

Effect of Temperature and Photoperiod on Development and Fecundity of an Acarophagous Ladybird Beetle, *Stethorus gilvifrons*

Tulin Aksit,^{*,1} Ibrahim Cakmak¹ and Gamze Ozer¹

The development, fecundity and survival of *Stethorus gilvifrons* Mulsant (Coleoptera: Coccinellidae) fed on *Tetranychus cinnabarinus* Boisduval (Acari: Tetranychidae) were recorded at three constant temperatures (20, 25 and 30±1°C) and 50±10% relative humidity, under two photoperiods (16:8 L:D and 8:16 L:D) produced using artificial light (4000 lux). The development rate for the egg stage ($r_{[Te]}$) increased linearly with increasing temperature ($r_{[Te]} = 0.0132 * T - 0.0955$; $R^2=0.95$). The theoretical egg-development threshold was estimated to be 7.24°C; 75.75 degree-days (DD) were required for hatching. The total development time ($r_{[Tt]}$) also decreased linearly with increasing temperature ($r_{[Tt]} = 0.0039 * T - 0.0325$; $R^2=0.98$). The development threshold was estimated to be 8.33°C and full development from egg to adult required 256.41 DD. Higher temperatures resulted in a shorter generation time (T_0) and decreased net reproductive rate (R_0). The length of the preoviposition and postoviposition period, as well as longevity, decreased significantly with increasing temperature under both photoperiods. The oviposition and postoviposition periods, longevity, and total fecundity were not significantly affected by photoperiod. The values of both the intrinsic rate of increase (r_m) and R_0 were highest under the long-day photoperiod at 25°C. The mortality rate was lowest at 20°C under the short-day photoperiod. Of the conditions tested, the optimum temperature for rearing *S. gilvifrons* was 25°C and the optimum photoperiod was 16:8 L:D.

KEY WORDS: *Tetranychus cinnabarinus*; *Stethorus gilvifrons*; Coccinellidae; life-history parameters; temperature; photoperiod; development; fecundity.

INTRODUCTION

The carmine spider mite, *Tetranychus cinnabarinus*, is widely distributed across the world and attacks more than 100 types of host plant, including crops such as cotton, strawberry, deciduous fruits, vegetables and ornamental plants (16). It is one of the most serious pests on fig, strawberry, cotton and vegetables (cucumber, tomatoes, eggplant, bean and pepper) in Turkey (2,5,6), crops that are very important for the economy of the Aydin region. *T. cinnabarinus* causes considerable economic losses due to reductions in both yield and quality of produce in this area (2,5,6).

Earlier studies have indicated that natural enemies are very effective in integrated pest management efforts targeting tetranychid mites and in other biocontrol programs (14). The ladybird beetles belonging to the genus *Stethorus*, including *S. gilvifrons*, are predators of tetranychid mites (7). *S. gilvifrons* is found in the Middle East and in southern

Received Oct. 15, 2006; accepted Feb. 15, 2007; <http://www.phytoparasitica.org> posting Aug. 5, 2007.

¹Dept. of Plant Protection, Faculty of Agriculture, University of Adnan Menderes, 09100 Aydin, Turkey.

*Corresponding author [Fax: +90-256-772-72-33; e-mail: tulinaksit@yahoo.com].

Europe (10,17,32) and is a natural enemy of *Panonychus ulmi*, *Tetranychus urticae*, *T. cinnabarinus*, *T. turkestanii* and *T. viennensis* on cotton, citrus, strawberry, apple, fig and vegetables in Turkey (25,32).

Although some studies have been conducted on the biology of *S. gilvifrons* on *P. ulmi* (11), *Tetranychus atlanticus* (12), *T. turkestanii* (1) and *Oligonychus coffeae* (29), only one study on *T. cinnabarinus* was found (30). The degree of *S. gilvifrons*' adaptation to these prey, and its efficiency in controlling mite populations, varies with the strain of species and environmental conditions, such as host plant type, ambient temperature, relative humidity, photoperiod, etc. (7). Temperature is also a critical abiotic factor influencing the population dynamics of mites (as well as the population dynamics of their natural enemies) (16). Furthermore, photoperiod has been reported to affect the development of insects (15). The duration, intensity and wavelengths of light have also been noted to have a strong influence on the predatory abilities of certain insects (23).

There is, however, little information on the life history of *S. gilvifrons*. The present study was therefore designed to evaluate its development rate and fecundity at different temperatures and photoperiods under laboratory conditions.

MATERIALS AND METHODS

Insect and mite rearing *Tetranychus cinnabarinus* was obtained from strawberry fields in Aydin and reared on bean plants (*Phaseolus vulgaris* cv. 'Barbunia') at $25 \pm 2^\circ\text{C}$ and $65 \pm 10\%$ r.h. under a 16-h light regime. The bean plants had previously been grown in a climate room (under the same conditions) up to the age of 2 weeks.

Stethorus gilvifrons obtained from eggplant were reared on detached bean leaves infested with *T. cinnabarinus* in plastic boxes (height 10 cm, top diameter 8.5 cm, and basal diameter 7 cm). Boxes incorporated insect-proof gauze for ventilation and were placed in a cabinet under controlled conditions ($25 \pm 1^\circ\text{C}$, $65 \pm 10\%$ r.h. and 16 h light per day).

Effects of temperature and photoperiod on development The development time and mortality of immature stages of *S. gilvifrons* at different temperatures (20, 25 and 30°C) and under two photoperiods (long-day, 16:8 L:D; and short-day, 8:16 L:D) were studied by transferring newly laid eggs, taken randomly from the stock culture, to Munger cells (4.5 × 6 cm) (26). The time to hatching and mortality of the eggs was determined through daily observations at all temperatures tested. The hatched larvae were confined individually in Munger cells. Prey was provided daily by brushing off bean leaves infested with different development stages of *T. cinnabarinus*. Prey corpses were removed from each cell daily. Daily observations allowed development time and mortality in the different development stages to be recorded for 44–49 individual *S. gilvifrons* per temperature and photoperiod treatment.

Effects of temperature and photoperiod on longevity and fecundity One newly emerged *S. gilvifrons* female and one male from the above experiment were subsequently placed in plastic boxes and each mating pair was transferred to one cell containing a mixture of prey at different growth stages. The number of eggs laid and mortality were recorded daily until all adults died. The sex ratio was determined after examining the genitalia of adults. The experiments were conducted at three constant temperatures (20, 25 and 30°C) and $50 \pm 10\%$ r.h., under two photoperiods (16:8 L:D and 8:16 L:D) provided by artificial light (4000 lux) in controlled cabinets.

Statistical analyses Data on development time, longevity and fecundity were analyzed using two-way ANOVA including the effects of temperature and photoperiod, and the temperature–photoperiod interaction. The thermal threshold for egg development and for egg-to-adult development time was computed by employing a linear technique that uses growth rate (day^{-1}) as the dependent variable and temperature as the independent variable. The lower development threshold temperature was determined as the x-intercept of the linear equation and (degree-day) DD requirements were determined as the inverse of the slope of the linear equation. Differences in sex ratio were analyzed using the chi-square test; $P=0.05$ was taken to be the level of significance. Population growth rates at different temperatures and photoperiods were calculated by constructing life tables using the following equation (4):

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

This incorporated age-specific survival rates (l_x) and number of female offspring (m_x) for each age interval (x) day. Net reproductive rate ($R_0 = \text{female offspring/female/generation}$), intrinsic rate of natural increase ($r_m = \text{female offspring/female/day}$), and mean generation time ($T_0 = \ln(R_0/r)$, in days) were calculated (19). Differences in r_m values were tested for significance by estimating the variance using the jack-knife method, which facilitated calculation of the standard errors of r_m estimates. The jack-knife pseudo-value r_j was calculated for n samples using the following equation (18):

$$r_j = n * r_{a11} - (n - 1) * r_i$$

The mean values of $(n - 1)$ jack-knife pseudo-values for mean growth rate in each treatment were subjected to analysis of variance followed by Duncan's multiple range test ($P \leq 0.01$). All analyses were conducted using SPSS statistical software (31).

RESULTS

Effects of temperature and photoperiod on development The egg incubation period of *S. gilvifrons* decreased significantly with increasing temperature, ranging from 6.22 ± 0.15 days at 20°C to 3.41 ± 0.07 days at 30°C under the long-day photoperiod (Table 1). A linear regression analysis was applied to egg development times within the $20\text{--}30^\circ\text{C}$ temperature range. Development rates for the egg stage ($r_{[Te]}$) increased linearly with increasing temperature ($r_{[Te]} = 0.0132 * T - 0.0955$; $R^2 = 0.95$) (Fig. 1). The theoretical development threshold for the egg stage was 7.24°C , and 75.75 DD were required for hatching. The post-embryonic development time (the four larval stages, and the prepupal plus pupal stage) was shortest at 30°C , and significantly longer at 20°C (Table 1). The total development time (egg to adult) ($r_{[Tt]}$) also decreased linearly with increasing temperature ($r_{[Tt]} = 0.0039 * T - 0.0325$; $R^2 = 0.98$) (Fig. 1). The development threshold obtained from regression analysis was estimated to be 8.33°C . On average, across all treatments, *S. gilvifrons* required 256.41 DD to complete its development from egg to adult. Overall, the duration of egg, first instar, and prepupal plus pupal stages, and total development time, differed significantly between short- and long-day photoperiods ($P < 0.01$). The development time of egg, first instar, prepupal and pupal stages, and total development time differed significantly between short- and long-day lengths at 20°C ($P < 0.01$), but the durations of different life-stages did not differ significantly between short- and long-day lengths at 25 and 30°C , except for the first instar at 25°C .

TABLE 1. Mean (\pm S.E.) duration of egg and immature stages of *Stethorus gilvifrons* feeding on *Tetranychus cinnabarinus* at different temperatures (20, 25, 30°C) and photoperiods (short-day, 8:16 L:D; long-day, 16:8 L:D)

	Photoperiod	Temperature (°C)			F ratio [$P < 0.0001$]
		20	25	30	
n^z	Short-day	57	58	46	
	Long-day	44	44	49	
Egg	Short-day	5.25 \pm 0.10 a ^y	4.20 \pm 0.08 b	3.23 \pm 0.07 c	112.57
	Long-day	6.22 \pm 0.15 a ^y	3.95 \pm 0.09 b	3.41 \pm 0.07 c	179.99
1st instar	Short-day	3.07 \pm 0.08 a ^y	1.93 \pm 0.06 b ^y	1.78 \pm 0.10 b	69.64
	Long-day	3.39 \pm 0.10 a ^y	2.52 \pm 0.08 b ^y	1.96 \pm 0.04 c	77.16
2nd instar	Short-day	1.68 \pm 0.07 a	1.13 \pm 0.04 b	1.09 \pm 0.04 b	32.94
	Long-day	1.82 \pm 0.08 a	1.29 \pm 0.06 b	1.06 \pm 0.03 c	37.55
3rd instar	Short-day	2.19 \pm 0.08 a	1.58 \pm 0.06 b	1.12 \pm 0.04 c	54.43
	Long-day	1.98 \pm 0.05 a	1.34 \pm 0.07 b	1.10 \pm 0.04 c	63.51
4th instar	Short-day	2.58 \pm 0.09 a	1.87 \pm 0.06 b	1.78 \pm 0.04 b	32.84
	Long-day	2.57 \pm 0.08 a	1.59 \pm 0.07 b	1.42 \pm 0.07 b	62.13
Prepupa + Pupa	Short-day	5.82 \pm 0.05 a ^y	4.02 \pm 0.07 b	3.02 \pm 0.02 c	750.82
	Long-day	6.68 \pm 0.09 a ^y	3.95 \pm 0.08 b	3.06 \pm 0.07 c	487.11
Total development time	Short-day	20.59 \pm 0.15 a ^y	14.77 \pm 0.14 b	12.05 \pm 0.15 c	810.00
	Long-day	22.65 \pm 0.19 a ^y	14.62 \pm 0.15 b	12.01 \pm 0.10 c	1259.06

^zNumber of replicates. Within rows, means followed by the same lower-case letter do not differ statistically (LSD test).

^yWithin columns, for both photoperiods, means differ significantly (t test; $P < 0.01$).

Overall mortality (egg to adult) at 20, 25 and 30°C was lower under the short-day photoperiod (28.10%, 12.34% and 39.55%, respectively) than under the long-day photoperiod (43.10%, 56.07% and 65.91%, respectively). Similarly, mortality in the egg stage at 20, 25 and 30°C was lower under the short-day photoperiod (15.60%, 5.16% and 10.72%, respectively) than under the long-day photoperiod (20.00%, 11.74% and 21.43%, respectively). Most mortality occurred in the first instar at all temperatures and under all photoperiods tested (12.50%, 4.91% and 20.63% under the short-day photoperiod, and 21.35%, 27.95% and 28.35% under the long-day photoperiod at 20, 25 and 30°C, respectively).

Effects of temperature and photoperiod on longevity and fecundity The durations of preoviposition, oviposition and postoviposition periods, as well as longevity, decreased significantly with increasing temperature under both photoperiods. Total fecundity was not significantly different at the temperatures tested under the short-day photoperiod, but it did differ significantly with temperature under the long-day photoperiod. Daily fecundity was significantly affected by temperature under the short-day photoperiod. The preoviposition period of *S. gilvifrons* was significantly longer and its longevity significantly greater at 20°C than at the higher temperatures (Table 2). Both the preoviposition period and daily fecundity differed significantly between short- and long-day photoperiods at 20°C ($P < 0.01$). However, photoperiod had no significant effect on preoviposition, oviposition and postoviposition periods, or on longevity, or on daily and total fecundity at 25 and 30°C (Table 2).

The offspring sex ratio of *S. gilvifrons* in all treatments was not significantly different from 1:1 (0.50:0.50, 0.48:0.52 and 0.54:0.46 under the short-day photoperiod, and 0.56:0.44, 0.65:0.35 and 0.46:0.54 under the long-day photoperiod, at 20, 25 and 30°C,

TABLE 2. Longevity and fecundity of *Stethorus gilvifrons* feeding on *Tetranychus cinnabarinus* at different temperatures (20, 25, 30°C) and photoperiods (short-day, 8:16 L:D; long-day, 16:8 L:D) (data are means \pm S.E.)

	Photoperiod	Temperature (°C)			F ratio
		20	25	30	
n ^z	Short-day	9	12	10	
	Long-day	14	10	10	
Preoviposition	Short-day	12.77 \pm 2.20 a ^y	5.16 \pm 0.58 b	2.00 \pm 0.31 b	17.32 <i>P</i> <0.0001
	Long-day	5.85 \pm 0.90 a ^y	2.20 \pm 0.32 b	1.03 \pm 0.15 b	13.56 <i>P</i> <0.0001
Oviposition	Short-day	23.77 \pm 4.35 a	12.25 \pm 1.47 b	9.00 \pm 1.60 b	7.60 <i>P</i> <0.01
	Long-day	19.64 \pm 3.26 a	25.90 \pm 4.45 a	8.20 \pm 1.14 b	5.59 <i>P</i> <0.01
Postoviposition	Short-day	4.11 \pm 1.18 a	3.00 \pm 1.07 a	1.87 \pm 0.39 a	1.03 <i>P</i> >0.05
	Long-day	8.28 \pm 2.11 a	2.80 \pm 0.91 b	2.00 \pm 0.75 b	4.51 <i>P</i> <0.05
Longevity ♀	Short-day	35.23 \pm 5.01 a	26.35 \pm 3.08 a	10.20 \pm 1.63 b	15.061 <i>P</i> <0.0001
	Long-day	28.22 \pm 3.29 a	19.86 \pm 3.52 b	8.29 \pm 1.17 c	18.194 <i>P</i> <0.0001
Total	Short-day	30.55 \pm 7.49 a	52.83 \pm 7.77 a	39.87 \pm 18.91 a	1.93 <i>P</i> >0.05
	Long-day	68.71 \pm 11.44 a	94.30 \pm 13.97 a	28.60 \pm 4.46 b	6.76 <i>P</i> <0.01
Per day	Short-day	1.31 \pm 0.22 b ^y	4.03 \pm 0.37 a	4.68 \pm 0.60 a	14.98 <i>P</i> <0.0001
	Long-day	4.01 \pm 0.78 a ^y	3.53 \pm 0.55 a	3.51 \pm 0.34 a	0.21 <i>P</i> >0.05

^zNumber of replicates.

Within rows, means followed by the same lower-case letter do not differ statistically (LSD test).

^yWithin columns, for both photoperiods, means differ significantly (*t* test; *P*<0.01).

TABLE 3. Net reproductive rate (R_0), intrinsic rate of increase (r_m), generation time (T_0) and sex ratio of *Stethorus gilvifrons* feeding on *Tetranychus cinnabarinus* at different temperatures (20, 25, 30°C) and photoperiods (short-day, 8:16 L:D; long-day, 16:8 L:D)

Photoperiod	Temperature (°C)	Net reproductive rate (R_0) (♀♀)	Intrinsic rate of increase (r_m) ^z (♀♀/day)	Generation time (T_0) (days)	Sex ratio (♀♀:♂♂) ^y
Short-day	20	15.27	0.0595 c	45.79	0.50
	25	25.08	0.1276 b	25.25	0.48
	30	22.88	0.1762 a	17.76	0.54
	F ratio		22.753 <i>P</i> <0.0001		
Long-day	20	41.44	0.1060 b	35.14	0.56
	25	59.36	0.1593 a	25.63	0.65
	30	13.38	0.1520 a	17.06	0.46
	F ratio		23.422 <i>P</i> <0.0001		

^zWithin the column and photoperiod, means followed by the same letter do not differ statistically (LSD test).

^yWithin the column and photoperiod, means do not differ statistically (chi-square test).

respectively; chi-square, *P*>0.05) (Table 3). Males lived longer than females at 20°C. However, at 25 and 30°C, under both photoperiods, the longevity of males was similar to that of females. The longest mean generation time (T_0) occurred at 20°C and the shortest at 30°C under both photoperiods (Fig. 2). The net reproductive rate (R_0) was highest at 25°C under both photoperiods. The highest intrinsic rate of increase (r_m) for *S. gilvifrons* was

found at 25 and 30°C and the lowest at 20°C under both photoperiods ($P < 0.001$) (Table 3). Survival rates of adults decreased mainly at the end of the oviposition period at all temperatures (Fig. 2).

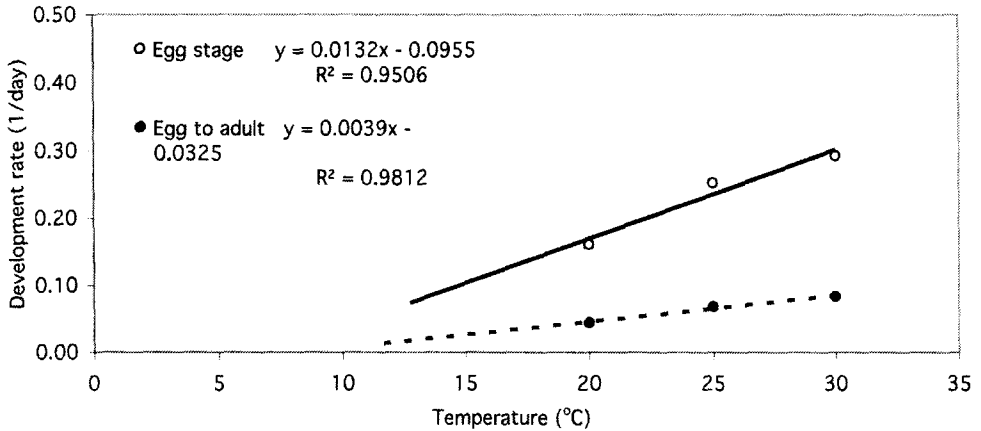


Fig. 1. Development rate of eggs ($r_{[T_e]}$) and total development rate (egg to adult) ($r_{[T_t]}$) of *Stethorus gilvifrons*. Lines represent linear regressions of development rates on temperature within the range of 20–30°C under a long-day photoperiod.

DISCUSSION

Effects of temperature and photoperiod on development This study showed that temperature had a strong influence on the growth and development of *S. gilvifrons*. The development periods of egg and larval stages, as well as total development time, decreased significantly with an increase in temperature (Table 1) ($P < 0.0001$). These results are in agreement with the findings of Atlihan and Ozgokce (3), Mori *et al.* (22) and Omkar and Pathak (24) for other ladybird beetles. A combination of high temperatures and long-day conditions may lead to a high metabolic rate, possibly resulting in high fecundity and a higher reproductive rate (20). However, both low and high temperature extremes have been reported to adversely affect gonadal maturation (21). In our study, the development time for the egg, first-instar, and prepupal + pupal stages, and total development time, differed significantly between long and short day lengths at 20°C ($P < 0.01$). However, the total development period was not significantly different under long and short day lengths at 25 and 30°C, except for the first instar at 25°C. These results are in agreement with findings of De Wilde (9) that sensitivity to photoperiod never extends to all life stages and that the photoperiod-sensitive stages differ mainly among species. Hence, Ishida *et al.* (15) reported that there was no significant difference between short and long photoperiods in terms of the development periods of *Frankliniella occidentalis* (Thysanoptera: Thripidae) at 15 and 20°C. By contrast, all life stages of the aphidophagous ladybird *Coelophora saucia* Mulsant (Coleoptera: Coccinellidae) were sensitive to photoperiod (24). However, the development of the larval and pupal stages of *Chrysoperla externa* (Neuroptera: Chrysopidae) was reported to be faster under long-photoperiod conditions than under short-photoperiod conditions (20).

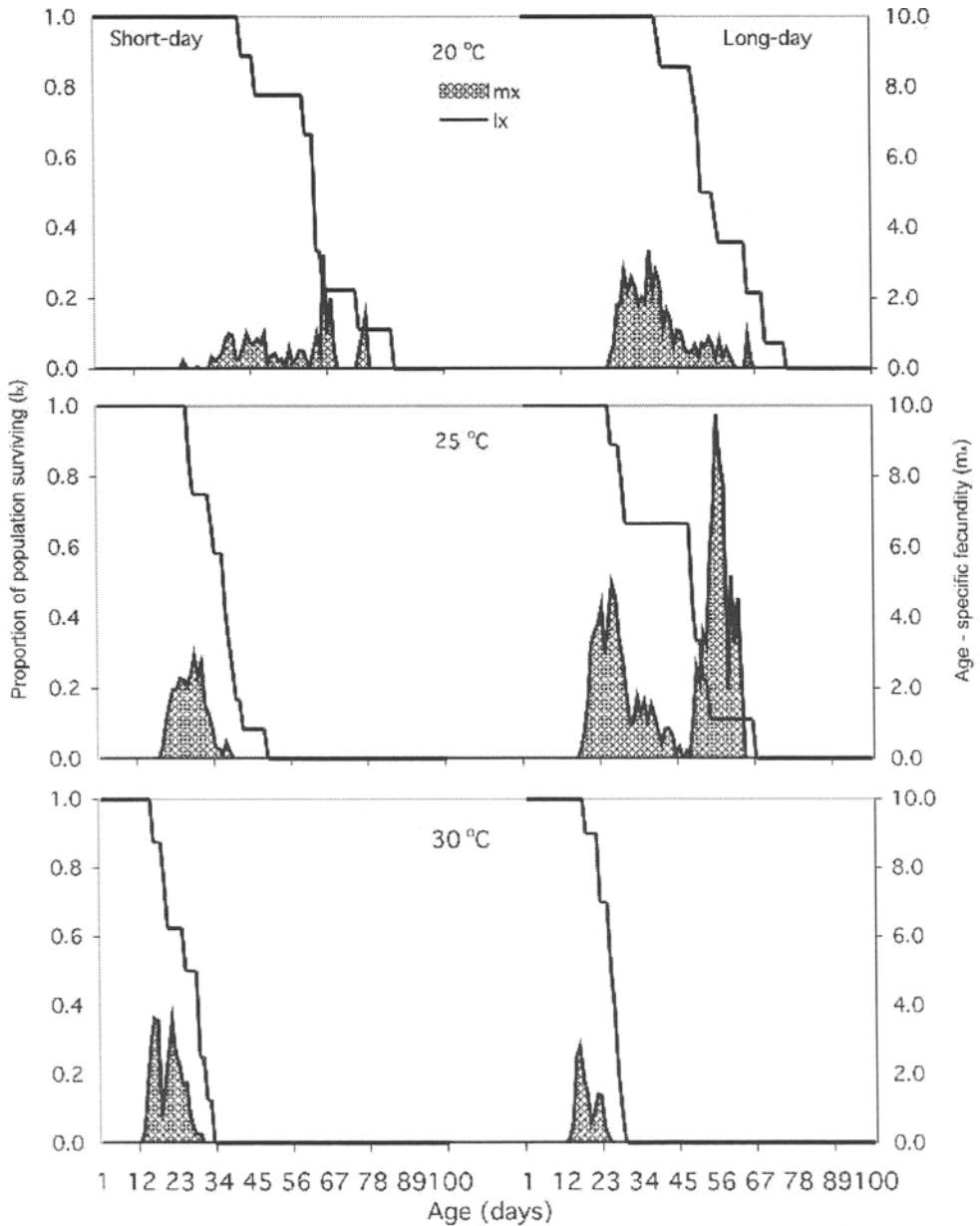


Fig. 2. Survivorship curve (l_x) and age-specific fecundity rate (m_x) of *Stethorus gilvifrons* at different temperatures and photoperiods.

Effects of temperature and photoperiod on longevity and fecundity The preoviposition period decreased significantly with increasing temperature. Similar results for *Chilocorus nigrinus* Fabricius and *Stethorus punctillum* Weise (Coleoptera: Coccinellidae) have also been reported (21,28). In our study, the preoviposition period was shorter under

a long photoperiod than under a short photoperiod. Such a result was similar to that reported for *Coelophora saucia* (24). We found that the oviposition period was affected significantly by temperature and not by photoperiod. By contrast, the oviposition periods of *F. occidentalis* and *C. saucia* have been reported to be longer under a short photoperiod than a long photoperiod at 15 and 20°C (15,24).

Temperature affected the longevity of insects in both photoperiods in our study. In addition, the longevity of females decreased with increasing temperature. These findings are in agreement with results obtained for some other coccinellids (3,22,33). We found no effect of photoperiod on longevity.

Total fecundity did not differ statistically in response to temperature under the short-day photoperiod, but was significantly different at the various temperatures tested under the long-day photoperiod. Gilles *et al.* (13) reported a decrease in fecundity with an increase in temperature, because of a shortening of the oviposition period. Our results agree with those authors' findings. By contrast, some researchers have reported an increase in fecundity with an increase in temperature for some insects (1,22,27,33). In another study, Ishida *et al.* (15) recorded no difference in the total number of eggs laid by *F. occidentalis* under different photoperiods at 15°C.

Daily fecundity differed at different temperatures under the short-day photoperiod. We also found that daily fecundity was affected only by photoperiod at 20°C. Two studies have shown that daily fecundity was not affected by different photoperiods (15,27). However, a negative correlation between daily fecundity and photoperiod has also been reported (24). In our study, the intrinsic rate of increase (r_m) was lowest (under both short and long photoperiods) at 20°C. The r_m value we obtained for *S. gilvifrons* was almost the same as, or slightly higher than, those reported for other *Stethorus* species (7,30).

The generation time (T_0) decreased with increasing temperature because the period between hatching and first oviposition was shorter at higher temperatures. The longest mean generation time occurred at 20°C and the shortest at 30°C, under both photoperiods. Low temperatures led to a longer development period for the insects. Miaoqing *et al.* (21) and Yigit and Uygun (33) likewise reported that development time of *S. punctillum* decreased with increasing temperature. Similar results have been published for other coccinellids (22,27).

The highest net reproductive rate (R_0) was recorded at 25°C under both photoperiods. It was lower at 30°C than at 20 and 25°C under the long photoperiod (Table 3). In our study, net reproductive rate was higher under long-day photoperiod than under short-day photoperiod. These findings are consistent with results obtained for *Coelophora saucia* (24).

We also found that the sex ratio was not significantly affected by temperature and photoperiod. This result is in agreement with the findings of Yiğit and Uygun (33).

Effects of temperature and photoperiod on survival Both temperature and photoperiod affected the survival of *S. gilvifrons*. The mortality rate was highest in the egg and first-instar stages. The lowest mortality rates for these stages were observed at 25°C under both photoperiods. The 50% survival periods for adult females were approximately 60, 40 and 30 days under the short photoperiod, and approximately 56, 45 and 25 days under the long photoperiod, at 20, 25 and 30°C, respectively. The mortality rates in the egg and larval stages in *S. gilvifrons* were lower under the short photoperiod than the long photoperiod at different temperatures. Ishida *et al.* (15) also reported that

the mortality rate of *F. occidentalis* decreased under a short photoperiod; our results are therefore consistent with their findings. The present study showed that an increase in the temperature and illumination period increased the mortality rate. By contrast, the nymph mortality rate of *Dichelops melacanthus* (Dallas) (Heteroptera: Pentatomidae) was lower under a long-day photoperiod in another study (8). Moreover, a decrease in temperature and photoperiod was reported to increase the mortality of *Gastroidea viridula* De Geer (Coleoptera: Chrysomelidae) (27).

Different photoperiods and temperatures affected different life stages of *S. gilvifrons*. Development time decreased with an increase in temperature. The effect of photoperiod was especially apparent at the lowest temperature studied (20°C). The length of the pre-oviposition and postoviposition periods, as well as longevity, decreased significantly with an increase in temperature under both photoperiods. The oviposition and postoviposition period, longevity and total fecundity were not affected by photoperiod. The values of intrinsic rate of increase (r_m) and net reproductive rate (R_0) were highest under the long photoperiod at 25°C. Of the conditions tested, the optimum temperature for rearing *S. gilvifrons* was 25°C and the optimum photoperiod 16:8 L:D. These results are important, as they will help to improve the rearing of ladybird beetles under laboratory conditions.

ACKNOWLEDGMENTS

The authors would like to thank the anonymous referees for their critical reviews and suggestions.

REFERENCES

1. Ahmed, Z. and Ahmed, R.F. (1989) Biological studies of predator *Stethorus gilvifrons* Mulsant (Coccinellidae: Coleoptera) on the strawberry mite *Tetranychus turkestanii* Ugarov and Nikolski (Acariformes, Tetranychus, Tetranychidae). *J. Biol. Sci. Res.* 20:22-33.
2. Aksit, T., Ozsemerci, F. and Cakmak, I. (2003) Studies on determination of harmful fauna in the fig orchards in Aydin province (Turkey). *Turk. Entomol. Derg.* 27:181-189 (Turkish, with English summary).
3. Atlihan, R. and Ozgokce, S. (2002) Development, fecundity and prey consumption of *Exochomus nigromaculatus* feeding on *Hyelopterus pruni*. *Phytoparasitica* 30:443-450.
4. Birch, L.C. (1948) The intrinsic rate of natural increase of an insect population. *J. Anim. Ecol.* 17:15-26.
5. Cakmak, I. and Baspinar, H. (1998) Studies on insect pests and mites and their natural enemies on summer vegetables in Aydin province. *Aegean Region 1st Agricultural Congr.* (Aydin, Turkey), pp. 427-435 (Turkish, with English summary).
6. Cakmak, I., Baspinar, H. and Madanlar, N. (2003) The population densities of spider mites and their natural enemies on protected strawberries in Aydin province. *Turk. Entomol. Derg.* 27:91-205 (Turkish, with English summary).
7. Chazeau, J. (1985) Predaceous Insects. in: Helle, W. and Sabelis, M.W. [Eds.] Spider Mites. Their Biology, Natural Enemies and Control. Vol. 1B. Elsevier, Amsterdam, the Netherlands. pp. 211-246.
8. Chocorosqui, V.R. and Panizzi, A.R. (2003) Photoperiod influence on the biology and phenological characteristics of *Dichelops melacanthus* (Dallas) (Heteroptera: Pentatomidae). *Braz. J. Biol.* 63:43-49.
9. De Wilde, J. (1962) Photoperiodism in insects and mites. *Annu. Rev. Entomol.* 7:1-20.
10. El-Adawy, A.M., Abdel-Gawad, N.M. and El-Sharkawy, T.A. (2001) Castor bean, *Ricinus communis*, a promising source of mite's predators. *Egypt. J. Agric. Res.* 79:149-160.
11. Fathipour, Y., Taghizadeh, R. and Kamali, K. (2006) Temperature-dependent fecundity of *Stethorus gilvifrons* (Col.: Coccinellidae) preying upon *Tetranychus urticae* (Tetranychidae). *Abstr. XIIIth International Congr. of Acarology* (Amsterdam, the Netherlands), p. 56.
12. Georgis, R., Wahab, W.A. and El-Haidari, H.S. (1976) Observations on biology of *Stethorus gilvifrons* Muls., a predator of *Tetranychus atlanticus* McG. Yearbook of Protection Research, Iraq Ministry of Agriculture and Agrarian Reform (1974/1976, recd. 1978) 1, 47-50. (*Rev. Appl. Entomol.* 66(10):Abstr. 4897).
13. Gilles, J., David, J.F. and Duvallet, G. (2005) Effects of temperature on the rate of increase of *Stomoxys calcitrans* and *Stomoxys niger* (Dipt.: Muscidae) from La Reunion Island. *J. Med. Entomol.* 42:959-965.
14. Helle, W. and Sabelis, M.W. (1985) Spider Mites: Their Biology, Natural Enemies and Control. Vol. 1B. Elsevier, Amsterdam, the Netherlands.

15. Ishida, H., Mural, T., Sonoda, S., Yoshida, H., Izumi, Y. and Tsumuki, H. (2003) Effect of temperature and photoperiod on development and oviposition of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Appl. Entomol. Zool.* 38:65-68.
16. Jeppson, L.R., Keifer, H.H. and Baker, E.W. (1975) Mites Injurious to Economic Plants. University of California Press, Berkeley, CA, USA.
17. Kaylani, S. (1967) Biology and life history of *Stethorus gilvifrons* Mulsant (Coccinellidae: Coleoptera) in Lebanon. *Magon Publ. Ser. Sci.* 11:1-24.
18. Krebs, C.J. (1998) Ecological Methodology. Harper and Row Publ., New York, NY.
19. Laing, J.E. (1968) Life history and life table of *Phytoseiulus persimilis* Athias-Henriot. *Acarologia* 10:578-588.
20. Luciano, P.M., Macedo, L.P.M., Souza, B., Carvalho, C.F. and Ecole, C.C. (2003) [Influence of the photoperiod on development and reproduction of *Chrysoperla externa* (Hagen) (Neuroptera: Chrysopidae).] *Neotrop. Entomol.* 32:91-96 (Portuguese, with English summary).
21. Miaoqing, S., Zhenzhong, G. and Jiwen, X. (1999) Influence of temperature on the experimental population of *Stethorus punctillum*. *Acta Ecol. Sin.* 18:181-187 (Chinese, with English summary).
22. Mori, K., Nozawa, M., Arai, K. and Gotoh, T. (2005) Life history traits of the acarophagous lady beetle, *Stethorus japonicus* at three constant temperatures. *BioControl* 50:35-51.
23. Nakamura, K. (2003) Effect of photoperiod on development and growth in a pentatomid bug, *Dolycoris baccarum*. *Entomol. Sci.* 6:11-16.
24. Omkar and Pathak, S. (2006) Effects of different photoperiods and wavelengths of light on the life-history traits of an aphidophagous ladybird, *Coelophora saucia* (Mulsant). *J. Appl. Entomol.* 30:45-50.
25. Oncuer, C. (1991) A Catalogue of the Parasites and Predators of Insect Pests of Turkey. Ege University, Agricultural Faculty Press No. 505, Bornova, Izmir, Turkey.
26. Overmeer, W.P.J. (1985) Rearing and Handling Spider Mites: Their Biology, Natural Enemies and Control. Vol. 1B. Elsevier, Amsterdam, the Netherlands. pp. 161-170.
27. Piesik, D. (2006) Effects of temperature and photoperiod on the development and survival of the Dock leaf beetle (*Gastroidea viridula* Deg.). *Electr. J. Pol. Agric. Univ. Biol.* 9(2):27.
28. Ponsonby, D.J. and Copland, M.J.W. (1998) Environmental influences on fecundity, egg viability and egg cannibalism in the scale insect predator, *Chilocorus nigrinus*. *Biocontrol* 43:39-52.
29. Sarmah, M. and Bhattacharyya, B. (2002) Biology and feeding potential of *Stethorus gilvifrons* Mulsant (Coccinellidae: Coleoptera) on Tea red spider mite, *Oligonychus coffeae* Neitner. *Shashpa* 9:23-26.
30. Senal, D. and Karaca, I. (1999) Some biological parameters of predator *Stethorus gilvifrons* Mulsant (Coccinellidae: Coleoptera) on *Tetranychus cinnabarinus* (Boisduval) (Acarina: Tetranychidae). *Proc. 4th Turkish National Congr. of Biological Control* (Adana, Turkey), pp. 417-426 (Turkish, with English summary).
31. SPSS (1999) SPSS for Windows, Release 10.0.1. SPSS Inc., Chicago, IL, USA.
32. Uygun, N. (1981) Taksonomische Untersuchungen über die Coccinellidenfauna (Coleoptera) der Türkei. *Çukurova Univ. Ziraat Fakültesi Yayın* No. 157, Adana, Turkey (Turkish, with German summary).
33. Yigit, A. and Uygun, N. (1986) Studies on the biology of *Stethorus punctillum* Weise (Col.: Coccinellidae). *Proc. 1st Turkish National Congr. of Biological Control* (Adana, Turkey), pp. 392-405 (Turkish, with English summary).