 24 and 30°C, respectively. Second instar lasted for 11.5, 9.2 and 5.2 days, respectively. While third nymphal stadium were 12.7, 10.0 and 8.2, respectively.

Results of Goldasteh *et al.* (2009) indicated that at 35°C, the survival rate of the second-instar nymphs of *P. citri* was 5%, but all of them died during the third instar. At 15°C, none of the females were successful in oviposition. The optimal temperature for survival of nymphs in all instars seems to be 25°C. However, developmental rates increased as the temperature increased between 20 and 27°C for both male and female mealybugs. Chong *et al.* (2008) found that the nymphal development of females decreased at 30°C, where the developmental time of second- and third-instar females were between those at 20 and 25°C. Chong *et al.*, (2003) found that the total duration of development of female of madeira mealybug, *Phenacoccus madeirensis* was ≈30 d at 25°C, 46 d at 20°C, and 66 d at 15°C. Adult longevity at 25°C was ≈3 and 20 d for males and ovipositing females, respectively.

Table (1) showed that the pre-oviposition periods for females of citrus mealy bug recorded 12.20, 15.20, and 0.80 days at 20, 25, and 30°C, respectively. The oviposition periods for females of citrus mealy bug recorded 10.12, 9.20, and 1.5 days at 20, 25, and 30°C, respectively. The postoviposition periods for females of citrus mealy bug recorded 8.15, 9.65, and 2.25 days at 20, 25, and 30°C, respectively. However, The prereproductive periods of *M. hirsutus* were the longest at 20 (12.6 day) and 30°C (12.6 day) and the shortest at 27 (10.8 day) and 25°C (9.3 day). The reproductive period of *M. hirsutus* was the longest at 20°C (11 day), whereas those at 25-30°C reproduced for 7-8 day (Chong *et al.*, 2008).

Table (1) showed that female longevity of *P. citri* were 28.2, 20.8 and 20.05 days when reared under 20, 25, and 30 °C, respectively. Data in Table (1) indicated also that the total development times of females were recorded 63.2, 51.10, and 41.55 days at 20, 25, and 30°C, respectively. However, citrus mealybug females successfully developed into adults at temperatures ranging from 15 to 32°C. The development time from egg to adult female of *P. citri* decreased gradually for laboratory rearing from 25°C to 15°C). It increased at temperatures higher than 25°C (Goldasteh *et al.*, 2009). These data are in agreement with the results of Walton and Pringle (2005) who studied *Pseudococcus ficus* (Signoret) on Waltham Cross grapevines. Cloyd (1999) reported 33.7 days for development of *P. citri* on red variegated coleus. The generation time of the citrus mealybug, *P. citri* at three different constant temperatures (18, 24 and 30°C) was 47.3, 34.2 and 21.4 days, respectively (Ahmed and Abd-Rabou, 2010). Our obtained results agree with the results of Ahmed and Abd-Rabou (2010) who indicated that 30°C was the best degree of temperature for the citrus mealybug, *P. citri* life because it resulted in the highest oviposition (362.3 eggs/female), and adult longevity (11.7 days). Results of Goldasteh *et al.* (2009) indicate that 25°C is the optimal temperature for *P. citri* development among the tested temperatures.

3.2. Temperature Effect on the Development of the Citrus Mealybug Males

Males of mealybug develop through four immature instars, 1st and 2nd nymphs, prepupa and pupa. The effect of three degrees of temperature (20, 25, and 30°C) on the male development of *P. citri* is presented in Table (2). Citrus mealybug males successfully developed into adults at temperatures ranging from 20 to 30°C.

Table (2) shows means periods of 1st nymphal instar, 2nd nymphal instar, 3rd nymphal instars, prepupa and 4th pupal instar of male of *P. citri* reared on potato tubers under the temperature of 20°C. It was observed that development time of the four instars of male adult differed significantly at the three tested temperatures. The 1st nymphal instar for males of citrus mealybug recorded 13.1, 7.23, and 5.7 days at 20, 25, and 30°C, respectively. The 2nd nymphal instar recorded 11.3, 8.0, and 6.5 days at 20,

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25, and 30°C, respectively. The 3rd nymphal instar recorded 11.0, 9.17, and 7.65 days at 20, 25, and 30°C, respectively. The pupal instar of males of citrus mealybug recorded 7.8, 7.0, and 4.1 days at 20, 25, and 30°C, respectively.

Generally, the male nymphal periods of citrus mealybug reared under laboratory condition (at 20°C to 30°C) were reduced gradually by increasing the rearing degree of temperature for the four tested nymphal instars. However, Goldasteh *et al.* (2009) mentioned that females and males of *Planococcus citri* had the highest average longevity at 18 and 20°C, respectively. The lowest longevity of both females and males occurred at 25°C. Mean adult longevity of females decreased with increasing temperatures, but this was reversed with a slight difference at 28 and 32°C. Walton and Pringle (2005) stated that more males at extreme temperature (32C) can be seen as an adoptive response and a result of stress, producing greater genetic variability and increasing the probability of survival of the population (Margolies and Wrensch, 1996; and Walton and Pringle, 2005).

Table2. Development time of adult males of *Planococcus citri* reared on potato tubers under different temperatures

Temperature (°C)	Nymphal period (day, mean ± S.D.)			
	1 st nymphal instar	2 nd nymphal instar	3 rd nymphal instar	4 th pupa Instar
20	13.10 ^a ±3.56	11.30 ^a ±3.07	11.00 ^a ±2.58	7.80 ^a ±1.29
25	7.23 ^b ±2.32	8.00 ^b ±2.45	9.17 ^b ±2.80	7.00 ^a ±1.83
30	5.70 ^c ±1.60	6.50 ^c ±1.84	7.65 ^b ±3.00	4.10 ^b ±1.12
L. S.D _{0.05}	1.58	1.62	1.73	1.94

Mean values followed by different letters in the same columns are significantly different ($P < 0.05$, SNK, after one-way ANOVA).

Generally, rearing the present insect under laboratory conditions at controlled temperature indicated the rate of population growth and effect of the cold or the worm weather on the presence of different stages of mealybug. Consequently, the best time of pest control is predictable. However, although these results are valuable as a first step for establishment an IPM program to control citrus mealybug in Egypt, more research needs to be conducted to determine the effect of fluctuating temperatures, various host plant cultivars, and other environmental factors on *P. citri* performance.

However, temperature has profound effects on insect life history parameters such as development, survival, and reproduction. The response of insects to temperature can be important in predicting the potential geographical range of a species and in developing phenological models to predict population dynamics and the timing of various stages for planning control or survey programs (Keena, 2006). Based on demographic studies, we can estimate extinction probabilities, predict life history evolution, anticipate outbreaks of pest species, analyze population stability, and examine the dynamics of colonizing or invading species (Vargas *et al.*, 1997).

3.3. Fecundety

Table (3) shows the number of deposited eggs per female of citrus mealybug, *Planococcus citri*, at controlled degrees of temperature. The highest average of egg laying per female of *P. citri* was recorded at 30°C with a number of 340.1 eggs, while the average numbers of egg laying were 62.1 and 276.8 eggs per female at 20 and 25°C, respectively. No significant difference was observed between the number of eggs laid by females of *P. citri* reared either at 25 or 30°C, while other females reared at 20 °C and fed on the same food (potato tubers) gave fewer number of eggs for each female and significant difference were found among these females and other reared under controlled condition of 25 and 30°C . However, Goldasteh *et al.* (2009) noted that the highest number of eggs laid per female of *P. citri* was recorded at 23°C. Chong *et al.* (2003) found that temperature had a strong influence on fecundity of the madeira Mealybug, *Phenacoccus madeirensis*. Fecundity was highest at 20 °C, with an average of 491 eggs, which was equal to 27 eggs per day for 13 day. Females at 25 °C had the lowest fecundity. A female at 25 °C produced 288 eggs in 8 day, which averaged 36 eggs per day.

Fecundity of *P. citri* females reared at controlled temperature females fed on potato tubers compared with previous studies i.e Sadof *et al.* (2003) indicated that fecundity of mealybugs reared on butternut squash in a growth chamber at 24 ± 2°C, 60-70% RH, on green plants (175.65 eggs) was significantly lower than those on red-variegated plants (191.97 eggs) and numerically lower than those on yellow-variegated plants (181.29 eggs). Also, female mealybug, *Maconellicoccus hirsutus*, incubated at 30°C

produced a significantly lower number of eggs (103 eggs per female). The fecundity of *M. hirsutus* was similar at 20 (260 eggs), 25 (300 eggs), and 27°C (274 eggs) (Chong *et al.*, 2008).

Table (3) and Fig (1) show the daily egg laying per female, when females were reared on potato tubers at 20°C. The daily egg laying was fewer than others reared at 25°C. The maximum rate of daily egg laying was recorded at the ninth day old with an average of 7.30 egg per female. While some of these females prohibited to laying eggs at tenth day age, while other females were laid eggs until eighteenth day. Generally the highest rate of egg laying was recorded through 1 to 12 days of adult age.

Data presented in and Fig (1) show that the daily egg laying from the 1st day of adult emergence with an average per female (22.2 eggs) and increased gradually to the topmost at the fifth day of the beginning egg laying (43.7eggs). The rate of egg laying decreased gradually from the sixth day old. Some of these females completely prohibited egg laying from the seventh day age and others continued to laying eggs until fourteen days old. Generally the highest rate of egg laying was recorded through the 1st week of adult age.

Table3. Effect of three degrees of temperature on the rate of egg laying of *Planococcus citri*

Females	Number of eggs laid per female		
	20°C	25°C	30°C
1	94	286	225
2	153	231	361
3	67	164	295
4	20	376	301
5	105	318	282
6	47	375	401
7	40	429	580
8	13	270	392
9	55	101	254
10	27	218	310
Average ± S.D.	62.1^b ± 43.88	276.8^a ± 102.1	340.1^a ± 101.360
L.S.D. 0.05	79.73		

Mean values followed by different letters in the columns are significantly different ($P < 0.05$, SNK, after one-way ANOVA).

Data in Fig (1) show that the maximum average daily eggs per female for citrus mealybug females reared on potato tubers at 30°C was achieved at fourth day old (54.10 eggs per female). At the fifth day old the deposited eggs decreased gradually to stop at the fifteenth day old of citrus mealybug females.

Generally the data show that the rate of daily eggs per female is affected by the degree of temperature, where the maximum rate of daily eggs per female was recorded for citrus mealybug females when females were reared on potato tubers at 30°C, followed by 25 and 20°C, with values 54.10, 43.7 and 7.03 eggs per female, respectively.

On the other hand, the deposited rate of daily eggs per female is increase with age progressive, then decrease gradually until the deposited eggs stopping (Fig 1).

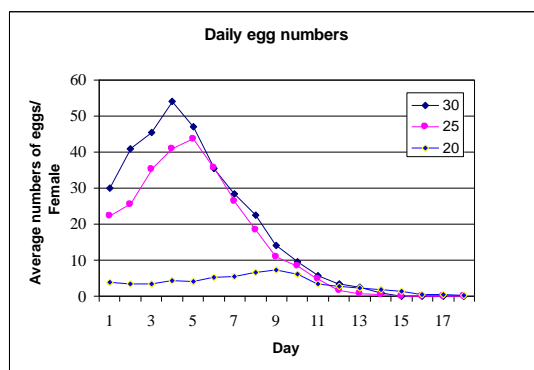


Fig1. Average daily egg deposited per female of *Planococcus citri* fed on potato tubers under 20, 25, and 30 °C

Our data indicated that the highest total fecundity (340 egg per female) occurred at 30°C. Printz (1923) and Bodenheimer and Gutfeld (1929) found that *P. citri* produces 12 and 180 eggs per female

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at 17 and 21°C, respectively. According to the study of Copland *et al.* (1985), *P. citri* lays fewer than 100 eggs above 30°C, but can lay over 400 at 18°C.

It is concluded that mean number of eggs for adult females of *P. citri* increased with increasing temperatures. However, Mafi and Radjabi (1997) reported that the mean numbers of eggs per female of *P. citri* were 150, 180, and 195 on citrus leaves at 19, 23, and 27°C with 70, 75, and 80% RH, respectively, which are also lower than those obtained in our results at near temperatures. These differences may be due to different host plants and experimental conditions.

3.4. Life Table Parameters

Age-specific survival and fertility tables were constructed using age (x), age specific survival rates (l_x), age specific fecundity (m_x) (Andrewartha and Birch, 1954). Several population growth parameters including intrinsic rate of increase (rm), net reproductive rate (R_0), finite rate of increase (λ), mean generation time (T), doubling time (DT), and intrinsic rate of increase (rm) were estimated based on the recorded data in fertility and survival schedules (Carey, 2001). The estimation of rm , R_0 , λ , T and DT was carried out by using Proc GLM of SAS statistical package (SAS Institute, 2001).

In specific environmental conditions, it is practical to use the intrinsic rate of natural increase (rm); an important demographic parameter, for predicting the potential of population growth of an animal (Ricklefs and Miller, 2000). The rm value for *P. citri* (Table 4) reared on potato tubers as a host plant were 0.064, 0.09, 0.128 and 0.129 for insect reared at 20°C, 25°C, 27 °C and 30 °C, respectively . These values indicated that reproductive potential for *P. citri* were affected with increasing the rearing degrees of temperature and carefully estimated the prediction of raising or reducing the population growth. However, the rm value of *C. montrouzieri* was higher than that of its prey, *P. citri*, on coleus at 28°C (0.14±0.005) (Goldasteh *et al.*, 2009).

Data presented in Table (4) clearly indicated the relationship between the temperature degrees and the main biological data. These data will be summarized in life table parameters to show the rate of population growth under designated laboratory conditions. Data in Table (4) show that the total number of daughters per female at 20±2 °C was 62.61 compared with 136.88, 380 and 339.62 daughters per female at 25, 27 and 30 °C, respectively. These values mean that the females fecundity increased gradually by increasing the degrees of temperature through a range of 20-30 °C. So, average number of daughters per females at 27 and 30 °C were very related; 380 and 339.62 at 27 and 30 °C, respectively.

The 2nd parameters was the generation time (Gt) of *P. citri* reared at 20, 25, 27 and 30 °C show that reduction of generation period by increasing the rate of degree of temperature. These values ranked to 64.45, 50, 46.35 and 44.88 for insect reared at 20, 25, 27 and 30 °C, respectively. So, the value followed the same trend of increase. While intrinsic rate of natural increase (rm) were 0.064, 0.09, 0.128 and 0.129 for insect reared at 20, 25, 27 and 30 °C, respectively.

The value of Dt (total days for population to double) decreased gradually with increase degree of temperature. These values were 10.83, 7.7, 5.41 and 5.37 at 20, 25, 27 and 30 °C, respectively.

Other parameters as m_x (daily egg deposited per female) were estimated from 1st day of oviposition period until completely prohibited egg laying at 20, 25, 27 and 30 °C were 134.59, 338.32, 417.17, and 395.36, respectively. While the survival rate of insect were recorded and $l_x.m_x$ were estimated.

Table 4. Life table parameters of *P. citri* reared in the laboratory under four different degrees of temperatures

Parameters	Temperature (°C)			
	20	25	27	30
R0	62.61	136.88	380	339.62
Ratio	1.00	2.186	6.069	5.424
Gt	64.45	50.00	46.35	44.88
Ratio	1.00	0.776	0.719	0.696
Rm	0.064	0.09	0.128	0.129
Ratio	1.00	1.406	2.00	2.016
λ	1.066	1.09	1.14	1.137
Ratio	1.00	1.023	1.064	1.285
Dt	10.83	7.7	5.41	5.37
Ratio	1.00	0.711	0.500	0.496
m_x	134.59	338.32	417.17	395.36

It is observed from data in Table (4) that R_m values were 0.064, 0.09, and 0.129 for 20, 25, and 30°C, respectively. The R_m value at 25 °C was increased by about 1.4-fold than those of 20 °C. Also, the R_m value at 30 °C was increased by about 1.4-fold than those of 25 °C. According to this finding we suggest the following equation to calculate the expected R_m value using a known R_m at a certain degree of temperature (°C):

$$R_{m(C+5)} = R_{m(C)} \times k \text{ (whereas } k \text{ is a constant value} = 1.4)$$

Generally, the life table parameters were varied according to the degrees of temperatures as indicated in Table (4). These values help us to predict the population density of insects under field condition and help to determine the date and methods of insect control.

These studies are very important to estimate the total number of insects gained by laboratory studies under control rearing conditions. The mass production is very important for test the efficiency of some insecticides and other biological studies. Other studies about the irradiation and insect sterilization of insects depend on the life table parameters under controlled temperature.

Knowledge of the life cycle of citrus mealy bugs is important to the success of its management program. Several studies were conducted by many researches i.e. Persad and Khan (2002) who reported that the R_o , T, DT and λ were 227.18 females per female, 40.13 and 5.13 days and 1.14 day⁻¹, respectively, when reared on *M. hirsutus*. Özgökce *et al.* (2006) observed that R_o , T, DT and λ was 340.703 females per female, 59.350 and 7.2 days and 1.101 day⁻¹, respectively, when reared on *P. citri*. Goldasteh *et al.*, (2009) found that the R_o , r_m , λ , DT and mean generation time (GT) values for *P. citri* were significantly different at various constant temperatures. The R_o was the highest at 25°C, with 154 eggs per female per generation, and the lowest at 32°C, with 8.83 eggs per female per generation. The r_m of *P. citri* rose with temperature to reach a maximum at 25°C and then declined at 28 to 32°C. The highest values of r_m and λ and the lowest values of DT and T occurred at 25°C, suggesting that this is the optimal temperature for *P. citri*.

The intrinsic rate of natural increase (r_m) of *P. citri* estimated in the study of Goldasteh *et al.* (2009) ranged from 0.055 to 0.170 female per female per day for rearing on (25°C -15°C). These values are similar to the values reported by Walton and Pringle (2005) for *P. ficus* at 20 (0.068), 25 (0.169), and 27°C (0.131), but they were higher at 30 °C and very close at 18°C. The highest intrinsic rate of natural increase (r_m) of *P. citri* occurred at 25°C and revealed high reproduction ability of citrus mealybug females at this temperature. Also, the mean generation time (Gt) was shortest at 25°C. This result indicates that development of *P. citri* took place faster at this temperature than at the other temperatures.

According to Yang and Sadof (1995), the intrinsic rate of natural increase for *P. citri* reared on red variegated coleus was 0.122 females/female/day. The intrinsic rate of natural increase is a composite statistic that takes into account life history parameters such as development rate, fecundity, longevity (survival), and sex ratio (Carey, 1993). Thus, it is one of the most important criteria used for evaluating the influence of temperature on life history of a pest. The values of population growth parameters of *P. citri* (except generation time) at 28°C in this study were higher than data reported for *M. hirsutus* by Persad and Khan (2002). Polat *et al.* (2008) investigated development, longevity, fecundity and life-table parameters of *Planococcus citri* (Hemiptera: Pseudococcidae) feeding on *Nerium oleander*, *Schefflera arbuticola*, *Kalanchoe blossfeldiana* and *Sygonium podophyllum* at 28±1°C, 65±10% RH and 16L: 8D under laboratory conditions. They found that the highest reproductive rate (R_o) occurred on *S. podophyllum*, with 205.46 female offspring per female, and the lowest occurred on *S. arbuticola*, with 32.27 female offspring per female. The intrinsic rate of increase (r_m) was significantly different among hosts, with the highest rate (0.138 female offspring per female per day) on *S. podophyllum*. However, mealybugs possess a waxy covering that protects them from insecticide sprays, so additional control methods are often times necessary (Copeland *et al.*, 1985 and Walker, 2000). Our findings showed citrus mealybug performances to be highly affected by temperature.

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