Acarina 22 (1): 52–60

TEMPERATURE-DEPENDENT DEMOGRAPHIC PARAMETERS OF *BRYOBIA RUBRIOCULUS* (ACARI: TETRANYCHIDAE) ON SWEET CHERRY

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ABSTRACT: The brown mite, *Bryobia rubrioculus* (Acari: Tetranychidae), is a serious pest in orchards in Iran. Laboratory experiments were preformed in growth chambers at eight constant temperatures (15, 17.5, 20, 22.5, 25, 27.5, 30 and 32.5ºC), 60 ± 5% RH and a photoperiod of 16:8 h. (Light: Dark) using the sweet cherry leaves (*Prunus avium*). The survival rate (l_x) was the highest at 15ºC and lowest at 32.5ºC. The life expectancies (e_x) of 1-day adults were determined 38.28 to 11.51 at 15 to 32.5ºC, respectively. There were significant differences between demographic parameters of *B. rubrioculus* at various temperatures. Net reproduction rate (R_0), generation time (tG) and intrinsic rate of increase (r_m) ranged from 5.83, 42.79 and 0.041 at 15ºC to 0.67, 24.15 and 0.025 at 32.5ºC. The gross fertility (4.4 eggs) was recorded at 32.5ºC, and the highest (29.5 eggs) was at 20ºC. 20ºC is the optimal temperature for *B. rubrioculus* population growth.

KEY WORDS: Mite, Population Parameters, Reproduction Parameters, Iran

INTRODUCTION

Bryobia rubrioculus Scheuten (Acari: Tetranychidae) is considered as one of the important phytophagous mites on the black cherries, sweet cherries, plum and apple trees in Hamedan (Khanjani and Haddad Irani-Nejad 2008). In vicinities of Hamedan, this mite adopted to high-altitude environments, especially in cooler periods, and can produce five generations per year and more than 90% eggs hatching at 25°C (Eghbalian 2007). However in warm and moderate regions (Karaj, Alborz province), it makes three generations per year (Keshavarze-Jamshidian 2004) and also was found on the apple, plum, prune, black cherry, sweet cherry, peach, grape, walnut, pear, apricot and almond from different areas in Iran (Khalilmanesh 1972; Sepasgozarian 1976; Nozari 1992; Sadeghi-Nameghi and Kamali 1993; Behdad 1994; Atamehr 1997; Khanjani and Kamali 1998; Modarresawal 2001; Khanjani 2004; Keshavarze-Jamshidian 2004; Eghbalian 2007). This mite also causes damage to apple trees with remarkable economic loss in different localities and apple varieties in Turkey (Kasap 2006, 2008).

Demographic parameters were assessed for *Eotetranychus pruni* and *Tetranychus urticae* (Grissa-Lebdi et al. 2002) and *Tetranychus turkestani* (Sohrabi and Shishehbor 2008) on different plant species. The results clearly showed the influence of temperature on population growth (Boufour and Tanigoshi 2001), similarly to previous studies in Africa (Bonato et al. 1995) .

Population parameters are indices of population growth rates under different bioclimatic conditions which may help assessing the potential of pest population growth (Southwood and Henderson 2000). Life table is considered to dynamics of animal frequencies with regards to population growth parameters (Maia et al. 2000). The mentioned information would be extremely precious for the future development of the crop management. Furthermore, demographic information may also be useful in constructing population models (Carey 1993, 2001) and understanding interactions with other pests and natural enemies (Omer et al. 1996). Also, the intrinsic rate of increase (r_m) is a factor of demographic parameter valuable for anticipating the population growth potential under environmental condition (Andrewartha and Brich 1954; Southwood and Henderson 2000).

The comprehensive knowledge of different biological characteristics of *B. rubrioculus* under variable environmental conditions is required for the establishment of a pest management program in the orchards. The demographic parameters of *B. rubrioculus* have not been studied on the sweet cherry yet. Therefore, the main objective of this study is to determine the relationship between various demographic parameters and temperature.

MATERIAL AND METHODS

Mite colony

Mites were collected from sweet cherry trees in Hamedan, Iran, in February 2009 to initiate the culture. Laboratory colonies of the brown mite were continuously reared on sweet cherry leaf discs in a growth chamber (25±1°C, 60±5% RH, 16:8 L: D).

Rearing unit

Experiments conducted at eight constant temperatures (15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5 ± 0.5°C) with 60 replications for each temperature, in separate growth chambers, with 60±5% RH and a photoperiod of 16L:8D h. Each rearing unit consisted of a detached leaf. Petri dishes with a 9 cm diameter were used as test arenas, and placed on pieces of water soaked sponge in Petri dishes. Detached sweet cherry leaflets were placed separately on the sponges in each arena. A narrow strip of tissue paper was placed on the periphery of each leaflet. The soaked sponge and tissue papers kept the leaflet moist and for each experiment, one adult female from the stock colony was transferred with the help of a fine camel brush (000) to the test arenas and was allowed to lay eggs. After oviposition period of 24 hours, the adult and all eggs except one were removed. For each temperature, the developmental time of different stages of the brown mite, was recorded daily (until the last female died) under a dissecting microscope at magnifications up to 70×. The detached sweet cherry leaflets were replaced every two days throughout the study.

Statistical analysis

The effect of temperature on fecundity, reproduction and population parameters was compared using one-way ANOVA. If significant differences were detected, multiple comparisons were made using the t-test ($P< 0.05$) (SPSS 2007). From the fertility and survivorship schedules, the following population growth parameters were calculated using formula suggested by Carey (1993): intrinsic rate of increase (r_m), mean generation time (tG), finite rate of increase (λ), net reproduction rate (R_0) and doubling time (tD). Differences in R_0, tG, λ, tD and r_m-values were tested for significance by estimating variances through the Jackknife technique (Meyer et al. 1986; Maia et al. 2000). Algorithm for jackknife is described only for r_m (ref). Similar procedures were used for other parameters (R_0, tG, λ and tD). The jackknife *pseudo*-value r_j was calculated for the n samples using the following equation:

$$r_{m(j)} = n \times r_{all} - (n-1) \times r_{m(i)}$$

After calculating all the n *pseudo*-values for r_m, jackknife estimate of the mean [$r_{m(Jackknife)}$ or $r_{m(j)}$], variance and standard error were calculated by the following equations:

$$r_{m(mean)} = \frac{\sum_{1}^{n} r_{m(j)}}{n}$$

$$VARr_{m(mean)} = \frac{\sum_{1}^{n} (r_{m(j)} - r_{m(all)})^2}{n-1}$$

$$SEMr_{m(mean)} = \sqrt{\frac{VAR(r_{m(mean)})}{n}}$$

(Carey 2001).

The mean values of n jackknife *pseudo*-values for each temperature were subjected to analysis of variance (ANOVA). The similar procedures were used for the other parameters such as R_0, λ, tG and tD. If significant differences were observed, multiple comparisons were made using t-test. The relationship between temperature and the egg developmental rate was described using linear regression:

$Y = a + bx$

Where Y is the egg developmental rate, x is the temperature, a is the intercept and b is the slope of the line. Life expectancy (e_x), the average of remainder days that mite can reach to age x, was calculated using the following formula (Carey 2001): $e_x = Tx / l_x$.

Where l_x is age-specific survival rates and Tx is the number of days after age x that the mite is lived.

RESULTS

Survival rate and fecundity

The mean life-span (egg to adult) of *B. rubrioculus* decreased from 38.77 days at 15°C to 12.02 days at 32.5°C (Fig. 1). Also age-specific survival at all eight temperatures decreased as the brown mite aged. Age-specific survival rates (l_x) and age specific fecundity rates (m_x) of *B. rubrioculus* at various temperatures are given in Fig. 2. The period of *B. rubrioculus* survived was the longest at 15°C and became shorter as temperature increased. The daily egg production was 4 eggs (the peak of daily egg rate) at 17.5°C and 20°C, also, 1.5 eggs (the lowest of daily egg rate) at 30°C and 32.5°C, respectively (see Fig. 2 for more details). Results of this study showed that the life expectancy (e_x) of newly laid eggs decreased from 38.28

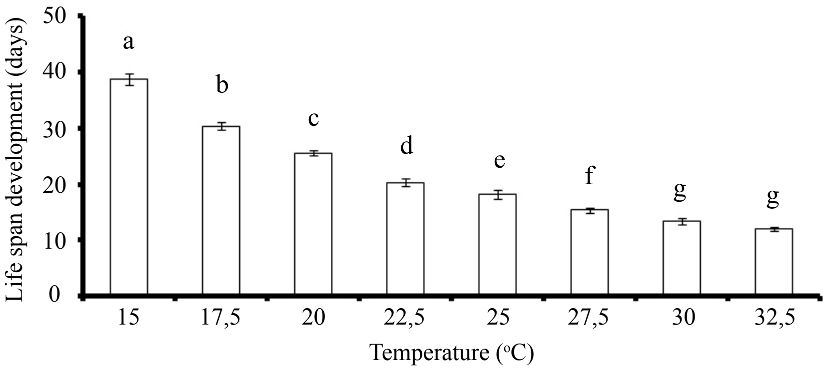

Fig. 1. Comparison of life-span of *Bryobia rubrioculus* at eight constant temperatures (mean±SE).

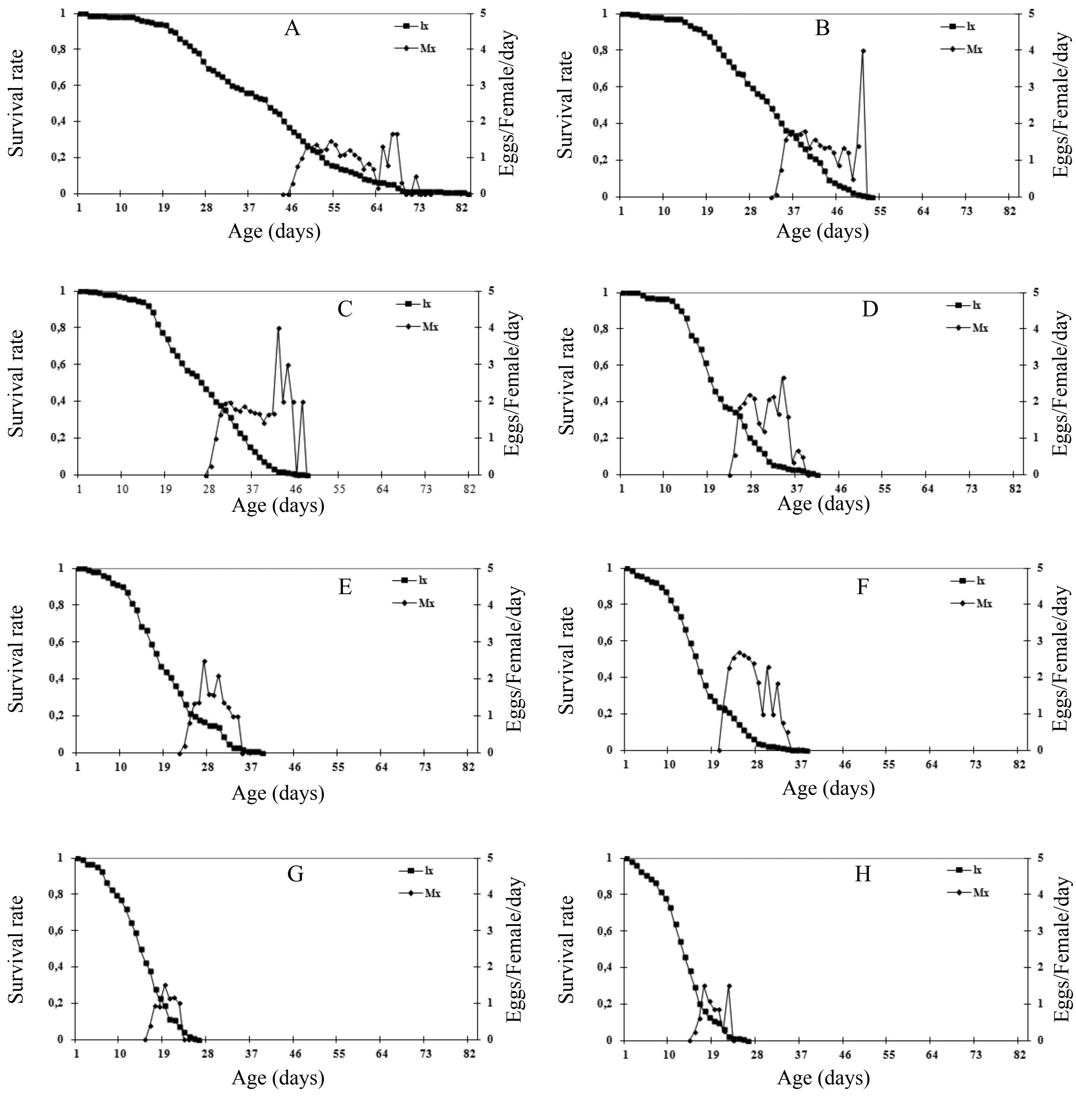

Fig. 2. Age-specific fecundity and survival rate of *Bryobia rubrioculus* at different temperatures. (A) 15ºC, (B) 17.5ºC, (C) 20ºC, (D) 22.5ºC, (E) 25ºC, (F) 27.5ºC, (G) 30ºC and (H) 32.5ºC on sweet cherry, *lx* is the proportion of alive brown mites at age *x*; m_x is the mean number of eggs laid per female at age *x*.

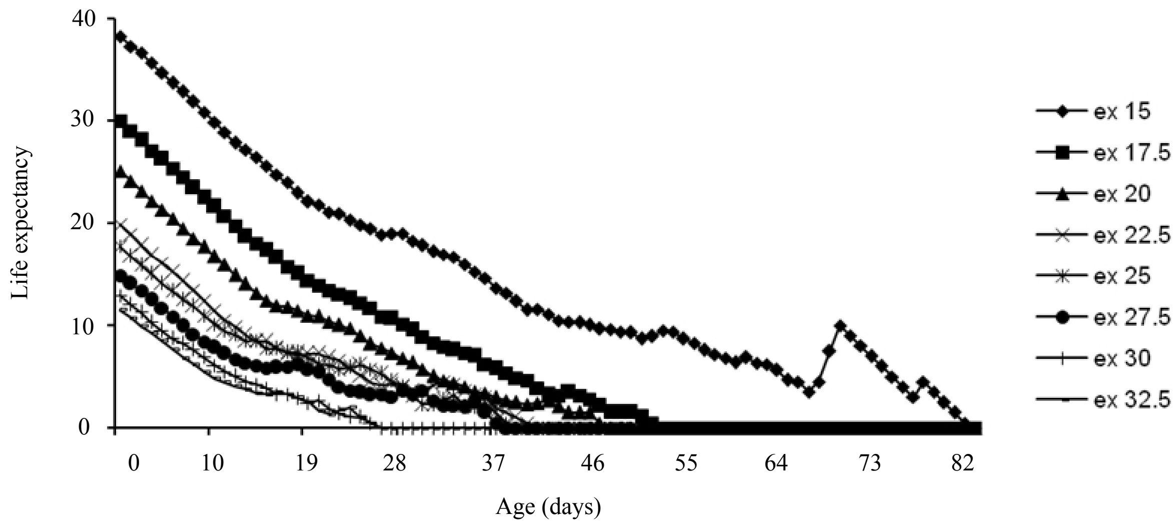

Fig. 3. Life expectancy (e_x) of the brown mite, *Bryobia rubrioculus* at various temperatures.

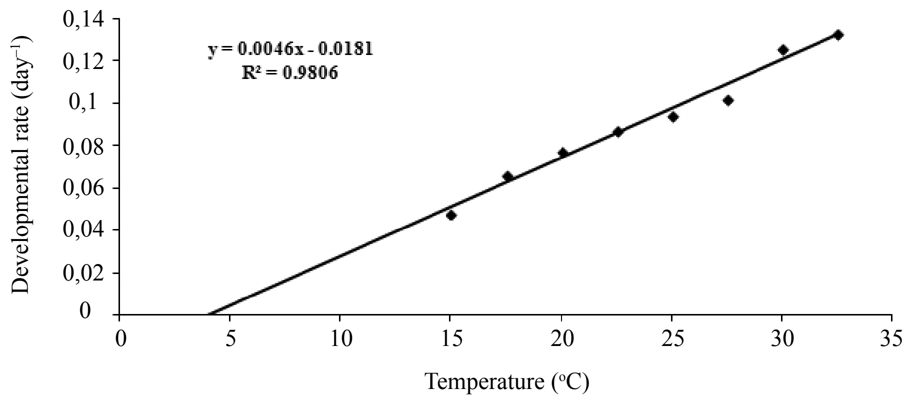

Fig. 4. Developmental rates for the egg stage of *Bryobia rubrioculus* at different temperatures.

days (the longest) at 15ºC to 11.51 days (the shortest) at 32.5ºC (Fig. 3).

The linear regression equation for the egg developmental under the eight temperatures is Y = 0.0046x – 0.0181, where *Y* is the egg developmental rate and *X* is the temperature (Fig. 4). The lower egg developmental threshold (T_o) for *B. rubrioculus* was estimated to be 3.93ºC. The thermal constant has been estimated from the linear equation to be 217.39 degree-days (*DD*).

Reproduction parameters

The reproduction parameters of the brown mite are shown in Table 1. Temperature significantly affected the gross fecundity rate of *B. rubrioculus* (F = 2.551, df = 7, P = 0.014). It was found to be 37.6 eggs/female at 20ºC (maximum rate) and 8.4 eggs/female at 30 and 32.5ºC (minimum rate).

The net fecundity rate significantly decreased with increasing temperature from 15 to 32.5ºC (F = 9.662, df = 7, P> 0.000). It was the highest at 15ºC (6.6 eggs/female) and lowest at 30 and 32.5ºC (0.6 eggs/female). The high temperatures (30 and 32.5ºC) had deleterious effect on the net fecundity rate compared to other temperatures tested (15–27.5ºC).

The gross fertility rate ranged from 29.5 eggs/female at 20ºC to 4.4 eggs/female at 32.5ºC. It was significantly lower at 30 and 32.5ºC compared to other temperatures (15–27.5ºC).

Net fertility rate decreased from low to high temperatures, so it was highest at 15ºC (4.9 eggs/female) and lowest at 32.5ºC (0.3 eggs/female).

The mean gross hatch rate was significantly affected by temperatures (F = 44.630, df = 7, P> 0.000), which recorded as the highest rate 0.9 eggs/female at 15ºC and lowest rate 0.5 eggs/female at 32.5ºC (Table 1).

The mean number of eggs per female per day, was significantly lower (F = 2.640, df = 7, P =

Table 1.
The reproduction parameters (Mean±SE) of the brown mite, *Bryobia rubrioculus* at various temperatures

Temperature (°C)	n	Gross fecundity rate	Net fertility rate	Net fecundity rate	Gross fertility rate	Gross hatch rate	Mean eggs per female per day	Mean fertile eggs per female per day
15	19	29.7±3.74[a]	4.9±0.53[a]	6.6±0.70[a]	28.4±2.78[a]	0.9±0.04[a]	1.0±0.12[ab]	0.9±0.09[ab]
17.5	20	33.1±4.61[a]	4.6±0.38[a]	6.2±0.52[a]	29.4±3.36[a]	0.7±0.00[b]	1.7±0.24[ab]	1.3±0.18[a]
20	22	37.6±3.36[a]	4.4±0.37[a]	5.6±0.47[a]	29.5±2.62[a]	0.8±0.00[b]	1.9±0.17[a]	1.5±0.13[a]
22.5	16	32.2±3.36[a]	2.1±0.30[b]	3.3±0.47[b]	20.4±1.71[a]	0.6±0.00[c]	1.7±0.17[ab]	0.1±0.10[ab]
25	14	29.9±2.28[a]	1.8±0.32[b]	2.8±0.53[bc]	20.0±2.28[a]	0.6±0.02[c]	1.7±0.21[ab]	0.1±0.15[ab]
27.5	11	28.2±2.49[a]	1.5±0.11[b]	2.7±0.35[bc]	15.7±1.38[ab]	0.6±0.00[d]	1.7±0.15[ab]	0.9±0.08[ab]
30	7	8.4±2.73[b]	0.4±0.14[b]	0.6±0.22[c]	5.3±1.72[b]	0.6±0.00[c]	0.8±0.25[b]	0.5±0.16[b]
32.5	5	8.4±1.47[b]	0.3±0.07[b]	0.6±0.13[c]	4.4±0.77[b]	0.5±0.00[d]	0.9±0.16[ab]	0.5±0.09[b]

Means followed by the same letters within columns are not significantly different by T-test (P< 0.05)

Table 2.
Comparison of population parameters of *Bryobia rubrioculus* at eight constant temperatures

Temperature (°C)	Population parameters (mean±SE)				
	R_0 females/♀/generation	r_m (day^{-1})	*tG* (days)	*tD* (days)	λ (day^{-1})
15	5.83±0.72[ab]	0.041±0.0029[bcd]	42.79±0.83[a]	18.26±0.82[a]	1.04±0.003[b]
17.5	6.52±0.54[a]	0.059±0.0025[ab]	31.51±0.29[b]	12.11±0.41[cd]	1.06±0.003[ab]
20	6.58±0.56[a]	0.067±0.0028[a]	26.71±0.30[c]	10.67±0.39[d]	1.07±0.003[a]
22.5	3.57±0.48[bc]	0.056±0.0057[abc]	22.68±0.51[de]	13.63±1.02[bc]	1.06±0.006[ab]
25	3.01±0.56[cd]	0.056±0.0084[abc]	21.69±0.36[e]	14.22±0.87[bc]	1.06±0.009[ab]
27.5	2.93±0.36[cd]	0.055±0.0062[abc]	19.52±0.29[f]	14.69±1.11[bc]	1.06±0.007[ab]
30	0.70±0.24[d]	0.039±0.0093[cd]	23.71±0.68[d]	15.45±0.96[ab]	0.99±0.018[c]
32.5	0.67±0.14[d]	0.025±0.0019[d]	24.15±0.41[d]	16.04±1.05[ab]	0.98±0.009[c]

0.011), when *B. rubrioculus* reared at 30 and was highest at 20ºC (1.9 eggs/female) (Table 1).

The mean fertile eggs per female per day, was significantly differed at various temperature (F = 3.129, df = 7, P = 0.003). This value was highest at 20ºC (1.5) and lowest at 30 and 32.5ºC (0.5) (Table 1).

Population parameters

The population parameters of *B. rubrioculus* at different temperatures are given in Table 2. The net reproductive rate (R_0) was significantly affected by different temperatures (F = 8.860, df = 7, P> 0.000). This parameter ranged from 6.58 females/female at 20ºC (highest) to 0.67 females/female at 32.5ºC (lowest).

The intrinsic rate of increase (r_m) gradually increased with increasing temperature to a peak of 0.067 females/female/day at 20ºC and then decreased to 0.025 females/female/day at 32.5ºC (Table 2). Therefore it appears that around 20ºC is the optimal temperatures for population increase of *B. rubrioculus* under laboratory conditions.

There was significant difference between generation times at different temperatures (F = 230.937, df = 7, P> 0.000). The generation time (*tG*) decreased from 42.79 days at 15ºC to 19.52 days at 27.5ºC but increased to 24.15 days at 32.5ºC (Table 2).

There were significant differences between the doubling time at various temperatures (F = 14.257, df = 7, P = 0.000). The doubling time (*tD*) was highest at 15ºC (18.26 days) and lowest at 20ºC (10.67 days) (Table 2).

Significant differences were observed between the finite rate of increase at different temperatures (F = 19.770, df = 7, P = 0.000). The *λ*-value reached its maximum at 20ºC (1.07), but this value was <1 at 30 and 32.5ºC, indicating a declining population at these two temperatures (Table 2).

The calculated r_m, R_0 and λ values increased by increasing temperature from 15ºC to 20ºC but those values decreased at 22.5 to 32.5ºC.

Means followed by the same letters within columns are not significantly different by t-test ($P< 0.05$). R_0 = net reproductive rate; r_m = intrinsic rate of increase; *tG* = generation time; *tD* = doubling time; λ = finite rate of increase.

DISCUSSION

In general, as temperature increased, survivorship periods of the brown mite decreased (Fig. 2). Similar trends were reported by Kasap (2003) for *Amphitetranychus viennensis* (Zacher) on Golden Delicious apple tree at three constant temperatures and for *T. urticae* on the same host at four temperatures (Kasap 2004).

The daily egg production had an increase from 15 to 20°C. The highest amount of egg production was 17.5 and 20°C, decreasing to 30°C. This parameter at 25ºC was equal to that of *Panonychus citri* (McGregor) on *Citrus aurantium* measured at 26ºC (Karaca 1994) whereas, it was higher for *Tetranychus cinnabarinus* Boisduval on Sweet Charlie (a strawberry cultivar) (Kazak and Kibritci 2008) and for *T. urticae* on the common bean plant at the same temperature (Kavousi et al. 2009). The differences observed might be due to the differences in experimental conditions.

On the other hand, our research clarified that the life expectancy decreased with increasing of temperature. This value (*B. rubrioculus*) was higher than that of *T. urticae* Koch at 25°C (Kavousi et al. 2009). The lower developmental threshold of the egg stage was 3.93ºC, which was lower than that (9.7ºC) for *Amphitetranychus viennensis* on apple cultivars (Kasap 2003). A total of 217.93 *DD* (degree days) above the minimum temperature threshold was needed to complete development of eggs. The higher developmental threshold and lower degree-days: 9.22ºC and 100 *DD* for females eggs were reported for *Panonychus citri* on Washington navel sweet orange (Kasap 2009).

Our results indicate the highest and lowest temperatures had negative effects on the reproduction parameters (Table 1). Similar results were obtained on bean different cultivars at 25°C (Ahmadi et al. 2004), but in other studies these values were higher (Gotoh 1986; Aponte and McMurtry 1997; Razmjou et al. 2009; Gotoh and Gomi 2003; Vasquez et al. 2008). The specific conditions of experiments (host, temperature and mite species) are probably affect these results. It assumed that 20°C is the optimal temperature for *B. rubrioculus* on sweet cherry because, the gross fecundity, the gross fertility and mean eggs (female^{-1} day^{-1}) were the highest at this temperature. In comparison with other spider mites, the brown mite had low reproduction parameters, so its damage is relatively low. Karaat (1991) reported that host plants have a more significant effect on the reproductive potential of tetranychids than that on developmental rate. Kasap (2004) stated that different apple cultivars have a more significant effect on reproductive potential than that on developmental rate of *T. urticae* Koch; therefore, these results should be expected.

The net reproduction rate (R_0) increased with increasing temperature from 15 to 20ºC and then gradually decreased to the lowest at 32.5ºC. The R_0 value was much lower than those reported for *B. rubrioculus* reared on two apple cultivars, Golden delicious (12.54 females/female) and Starking (17.62 females/female) at 25ºC (Kasap 2008). The R_0 for *Panonychus citri* on Washington navel sweet orange at 15, 20, 25, and 30ºC was 8.8, 13.3, 16.5 and 11.5 (Kasap 2009). For *Tetranychus urticae* Koch kept on red raspberry leaf discs R_0 was 24.66, 80.99, 54.86 and 86.01 at 15, 20, 25 and 30ºC, respectively and 13.54, 23.75, 27.92 and 22.74 for *Eotetranychus carpini borealis* at the same temperatures on red raspberry (Bounfour and Tanigoshi 2001). On apple leaf discs the net reproductive rate (R_0) was 19.2 and 14.0, for *T. urticae* and *Eotetranychus pruni* (Grombalia), respectively (Grissa-Lebdi et al. 2002). According to Taleb and Sardar (2008) the net reproduction rate (R_0) for *Tetranychus bioculatus* (Wood-Mason) was 78.69, 37.02 and 53.87 on Marigold, Rose and Cosmos (ornamental plants). Differences in the ecological, strain of mite and host plant, as well as measurement and data analysis methods, may provide an explanation for variation in this rate.

In our study, the generation time was 21.69 days at 25ºC. Similar results, 23.87 and 26.82 days, on two apple cultivars (Golden delicious and Starking) were obtained previously for *B. rubrioculus* at 25ºC (Kasap 2008). On sweet and black cherry and apple trees the mean generation time was 18.24, 18.47 and 19.16 days at 25ºC for *Amphitetranychus viennensis* (Zacher) (Kafil et al. 2007) and 14.9 days at 25ºC for *Pananychus citri* (McGregor) on bitter orange leaves (*Citrus aurantium*) (Karaca 1994). Delhiro and Monagheddu

(1986) reported that the mean generation time decreased with the increase of temperature (similarly to our results), ranging from 158.9 days at 11ºC to 11.7 days at 33ºC for *Pananychus citri* (McGregor) on bitter orange leaves.

In our study, the r_m-value of the brown mite at 25ºC (0.056 day^{-1}) was lower than those of this species on two apple cultivars (0.106 day^{-1} on Golden delicious and 0.107 day^{-1} on Starking) and 0.160 on Washington navel sweet orange for the citrus red mite at the same temperature (Kasap 2008, 2009). According to Adango et al. (2006), r_m-value of *Tetranychus ludeni* Zacher at 27ºC was determined to be 0.173 day^{-1} on *Amaranthus cruentus L.* and 0.215 day^{-1} on *Solanum macrocarpon* L., which were higher than that of the brown mite in the present study. Skorupska (1998) reported r_m as 0.093, 0.087, 0.105, 0.119, and 0.112 for *Amphitetranychus viennensis* (Zacher) and 0.084, 0.078, 0.088, 0.113 and 0.108 for *T. urticae* on five scab-resistant apple varieties (Primula, Pionier, Lodel, Novamac and Freedom), at room temperature. The r_m value is widely used for evaluating the reproductive potentials of spider mites and predacious mites (Bozai and Bream 1996; Li 1993). Andrewartha and Birch (1954) emphasized the importance of r_m as the only statistic that would summarize adequately the physiological quality of an animal.

The λ-value of *T. urticae* was determined to be 1.17 on bean leaf discs and 1.26 on whole bean leaves at 25ºC (Kavousi et al. 2009). However, it was lower than that of *Tetranychus evansi* Baker and Pritchard, which ranges from 1.20 at 21ºC to 1.43 at 31ºC on tomato leaf discs (Bonato 1999). Razmjou et al. (2009) determined the finite rate of increase as: 1.35, 1.27 and 1.26 on soybean, cowpea and bean, respectively, at 25ºC for *T. urticae* as we found 1.06 at 25ºC.

Imani and Shishehbor (2009) observed that the *tD*-values of *Eutetranychus oreintalis* (Klein) reared on lebbeck leaflets were 7.34, 6.20 and 4.79 days at 20, 25 and 30ºC, respectively, which were shorter than those reported in the present study at the same temperatures. Sohrabi and Shishehbor (2008) found that *tD*-value of *Tetranychus turkestani* Ugarov and Nikolski reared on cowpea, green gram and pinto were 3.06, 2.84 and 3.61 days at 25ºC and 2.17, 2.42 and 2.53 days at 30ºC, which was lower than those obtained in the present study at the same temperatures.

The brown mite achieved the highest r_m and R_0 at 20ºC because of their highest m_x. Decreasing R_0 and r_m values at 15 and 32.5ºC suggests that low and high temperatures affect mite reproduction. The mean generation time was significantly higher at the lowest temperature (15ºC) and decreased by increasing the temperature from 15 to 32.5ºC but the doubling time was significantly higher at 15ºC and decreased as temperature increased from 15 to 20ºC, then increased at temperatures from 20 to 32.5ºC. The population growth parameters may be affected by ecological differences, geographical region, host plants, and experimental conditions. Tripathi and Singh (1990) noticed that a number of extrinsic and intrinsic factors have been shown to affect the r_m-value and related demographic parameters, such as the host plant and temperature (Force and Messenger 1964).

This study indicates that temperature plays a significant role in population's dynamics of this mite through its influence on survival and reproduction. Nevertheless, further research of its biology, thermal requirements and evaluation of the intrinsic rate of increase under the field condition at moderate climate areas are needed. Our study evaluates the effect of temperature on demographic parameters of *B. rubrioculus* and provides direction for future research on the performance of *B. rubrioculus* in orchards under variable environmental conditions. Our findings revealed that the population characteristics of *B. rubrioculus* are lower than those of other mites (*Tetranychus urticae*, *Eotetranychus carpini borealis*, *T. ludeni*, *Amphitetranychus viennensis* and *T. evansi*);(Kasap 2008; Bounfour and Tanigoshi 2001; Skorupska 1998; Adango et al. 2006; Kavousi et al. 2009; Bonato 1999) and 20ºC is the most suitable temperature for population growth of *B. rubrioculus* on the sweet cherry.

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