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Orijinal araştırma (Original article)

Temperature influence on development of *Sympherobius pygmaeus* (Rambur) (Neuroptera: Hemerobiidae) reared on *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae)[1]

Sıcaklığın *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) üzerinde beslenen *Sympherobius pygmaeus* (Rambur) (Neuroptera: Hemerobiidae)'un gelişmesine etkisi

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Summary

Sympherobius pygmaeus (Rambur) (Neuroptera: Hemerobiidae) is a predator recorded on several pest species, including mealybug in Turkey. The present study was performed to determine the relationship between growth rate and temperature effects on *S. pygmaeus.* Development and fecundity were investigated at 15, 20, 25, 30 and 35±1 °C and 60%±10 relative humidity with 16 hours lighting in a growth chamber.

The development time from egg to adult decreased with increasing temperatures. The longest development time was at 15 °C with 147.3±4.37 days and the shortest time was at 30 °C with 21.8±0.20 days, while development was not completed at 35 °C. The oviposition period was 22.00±4.22, 19.58±1.37 and 2.38±0.14 days at 20, 25 and 30 °C, respectively. When the temperature effects on body size and weight of female and male individuals were compared, they were slight differences in size and weight at the same temperatures. Males and females reared at 25 °C were bigger than specimens reared at other temperatures. Daily and total egg production was highest at 25 °C, with 11.9±0.80/female/day and 258.4±12.25 per female. The net reproductive rate (R_o) and intrinsic rate of increase (r_m) were highest at 25 °C at 109.31 females/female and 0.1235 females/female/day^{-1}, respectively, and average generation time (T_o) was lowest at 30 °C at 23.49 days.

Key Words: *Sympherobius pygmaeus,* development time, temperature, thermal constant, life table

Özet

Sympherobius pygmaeus (Rambur) (Neuroptera: Hemerobiidae) Türkiye'de Unlubitin de dahil olduğu bir kaç önemli zararlı üzerinde kayıt edilmiş bir avcıdır. Bu çalışma 15, 20, 25, 30 ve 35 ± 1 °C farklı sıcaklıklarda %60±10 orantılı nem ve 16 saat uzun gün aydınlatmalı iklim dolaplarında sıcalığın *S. pygmaeus*'un gelişme ve üreme gücüne etkilerini belirlemek için yürütülmüştür.

Avcının yumurtadan ergine kadar olan gelişme süresi sıcaklık artışıyla beraber kısalmıştır. 35 °C sıcaklıkta gelişme tamamlanamazken, gelişim süresi en uzun 147.3±4.37 günle 15°C' de, en kısa 21.8±0.20 günle 30 °C' de tamamlanmıştır. Ovipozisyon periyodu 20, 25 ve 30 °C' de sırasıyla 22.00±4.22, 19.58±1.37 ve 2.38±0.14 gün sürmüştür. Farklı sıcaklıkların *S. pygmaeus'*un erkek ve dişi bireylerinin vücut iriliklerine etkileri karşılaştırıldığında ise dişi ve erkek bireylerin aynı sıcaklıklarda farklı vücut ağırlığı ve büyüklüğüne sahip olduğu görülmüş, en iri bireyler hem erkek hem de dişiler için genelde 25 °C'de elde edilmiştir. Günlük ve toplam bırakılan yumurta sayısı sırasıyla 11.91±0.80 dişi/gün, 258.43±12.25 dişi/ömür ile en fazla 25°C' de olmuştur. Net üreme gücü (R_o) ve kalıtsal üreme kapasitesi (r_m) en yüksek 25 °C' de sırasıyla 109.31 dişi/dişi ve 0.1235 dişi/dişi/gün^{-1} ve ortalama döl süresi (*To*) en düşük 30 °C' de 23.49 gün olarak bulunmuştur.

Anahtar sözcükler: *Sympherobius pygmaeus,* gelişme süresi, sıcaklık, termal konstant, yaşam tablosu

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Introduction

The citrus production in Turkey is centered in the Mediterranean Region because of climate characteristics, with nearly 85% of the country's production (Anonymous, 2010a). Citrus production, quite important for domestic consumption and export, is restricted by many diseases and pests.

In citrus orchards in Turkey, 89 pest species and 159 parasitoids and predators have been recorded (Uygun & Satar, 2008). In recent years, the number of damaging outbreaks of citrus pests has increased as a result of pesticide use and a decrease in natural enemy populations. *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) is one of the important pests among them. Except for summer oil and Spirotetramat, there is increased usage of unregistered chemicals which threaten the environment, human health and impact on the export of fruit due to residues. Because biological control reduces the negative impact of chemicals by using natural pest control, it is increasingly being used.

Most insects in the Order Neuroptera are predators. Several families are widely distributed in both natural and agro-ecosystems in many parts of the world and especially two of them, the Chrysopidae and Hemerobiidae, have attracted considerable attention as biological control agents (New, 1975). Among them, brown lacewings (Neuroptera: Hemerobiidae) are predaceous as both adults and larvae. They prefer soft-bodied insects such as aphids, mealybugs, and also insect eggs. Because of the longevity of the adults, insatiable hunger, and high reproductive capacity, they are accepted as useful biological control agents (MacLeod & Stange, 2011). Thus, brown lacewings have been used as natural enemies of these pests in classical biological control (Sato & Takada, 2004). *Micromus timidus* Hagen was introduced from Australia to the Hawaiian Islands in 1919 for controlling various aphids and *Hemerobius nitidulus* Fabricius and *Hemerobius stigma* Stephens were introduced from Europe to Canada as biological control agents against the balsam woolly aphid. In another neuropteran family, Chrysopidae, *Chrysoperla carnea* (Stephens) and *Chrysoperla rufilabris* (Burmeister) have already been used commercially as biological control agents of pest aphids in Europe (van Lenteren et al., 1997). While Kansu & Uygun (1979) indicated that coccinellids and *Sympherobius sanctus* Tjeder (Neuroptera: Hemerobiidae) were important predators in the East Mediterranean Region of Turkey, Kaydan et al. (2006) reported twenty-three predatory species belonging to the Coccinellidae (Coleoptera), Chamaemyiidae (Diptera), Chrysopidae and Hemerobiidae (Neuroptera) and 22 parasitoid species belonging to Hymenoptera on mealybugs in Ankara, Turkey. In addition, Uygun et al. (2010) stated that there were thirty different native predators and parasitoids of *P. citri* in the citrus orchards of the East Mediterranean Region of Turkey. In Israel, Avidov & Harpaz (1969) stated that from the Coccinellidae family, *Scymnus apetzi* Muls., *Scymnus quadrimaculatus* Herbst *and Scymnus suturalis* Thunberg are common predators of citrus mealybug and that the neuropteran *Sympherobius sanctus* Tjeder (Hemerobiidae) is an important predator. Also, seven parasitoids and ten predators were recorded in Israel for *P. citri*. However, only *Anagyrus pseudococci* (Girault) (Hymenoptera: Encyrtidae) and *S. sanctus* were found in significant numbers in recent surveys (Mendel et al., 1992). *Sympherobius pygmaeus* Rambur (Neuroptera: Hemerobiidae) was first determined as a citrus pest predator by Şengonca (1979) in Kahramanmaraş. Furthermore, Türkyılmaz (1984) reported that *S. pygmaeus* also fed on *P. citri* in the citrus orchards of Antalya. In addition, *S. pygmaeus* also fed on *Planococcus aceris* (Signoret), *P. ficus* (Signoret) and *P. vovae* (Nasonov).

The aim of this study was to evaluate the effects of temperature on the growth of *S. pygmaeus*. Various life history parameters of *S. pygmaeus,* such as developmental time, longevity, and growth rates, were studied at different temperatures to obtain background data for further study on the use of *S. pygmaeus* for the biological control of mealybug in citrus orchards.

Materials and Methods

Planococcus citri rearing

Planococcus citri were obtained from citrus orchards at Çukurova University, Faculty of Agriculture, Research and Implementation Farm. *P. citri* were reared on sprouted potatoes in a climate controlled room at 20±2 °C and 60%±10 relative humidity for 30 or 45 days. The potatoes were used in *P. citri* rearing when their sprouts were about 4 or 5 cm long. The newly hatched crawlers and eggs were transferred on to new potato sprouts to multiply the mealybug population. This process was continued until the end of the study.

Sympherobius pygmaeus rearing

Sympherobius pygmaeus adults were transferred to mealybugs reared on sprouted potatoes at 24±3 °C temperature and 16 h of light in Petri dishes in insect rearing rooms. Sponge pieces were placed in Petri dishes for adults egg laying. Hatching individuals were identified by Prof. Dr. Norm Penny at California University when they became adults.

Experimental design

Randomly selected females and males of *S. pygmaeus* from stock cultures were transferred onto *P. citri*-infested sprouted potatoes in Petri dishes (5 cm diam. X 4 cm height) containing small pieces of sponge. Eggs laid on the sponge pieces within 24 h were maintained individually. When larvae became adults, male and female individuals were separated using a binocular microscope and one female and one or two males were kept per Petri dish for mating. Males and females were retained together until the end of their lives. New prey for *S. pygmaeus* larvae and adults were added every 3–5 days to the Petri dishes, depending on the numbers of *P. citri* present. Experiments were arranged in a completely randomized design with 73, 43, 35 and 40 replicates in the developmental stage at 15, 20, 25, and 30 °C, respectively, and 8, 12 and 13 replicates in the adult stage at 20, 25, and 30 °C, respectively.

Climate cabinets were maintained at various temperatures (15, 20, 25, 30 and 35±1 °C), 60%±10 relative humidity and with 16 h of light (5,000 Lux). Immature stages and adults were observed daily at all temperatures and their survival recorded. Laid eggs were removed after counting. Upon death, the body size of individual insects was measured using a binocular microscope fitted with a Leica DFC 280 camera. Adult dry weight was determined for all individuals after desiccation at 45 °C for 48 hours.

Data analysis and life tables

Significance of differences in developmental time, longevity, reproduction and morphometric measurements of *S. pygmaeus* were tested by analysis of variance (ANOVA). If significant differences were detected, multiple comparisons were made using the LSD multiple range test (α =0.05%). All statistical tests were assessed by SPSS 10 (Anonymous, 1998).

Population growth rates were calculated from the equation of Lotka (Birch 1948; Southwood 1978),

$$1 = \sum e^{-r_m x} l_x * m_x$$

$$R_o = \sum l_x * m_x$$

$$T_o = \ln R_o / r_m$$

$$\lambda = e^{r_m}$$

$$DT = \ln 2 / r_m$$

in which: x is the age in days (including immature stages), r_m is the intrinsic rate of increase is the natural base of a logarithm, l_x is the age-specific survival (including immature mortality) , m_x is the age-specific number of female offspring, R_o is net productive rate, T_o is generation time, λ is the finite rate of increase, the number of female offspring per female per day, and DT is doubling time, the number of days required by a population to double. After r was computed for the original data (r_{all}), differences in r_m-values were tested for significance by estimating variances through the jackknife method (Meyer et al., 1986). The mean of jackknife pseudo-values for each treatment were subjected to analysis of variance. The LSD Multiple Range Test was used to compare mean growth rates at different temperatures at α = 0.01 level (Jones, 1984).

A linear technique was employed to compute the lowest development threshold from egg to adult by using growth rate data as the dependent variable and temperature treatments as the independent variable. The lower developmental threshold was determined as the *x*-intercept of the linear equation and the degree-day requirements were determined as the value of the inverse of the linear equation slope (Campbell et al., 1974).

Results

Development and mortality rate

The development time of *S. pygmaeus* from egg to adult at 15, 20, 25, 30 and 35 °C with 60 % relative humidity are given in Table 1.

Table 1. Developmental times of *Sympherobius pygmaeus* reared on *Planococcus citri* at four constant temperatures (mean ± SE*)

Temperature °C	n	Egg-stage (days)	Larval stage (days)	Pupal stage (days)	Total development (days)
15	73	23.7 ± 0.24 a	55.7 ± 1.67 a	66.7 ± 3.84 a	147.3 ± 4.37 a
20	43	13.1 ± 0.21 b	25.4 ± 0.35 b	26.9 ± 0.38 b	65.5± 0.56 b
25	35	6.5 ± 0.13 c	11.8 ± 0.15 c	12.6 ± 0.24 c	30.9 ± 0.33 c
30	40	3.3 ± 0.08 d	8.1 ± 0.18 d	10.1 ± 0.12 d	21.8 ± 0.20 d
35		No eggs were obtained			

*Within the same column, means followed by the same letter are not significantly different according to the LSD test (P= 0.05)

Immature *S. pygmaeus* development time decreased with increasing temperatures. Total development time of *S. pygmaeus* was 147.3, 65.5, 30.9, and 21.8 days at 15, 20, 25 and 30 °C, respectively. *S. pygmaeus* had the longest immature period at 15 ^{o}C and the shortest developmental time at 30 °C. No eggs were obtained at 35 °C, since the constant temperature of 35 °C was lethal for the adult stage. Egg, larval and pupal development time decreased in parallel with increasing temperatures. The effect of temperature on total development period was statistically significant (F=3851.162; P=0.0001). When immature development periods were analyzed, the differences between egg hatching period (F= 2619.141; P=0.0001), larval development period (F= 1692.151; P=0.0001) and pupal development period (F= 1320.672; P=0.0001) were determined to be statistically significant.

The mortality rate of the egg stage was 58.90%, 30.23%, 14.28%, and 25.00% at 15, 20, 25, and 30 °C, respectively. In immature stages, mortality occurred at the larval stage at 15, 20 and 30 °C and in pupal stage at 20, 25 and 30 °C. Total mortality was considerably high at 15 °C (95.89%), but relatively low at 20 °C (39.53 %), 25 °C (20.00 %) and 30 °C (35.00 %). Two male and one female, out of 73, developed to the adult stage at 15 °C (Table 2).

Table 2. Immature mortality rate of *Sympherobius pygmaeus* reared on *Planococcus citri* at four constant temperatures

Temperature (°C)	n	Eggs	Larval	Pupa	Total
		% mortality rate			
15	73	58.90	36.99	0.00	95.89
20	43	30.23	2.32	6.98	39.53
25	35	14.28	0.00	5.71	20.00
30	40	25.00	2.50	7.50	35.00
35		No eggs were obtained			

Oviposition time and fecundity

At different temperatures, preoviposition, oviposition and postoviposition periods shortened due to increasing temperature (Table 3). The preoviposition time was about 2 days at 20 °C, 1.2 days at 25 °C and 1 day at 30 °C and the differences were significant (F= 33.889; P=0.0001). Oviposition time was 22.0 days at 20 °C, 19.6 days at 25 °C and 2.4 days 30 °C; 20 °C and 25 °C were statistically the same, while 30 °C was different from 20 °C and 25 °C (F=31.585; P=0.0001). In addition, 20 °C was statistically different from 25 °C and 30 °C in terms of postoviposition periods (F=7.495; P=0.002) (Table 3).

Table 3. Preoviposition, oviposition, postoviposition, female longevity and female eggs daily and total number of eggs of *Sympherobius pygmaeus* reared on *Planococcus citri* at four constant temperatures (mean ± SE*)

Temp (°C)	n	Preoviposition (days)	Oviposition (days)	Postoviposition (days)	Female Longevity (days)	Daily Eggs (female/day)	Total Eggs (egg/female)
15		No egg was obtained					
20	8	2.0 ± 0.00 c	22.0 ± 4.22 b	2.4 ± 0.46 b	28.4 ± 3.95 b	6.9 ± 1.59 a	168.7 ± 30.11 b
25	12	1.2 ± 0.13 b	19.6 ± 1.37 b	1.6 ± 0.23 a	26.2 ± 1.28 b	11.9 ± 0.80 b	258.4 ± 12.25 c
30	13	1.0 ± 0.00 a	2.4 ± 0.14 a	1.0 ± 0.00 a	3.4 ± 0.59 a	5.7 ± 0.51 a	18.9 ± 1.85 a
35		No egg was obtained					

*Within the same column, means followed by the same letter are not significantly different according to the LSD test (P= 0.05)

Female longevity in *S. pygmaeus* decreased with increasing temperatures (Table 3). The longest female longevity was 28.4 days at 20 °C and the shortest female longevity was 3.4 days at 30 °C. While there was no statistical difference between 20 °C and 25 °C, it was determined between these temperatures and 30 °C (F=58.132; P=0.0001). *Sympherobius pygmaeus* females laid 6.9, 11.9, and 5.7 eggs daily on average at 20, 25 and 30 °C temperatures respectively (F=14.385; P=0.0001). *Sympherobius pygmaeus* laid 168.7 eggs at 20 °C, 258.4 eggs at 25 °C and 18.9 eggs at 30 °C during the oviposition period. The difference in the total number of eggs, at different temperatures, was significant statistically (F=77.012; P=0.0001).

Population growth rates

The value of generation time decreased linearly with increasing temperatures above 20°C, while net reproductive rate was highest at 25 °C. In addition, *S. pygmaeus* reared at 25 °C also had the highest r_m (Table 4).

Table 4. Net reproductive rate (R_o), generation time (T_o), intrinsic rate of increase (r_m), doubling time (DT) and finite rate of increase (λ) of *Sympherobius pygmaeus* reared on *Planococcus citri* at four constant temperatures (mean ± SE*)

Temp. (°C)	n	Generation time (T_o, day)	Net reproductive rate (R_o, ♀/♀/generation)	Intrinsic rate of increase (r_m, ♀/♀/day^{-1})*	Finite rate of İncrease (λ, ♀/♀/day)	Doubling time (DT, day)
20	10	78.14	42.93	0.0495±0.00349 a	1.050	14.14
25	13	39.45	109.31	0.1237±0.00332 c	1.131	5.61
30	15	23.49	8.06	0.0894±0.00613 b	1.093	7.78

* Means in columns followed by the same letter are not significantly different by LSD Multiple Range Test (α = 0.01)

Generation time decreased with increasing temperature. Net reproductive rate was highest at 25 °C (109.31, females/female) and lowest at 30 °C (8.06, females/female). r_m fluctuated with temperature and was 0.0495, 0.1237, and 0.0894 females/female/day^{-1} at 20, 25, and 30 °C, respectively. The r_m at 25 °C was statistically different from the other two temperatures (F=51.006; P<0.0001). λ was 1.131 female offspring per female per day with a doubling time of 5.61 days at 25 °C (Table 4).

It was determined that the surviving proportion of the population was different for different temperatures (Figure1). Females laid their first eggs at 65 days at 20 °C, at 33 days at 25 °C and at 19 days at 30 °C. Oviposition continued to the 48th, 24th and 10th day, respectively, for those temperatures. The oviposition period for *S. pygmaeus* therefore decreased with increasing temperature.

The oviposition period continued during the adult life time at 20, 25 and 30 °C temperatures, while the postoviposition period lasted 2.38, 1.38 and 1.00 days, respectively. When the per female daily egg (female) number (m_x) was observed, the highest m_x rate was observed at the 38th day with 19.6 females/ female for 25 °C, at the 73rd day with 4.9 females/ female for 20 °C and at the 24th day as 4.5 females/female for 30 °C. Immediately after the highest point of age-specific fecundity, the death ratio of the individuals increased gradually for all temperatures (Figure 1).

In this study, the best temperature for optimum development period at egg hatching, larva development, pupa period and longevity in the adult period was 25 °C.

Developmental threshold and thermal constant

A linear regression analysis was applied to the developmental threshold within the 15–30 °C range. No successful development was obtained at >30 °C so it was excluded from the linear regression. Within the temperature range, the developmental rates (rT) of *S. pygmaeus* stages increased linearly with increasing temperature (Figure 2).

Developmental times from egg to adult at all temperatures were used in order to determine the relationship between temperature and the *S. pygmaeus* immature development period. Developmental threshold analyses showed a linear relationship. As seen at Figure 2, egg (0.9821), larva (0.9821), pupa (0.989), and total development R^2 (0.9853) values derived from the immature development period and the temperature were close to one. When all development periods were analyzed, the *S. pygmaeus* development threshold (C) was determined to be 13.1 °C. At the same time, the thermal constant (Th.C.), necessary for the predator to complete its development from egg to adult, was calculated 370.37 day-degrees (Table 5).

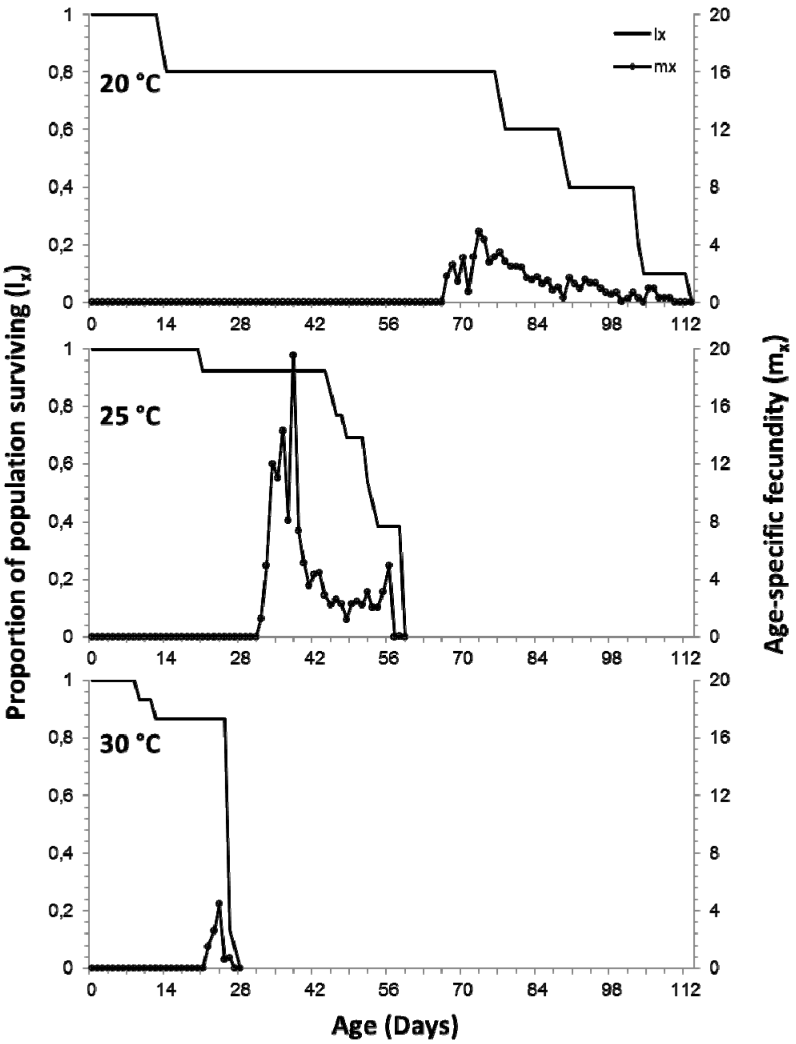

Figure.1. Age-specific survival rate (l_x), and age-specific fecundity (m_x) of *Sympherobius pygmaeus* reared on *Planococcus citri* at three constant temperatures.

Table 5. Immature stage development threshold and total of effective temperatures of *Sympherobius pygmaeus*

Periods	Development threshold (°C)	Total of effective temperature (day-degree)
Egg	14.14	57.47
Larva	13.30	138.88
Pupa	12.57	169.49
Total development	13.11	370.37

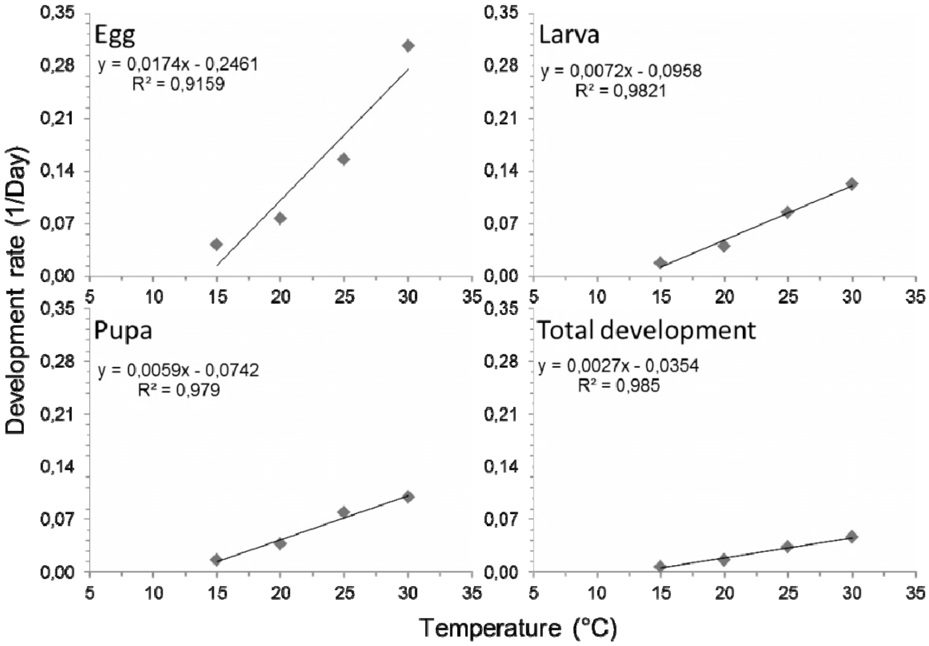

Figure 2. Egg, larva, pupa, and total development rate (r) of *Sympherobius pygmaeus* at four constant temperatures.

Adult body size and weight

There were statistical differences between *S. pygmaeus* male and female individual body sizes at 20, 25 and 30 °C (Tables 6 and 7). The largest and the longest male and female individuals were obtained at 20 and 25 °C. Body sizes of males and females were not greatly affected by temperature, In addition, females were bigger than males at all temperatures.

Table 6. Body weight, length, thorax width, wing and hind tibia sizes of males of *Sympherobius pygmaeus* reared on *Planococcus citri* at four constant temperatures (mean ± SE*)

Temperature °C	n	Weight (mg)	Body Length (mm)	Thorax Width (mm)	Wing Length (mm)	Hind Tibia (mm)
15	*2*	0.10±0.000 a	5.1±0.01 ab	1.6±0.083 ab	5.7± .524 b	1.39±0.083 a
20	*17*	0.33±0.035 a	5.2±0.12 a	1.7±0.021 ac	7.5±0.070 a	1.74±0.062 a
25	*16*	0.43±0.051 a	5.1±0.15 ab	1.8±0.020 b	7.2±0.068 ac	1.84±0.063 a
30	*13*	0.30±0.052 a	4.7±0.17 b	1.6±0.015 c	6.6±0.067 bc	1.62±0.090 a
35		No individuals were obtained				

* Within the same column, means followed by the same letter are not significantly different according to the LSD test (P= 0.05)

Statistical differences were determined for the wing length of males (F=8.117; P=0.0001). However, there were no difference in terms of body length (F= 1.644; P=0.191), body weight (F=2.678; P=0.057), thorax width (F=1.813; P=0.156) and hind tibia length (F=2.190; P=0.10) (Table 4). On the other hand, *S. pygmaeus* females showed a statistical difference in terms of body length (F=3.837; P=0.033) and hind tibia length (F=5.812; P=0.007) at different temperatures. There was no statistical difference determined for weight (F=1.785; P=0.185), thorax width (F= 1.515; P=0.236) and wing length (F= 5.376; P=0.010) of females. Wing length and hind tibia length of females were longer than in males at all temperatures.

Table 7. Body weight, length , thorax width, wing and hind tibia sizes of females of *Sympherobius pygmaeus* reared on *Planococcus citri* at four constant temperatures (mean ± SE*)

Temperature °C	n	Weight (mg)	Body Length (mm)	Thorax Width (mm)	Wing Length (mm)	Hind Tibia (mm)
15				No individual was obtained		
20	8	0.46±0.060 a	5.2±0.259 a	1.9±0.06 a	8.2±0.19 a	1.7±0.012 a
25	12	0.47±0.052 a	5.1±0.131 a	1.9±0.05 a	8.0±0.26 a	2.0±0.007 b
30	13	0.34±0.061 a	4.6±0.099 b	1.8±0.04 a	7.2±0.20 b	1.6±0.008 a
35				No individuals were obtained		

* Within the same column, means followed by the same letter are not significantly different according to the LSD test (P= 0.05)

Both genders have longer tibia at 25 °C than at 20 °C and 30 °C. The females had larger hind tibia and higher intrinsic rate of increase when life table parameters and female size were combined. Moreover, females, which had a small hind tibia size at 20 and 30 °C, had the lowest per capita growth rate at the same temperature (Tables 4 and 7).

Discussion

The life table is a way of keeping track of the age specific mortality and reproductive rates, and estimating r and other parameters. The intrinsic rate of increase, mean generation time and population doubling times are useful indices of population growth under a set of growing conditions. Southwood (1978) reported that a short developmental time and high levels of reproduction on a prey reflect suitability of the foods tested. Controlled laboratory studies provide insights into the development and population dynamics of insects such as *S. pygmaeus*, although insects are not subjected to a constant temperature in nature.

Very little information is available in the literature on developmental time, fecundity and individual size of *Sympherobius spp*., and *S. pygmaeus* in particular. This study clearly demonstrates the effects of temperature on developmental time, mortality rate, longevity, fecundity and size of *S. pygmaeus*. Similar results were reported by other researchers. For instance, Bodenheimer (1951) reported *S. sanctus* average development time as 121 days at 14.4 °C, 49 days at 19.5 °C and 26 days at 24.8 °C, both in its natural environment and laboratory conditions. Our findings parallel the results of Bodenheimer (1951). Sato & Takada (2004) evaluated the potential of *Micromus numerosus* Navas, *Micromus angulatus* (Stephens), and *Micromus linearis* (Hagen) (Neuroptera: Hemerobiidae) as biological control agents against pest aphids at five constant temperatures under laboratory conditions. The development times were 49.4, 26.9, 19.2, and 15.7 days for *M. numerosus;* 57.7, 26.2, 16.3, and 14.0 for *M. angulatus;* and 83.7, 57.5, 27.8, 20.8 for *M. linearis,* at 15, 20, 25 and 30 °C, respectively. Besides this, Honék & Kocaurek (1998) reported that the adaptive strategies of aphidophagous species include adjustment of developmental time and sensitivity to temperature to decrease the demands of timing the life cycles and adaptation to habitat conditions. Different environments and prey may affect the development of the species. Thus, the developmental time of *Micromus* species are quite different to our results.

In our study, the highest mortality rate was at 15 °C, while the lowest rate was at 25 °C in immature periods. In a similar way, Bodenheimer (1951) also reported that egg mortality rates increased in parallel with decreasing temperatures and there wasn't any egg hatching below 10 °C in *S. santus*. In our study, when all development periods were analyzed, *S. pygmaeus* development threshold was determined to be 13.1 °C. At the same time, the thermal constant necessary for a predator to complete its development, was 370.37 days-degrees (Table 7). Bodenheimer (1951) calculated the development threshold from egg to adult and Th.C for *S. sanctus* as 10.5 °C and 350 day- degrees, respectively. In the present study, two parameters for *S. pygmaeus* were a little higher than for *S. sanctus*. Lower thermal thresholds and thermal constants for total development of brown lacewings were estimated at 7.7 °C and 343 degree-days (DD), respectively, for *M. numerosus*, 9.0 °C and 297 DD for *M. angulatus*, and 5.2 °C and 447 DD for *M. linearis* (Sato & Takada 2004). Although these values are quite different from the values for *S. pygmaeus*, species within the genus *Micromus* also have different values. In addition to this, Neuenschwander (1975) considered that the extremely low thermal threshold might be a characteristic of Hemerobiidae. Our result clearly indicated that this is not true for *S. pygmaeus*.

Temperature affected female body sizes more than males. Moreover, males are smaller than females at all temperatures. Metabolism of the female is quite different and more complex than the male due to its reproductive capacity. Besides that, female individuals at 20 and 30 °C were smaller than females at 25 °C. Chambers (1979) revealed that although insects reared at high temperatures are small, they have a higher growth rate than those reared at low temperatures. Dixon et al. (1982) stated that size is a consequence of the relative effect of temperature on the growth and development rate. Similar results were detected by other researchers in different studies. For instance, in his study at 15 and 35 °C temperatures on the live weight and development of *Coccinella septempunctata* L., *Propylaea japonica* (Thunberg) and *S. hoffmanni* Weise (Coleoptera: Coccinellidae), ‚Kawauchi (1986) detected that male and female weight decreased with increasing temperatures. In experiments at different temperatures with *Hipodomia convergens* Guérin-Méneville and *C. septempunctata* (Coleoptera: Coccinellidae) on *Myzus persicae* Sulzer (Hemiptera: Aphididae), Katsarou et al. (2004) obtained the heaviest and longest adult individuals at 17 and 20 °C. *Coccinella septempunctata* adult weight wasn't affected by temperature. In their experiments with *S. levallianti* (Mulsant), Uygun & Atlıhan (2000) reported that male and female size decreased with increasing temperature.

In the present study, the best temperature for optimum development at egg hatching, larva development, pupa period and longevity was at 25 °C. *Sympherobius. pygmaeus* can complete its development in winter in the Mediterranean Region since the lowest mean temperatures for December, January and February are 14.3, 12.8 and 15.2 °C, respectively (Anonymous, 2010b). The biological parameters of *S. pygmaeus,* such as development time, mortality rate, and reproductive potential, were determined on mealybugs on potato plant under laboratory conditions at different temperatures. *Sympherobius pygmaeus* was found to be a potential biological control agent of *P. citri.* However, detailed experiments need to be done under laboratory conditions and in citrus orchards, in order to determine if *S. pygmaeus* has a legitimate role in biological control.

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