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ORIGINAL RESEARCH PAPER

# Influences of temperature and humidity on the life history parameters and prey consumption of *Anthocoris minki* Dohrn (Heteroptera: Anthocoridae)

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**Abstract** *Anthocoris minki* Dohrn is a promising indigenous *Anthocoris* species for the biological control of *Agonoscena pistaciae* Burck. and Laut. (Homoptera: Psyllidae) in pistachio orchards in Turkey. The adult longevity, fecundity, life table parameters and prey consumption of *A. minki* fed on *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs were studied at combinations of three constant temperatures (20, 25 and 30 ± 1°C) with two relative humidity (RH) levels (40 and 65 ± 5%). Studies indicated that temperature and RH significantly affected adult longevity, fecundity and prey consumption of *A. minki*. The greatest adult female longevity was 116.0 days at 20°C and 65% RH; the shortest adult female longevity was 27.5 days at 30°C and 40% RH. At all tested temperatures, the oviposition period and prey consumption of both females and males significantly decreased at low RH compared to high RH. The highest and lowest total fecundities were 276.0 eggs (at 20°C and 65% RH) and 42.4 eggs (at 25°C and 40% RH), respectively. The intrinsic rates of natural increase ($r_m$) at 40 and 65% RH were 0.049 and 0.076 at 20°C, 0.072 and 0.096 at 25°C and 0.076 and 0.112 at 30°C, respectively. The highest mean numbers of *E. kuehniella* eggs consumed by females and males were 859.6 (at 20°C) and 515.3 (at 25°C) at 65% RH, respectively; the lowest were 183.3 (at 20°C) and 95.5 (at 25°C) at 40% RH, respectively.

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## Introduction

Insecticide resistance and adverse environmental effects due to the intensive use of insecticides prompted the development of biological control for pest management. Biological control is a major component of integrated pest management (Debach and Rosen 1991). The Anthocoridae family is an important natural enemy of small arthropods such as thrips, scales, aphids and psyllids (Lattin 1999). *Anthocoris* spp. (Heteroptera: Anthocoridae) are economically useful predators on arthropod pests (Lattin 1999). Among *Anthocoris* species, *Anthocoris nemoralis* (F.) and *Anthocoris nemorum* (L.) (Heteroptera: Anthocoridae) have been released in pear orchards to control pear psylla in Europe (Fauvel et al. 1994; Rieux et al. 1994; Unruh and Higbee 1994; Sigsgaard et al. 2006a, b).

*Anthocoris minki* Dohrn is a well-known predator of aphids such as *Pemphigus spyrothecae* Passerini and *Pemphigus gairi* Stroyan (Hemiptera: Aphididae) in galls on *Populus nigra* L., *Populus nigra* L. var. italica (Salicaceae), almond leaf-curl aphid *Brachycaudus* (*Thuleaphis*) *amygdalinus* (Schouteden) (Hemiptera: Aphididae) (Foster 1990; Urban 2002, 2004; Almatni and Khalil 2008), and psyllid species such as poplar psyllid *Camarotoscena speciosa* Flor. (Homoptera: Psyllidae) (Al-Maroof 1990) and pistachio psylla *Agonoscena pistaciae* Burckhardt and Lauterer (Homoptera: Psyllidae) in pistachio orchards (Celik 1981; Mart et al. 1995; Bolu et al. 1999).

The pistachio psylla is a major pest of pistachio trees, *Pistacia vera* L. (Anacardiaceae), resulting in severe damage and yield reduction (Mart et al. 1995; Mehrnejad

2001; Souliotis et al. 2002). It is difficult to control *A. pistaciae* with traditional insecticides due to the development of resistance (Mehrnejad 2001); therefore, augmentation biological control offers an alternative means to control *A. pistaciae* in pistachio orchards.

A suitable mass production method is needed to commercialize applications of *A. minki* in pistachio orchards. The effectiveness of a predator for biological control should be assessed based on its demographic parameters at different temperatures and relative humidities before fieldwork. Anthocorids have been successfully reared on *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs (Parker 1981; Samsoe-Petersen et al. 1989; Ohta 2001; Yano et al. 2002; Yanik and Ugur 2002, 2005). Rearing of *A. minki* on *E. kuehniella* eggs was achieved by Yanik and Unlu (2010), who determined the development time and prey consumption of nymphs; however, there have been no studies on the demographic characteristics and prey consumption of the adult stage of *A. minki* on *E. kuehniella* eggs.

The objective of this study was to determine the life history parameters and prey consumption of the adult stage of *A. minki* reared on *E. kuehniella* eggs under different temperatures and relative humidities for the development of mass-rearing methods.

## Materials and methods

### Laboratory rearing of *A. minki*

The initial population of *A. minki* adults was collected from pistachio orchards located in Sanliurfa, Turkey in September 2008. The stock culture was reared as described by Samsoe-Petersen et al. (1989), with *Pelargonium peltatum* (Strack) (Geraniaceae) leaves used as the oviposition substrate. Both adults and nymphs were kept at 25 ± 1°C and 65 ± 5% RH with a photoperiod of 16L8D. The nymph and adult predators were fed with frozen eggs of *E. kuehniella*, adhered to paper with water. Green bean pods, *Phaseolus vulgaris* L. (Fabaceae), were used for adult females as the oviposition substrate and water source (Isenhour and Yeargan 1981). The adults and nymphs were reared in a plastic container (12 cm dia., 13 cm height) with a ventilation hole (5 cm dia.) covered with a fine-mesh nylon screen. Prey and green bean pods were replaced every 2 or 3 days. Green bean pods containing *A. minki* eggs were placed in the same type of plastic container. One day before the expected day of hatching of *A. minki* eggs, *E. kuehniella* eggs were placed near the green bean pods as a food source for newly emerging nymphs. A piece of paper towel was placed inside the plastic container to facilitate roaming and shelter for the nymphs. The diet was replaced every 2 or 3 days. Newly emerged adults were removed from the nymphal containers and used to maintain the stock culture. *A. minki* was reared for at least two consecutive generations prior to the experiments.

### Life history parameters and prey consumption

Adult longevity, fecundity and prey consumption of *A. minki* were evaluated at various combinations of temperature (20, 25 and 30 ± 1°C) and RH (40 and 65 ± 5%) with a photoperiod of 16L8D. A high humidity value was selected to protect against fungus contamination and to keep mass production costs to a minimum level. Experiments were performed in a plastic container (5.5 cm dia., 5 cm height) with vent-holes covered with fine-mesh nylon screen, and a piece of paper towel was placed on the bottom to facilitate roaming. Prey was provided in excess of *A. minki*'s daily consumption.

Eggs taken from a stock culture of the predator were reared to adult stage under the same condition as the adults. Newly emerged females and males less than 6 h old were caged separately in plastic containers with *E. kuehniella* eggs for 4 days. At the end of this period, males and females were paired in glass vials (2 cm in diameter) and observed until mating occurred. After mating, males and females were placed individually in plastic containers and provided with *E. kuehniella* eggs and green bean pods. The number of eggs deposited in the pods and *E. kuehniella* eggs consumed by the predators were counted under a stereomicroscope at 24 h intervals until the day before their death under all conditions. Green bean pods containing deposited eggs and the *E. kuehniella* egg sheet were replaced daily.

Life table parameters were calculated from the Lotka equation (Birch, 1948):

$$1 = \Sigma e^{-rx} l_x m_x, \tag{1}$$

in which $x$ = age in days (including immature stages), $r_m$ = intrinsic rate of natural increase, $l_x$ = age-specific survival (including immature mortality), and $m_x$ = age-specific number of female offspring.

Mean generation time was calculated by;

$$T_0 = \ln(R_0/r), \tag{2}$$

in which $T_0$ = mean generation time, $R_0$ = net reproductive rate ($R_0 = \Sigma l_x m_x$) and $r$ = intrinsic rate of natural increase. The sex ratio of progeny from the stock culture of the predator was found to be 1:1. The developmental time (from egg to adult stage) was measured for each temperature and RH in a previous study (Table 1) (Yanik and Unlu 2010).

**Table 1** Developmental times and mortality rates of *Anthocoris minki* on *Ephestia kuehniella* eggs at different temperatures and relative humidities (Yanik and Unlu 2010)

| Temp (°C) | RH (%) | Developmental time (mean ± SE) (days)[a] | | Mortality (%) | |
|---|---|---|---|---|---|
| | | Egg | Nymph | Egg | Nymph |
| 20 | 40 | 6.1 ± 0.08 (101) a | 18.6 ± 0.15 (32) a | 9.4 (116) | 51.5 (66) |
| | 65 | 5.9 ± 0.05 (153) a | 18.6 ± 0.22 (35) a | 8.1 (173) | 41.6 (58) |
| 25 | 40 | 4.1 ± 0.05 (102) b | 13.7 ± 0.20 (36) b | 13.4 (119) | 30.1 (53) |
| | 65 | 3.9 ± 0.04 (128) b | 14.6 ± 0.29 (31) b | 14.2 (267) | 32.1 (55) |
| 30 | 40 | 3.1 ± 0.03 (104) c | 10.8 ± 0.21 (30) d | 14.5 (103) | 52.1 (46) |
| | 65 | 3.2 ± 0.03 (200) c | 11.8 ± 0.25 (30) c | 15.5 (290) | 30.5 (50) |

[a] The numbers of eggs and nymphs tested for developmental time and mortality are given in parentheses. Means within a column followed by the same letter are not significantly different ($p > 0.05$, least square means test was applied to 3 × 2 factorial designs)

Statistical analysis

Data for adult longevity, fecundity and prey consumption of predators at different temperatures and RHs were evaluated by two-factor ANOVA, and the means were separated using the Tukey–Kramer test. A Tukey-type multiple comparison test was applied to the proportion of ovipositing females after arcsine transformation. After $r$ was computed from the original data ($r_{all}$), differences in $r_m$ values were tested for significance by estimating the variance using the jackknife method (Meyer et al. 1986). The jackknife pseudo-value $r_j$ was calculated for $n$ samples using the following equation:

$$r_j = n\, r_{all} - (n-1) r_i. \quad (3)$$

The mean values of ($n-1$) jackknife pseudo-values for the mean growth rate in each treatment were subjected to analysis of variance (ANOVA), and the means of treatments were compared by the Tukey–Kramer test.

## Results

The longevity, oviposition period and fecundity of adult predators were significantly affected ($p < 0.05$) by temperature, RH and their interactions (Table 2). The preoviposition period was not significantly affected ($p > 0.05$) by either RH or the interaction between temperature and RH, but was significantly affected ($p < 0.05$) by temperature.

The adult longevities, proportions of oviposition females, preoviposition periods, oviposition periods and fecundities of predators at different temperatures and RH levels are shown in Table 3. *A. minki* females began laying eggs after 7 days. The proportion of ovipositing females ranged from 82.1 to 86.9 at 65% RH, and from 47.6 to 62.5 at 40% RH at different temperatures (Table 3). The oviposition period at all tested combinations was significantly shorter ($p < 0.05$) at low RH compared to high RH. The greatest adult female longevity was 116.0 days at 20°C and 65% RH, whereas the shortest was 27.5 days at 30°C and 40% RH. Greater adult longevity and higher fecundity were noted at 20 and 25°C at high RH than at these temperatures at low RH. The highest and lowest fecundities were 276.0 eggs (at 20°C and 65% RH) and 42.4 eggs (at 25°C and 40% RH), respectively.

**Table 2** Results of two-factor ANOVA on effects of temperature and relative humidity on the life history parameters of adult *Anthocoris minki*

| Source | *df* | Mean square | *F* value | *p* value |
|---|---|---|---|---|
| Preoviposition | | | | |
| Temperature | 2 | 50.265 | 8.75 | 0.0003 |
| Relative humidity | 1 | 13.275 | 2.31 | 0.1319 |
| Temperature × relative humidity | 2 | 1.378 | 0.24 | 0.7872 |
| Oviposition | | | | |
| Temperature | 2 | 7370.718 | 32.96 | <0.0001 |
| Relative humidity | 1 | 21313.952 | 95.32 | <0.0001 |
| Temperature × relative humidity | 2 | 2706.911 | 12.11 | <0.0001 |
| Female longevity | | | | |
| Temperature | 2 | 19176.760 | 50.37 | <0.0001 |
| Relative humidity | 1 | 69801.627 | 183.33 | <0.0001 |
| Temperature × relative humidity | 2 | 11857.919 | 31.14 | <0.0001 |
| Male longevity | | | | |
| Temperature | 2 | 31565.478 | 100.34 | <0.0001 |
| Relative humidity | 1 | 97995.214 | 311.51 | <0.0001 |
| Temperature × relative humidity | 2 | 17803.301 | 56.59 | <0.0001 |
| Fecundity | | | | |
| Temperature | 2 | 38039.403 | 7.97 | 0.0006 |
| Relative humidity | 1 | 460053.508 | 96.45 | <0.0001 |
| Temperature × relative humidity | 2 | 41604.293 | 8.72 | 0.0003 |

**Table 3** Fecundities, longevities and related parameters of *Anthocoris minki* reared on *Ephestia kuehniella* eggs at different temperatures and relative humidities

| Temp (°C) | RH (%) | $n$[b] | Longevity (days) (mean ± SE)[a] | | % Ovipositing females[c] | Preoviposition period (days) (mean ± SE)[d] | Oviposition period (days) (mean ± SE) | Fecundity per female (mean ± SE) |
|---|---|---|---|---|---|---|---|---|
| | | | Female | Male | | | | |
| 20 | 40 | 20 | 43.1 ± 3.5 b | 37.1 ± 2.5 b | 48.8 (41) | 9.3 ± 0.5 a | 33.1 ± 3.8 b | 71.2 ± 10.0 cd |
| | 65 | 20 | 116.0 ± 7.5 a | 132.1 ± 11.8 a | 86.9 (23) | 9.8 ± 0.7 a | 76.5 ± 5.8 a | 276.0 ± 35.4 a |
| 25 | 40 | 20 | 31.3 ± 3.2 b | 23.7 ± 1.4 bc | 47.6 (42) | 8.1 ± 0.7 a | 20.3 ± 2.6 bc | 42.4 ± 4.8 d |
| | 65 | 23 | 115.1 ± 9.9 a | 110.6 ± 7.4 a | 82.1 (28) | 9.3 ± 0.9 a | 60.4 ± 5.1 a | 208.3 ± 33.2 ab |
| 30 | 40 | 20 | 27.5 ± 2.9 b | 18.2 ± 1.7 c | 62.5 (32) | 6.7 ± 0.1 a | 18.4 ± 3.0 c | 71.7 ± 11.8 cd |
| | 65 | 23 | 38.7 ± 3.3 b | 28.0 ± 3.6 bc | 82.1 (28) | 7.3 ± 0.3 a | 27.6 ± 2.8 b | 132.1 ± 16.6 bc |

[a] Means within a column followed by the same letter are not significantly different ($p > 0.05$; Tukey–Kramer test)

[b] The $n$ value shows the number of predators tested for each parameter. Only the numbers of females tested for % ovipositing females are given in parentheses

[c] A Tukey-type multiple comparison test was applied after arcsine transformation. It showed that statistically significant differences among transformed % ovipositing females were observed at different levels of RH

[d] Newly emerged females and males were caged separately for 4 days, and this period was added to the preoviposition

**Table 4** Results of a two-factor ANOVA on the effects of temperature and relative humidity on the prey consumption of adult *Anthocoris minki*

| Source | *df* | Mean square | *F* value | *p* value |
|---|---|---|---|---|
| Female | | | | |
| Temperature | 2 | 49794.858 | 2.22 | 0.1146 |
| Relative humidity | 1 | 5779332.751 | 257.57 | <0.0001 |
| Temperature × relative humidity | 2 | 367885.774 | 16.40 | <0.0001 |
| Male | | | | |
| Temperature | 2 | 190549.444 | 28.85 | <0.0001 |
| Relative humidity | 1 | 2007270.982 | 303.90 | <0.0001 |
| Temperature × relative humidity | 2 | 227005.179 | 34.37 | <0.0001 |

The effects of temperature and RH on the prey consumptions of both female and male predators are shown in Table 4. The prey consumptions of both sexes were significantly affected ($p < 0.05$) by RH and temperature and their interactions, but the effect of temperature was only significant ($p < 0.05$) for prey consumption by male predators. Table 5 shows the *E. kuehniella* egg consumptions of females and males at different temperatures and RHs. At all tested temperatures, female and male prey consumptions significantly decreased ($p < 0.05$) at low RH compared to high RH. The highest mean *E. kuehniella* egg consumption of females and males was 859.6 and 515.3, respectively, which were obtained at 65% RH and 20 and 25°C, respectively. At all temperatures and RHs tested, adult females consumed a significantly ($p < 0.05$) higher number of *E. kuehniella* eggs than males.

Table 6 shows the mean generation times ($T_0$), the intrinsic rates of natural increase ($r_m$) and the net

**Table 5** *Ephestia kuehniella* egg consumption by adult *Anthocoris minki* at different temperatures and relative humidities

| Temp (°C) | RH (%) | $n$[b] | No. of eggs consumed by adults (mean ± SE)[a] | | | |
|---|---|---|---|---|---|---|
| | | | Total | | Per day | |
| | | | Female | Male | Female | Male |
| 20 | 40 | 20 | 183.3 ± 24.8 cA | 99.0 ± 8.1 cB | 4.2 | 2.6 |
| | 65 | 20 | 859.6 ± 60.1 aA | 443.3 ± 38.0 aB | 7.4 | 3.3 |
| 25 | 40 | 20 | 187.1 ± 17.9 cA | 95.5 ± 6.6 cB | 5.9 | 4.1 |
| | 65 | 23 | 780.2 ± 56.2 aA | 515.3 ± 37.6 aB | 6.7 | 4.6 |
| 30 | 40 | 20 | 309.7 ± 31.3 cA | 108.8 ± 9.1 cB | 11.2 | 5.9 |
| | 65 | 23 | 568.0 ± 54.9 bA | 212.1 ± 34.8 bB | 14.6 | 7.5 |

[a] Means within a column followed by the same small letter are not significantly different ($p > 0.05$; Tukey–Kramer test), and means within a row followed by the same large letter are not significantly different ($p > 0.05$)

[b] The $n$ value shows the number of predators tested for each parameter

**Table 6** Life table parameters of *Anthocoris minki* on *Ephestia kuehniella* eggs at different temperatures and relative humidities

| Temp (°C) | RH (%) | Mean generation time (days) $T_0$ | Intrinsic rate of natural increase (females/females/day) $r_m$ | Net reproductive rate (females/females) $R_0$ |
|---|---|---|---|---|
| 20 | 40 | 45.2 | 0.049 e[a] | 9.1 |
| | 65 | 55.3 | 0.076 b | 67.9 |
| 25 | 40 | 32.8 | 0.072 d | 10.7 |
| | 65 | 44.2 | 0.096 b | 69.5 |
| 30 | 40 | 27.5 | 0.076 c | 8.1 |
| | 65 | 32.9 | 0.112 a | 39.3 |

[a] Means within a column followed by the same letter are not significantly different ($p > 0.05$; Tukey–Kramer test)

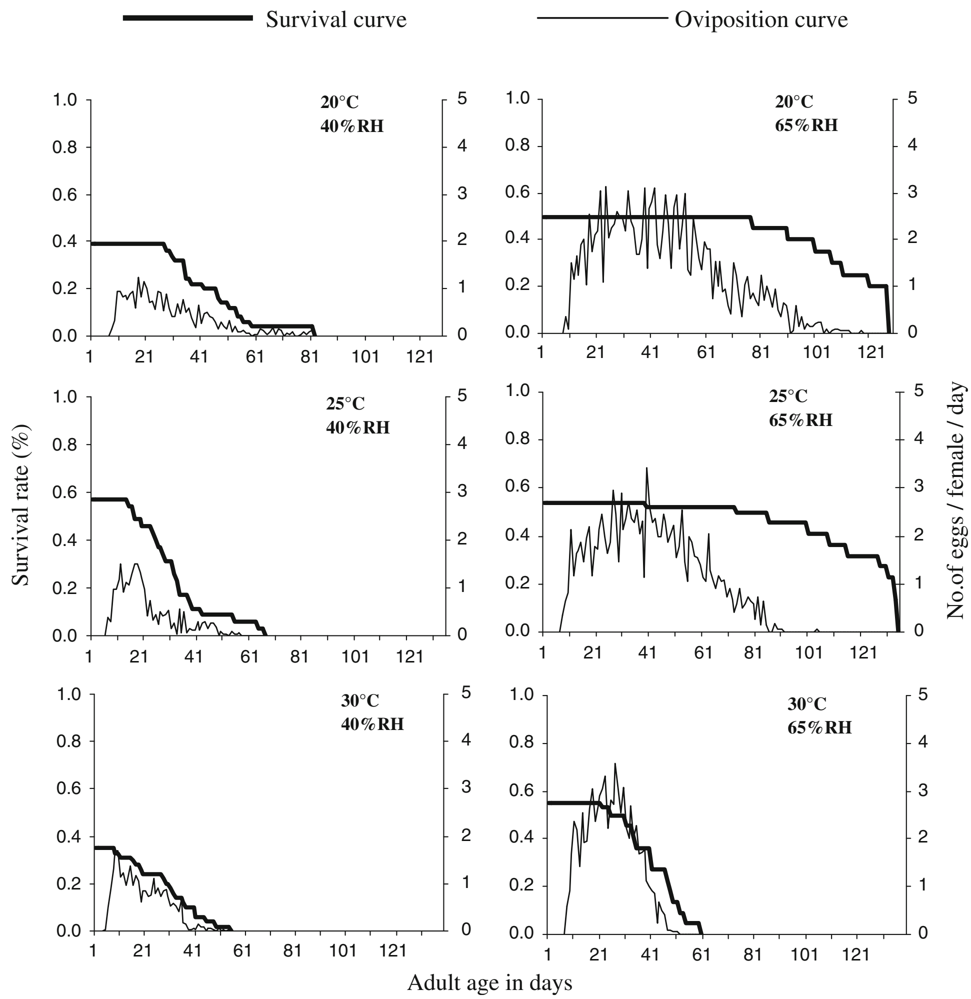


**Fig. 1** Mean survival curves (*thick lines*) ($l_x$) and oviposition curves (*thin lines*) ($m_x$) of *Anthocoris minki* reared on *Ephestia kuehniella* eggs at different temperatures and relative humidities

reproductive rates ($R_0$) of *A. minki* on *E. kuehniella* eggs at different temperatures and RHs. Mean generation time at the same temperature was longer at 65% RH than at 40% RH. Mean generation time of *A. minki* under the same RH conditions decreased with increasing temperature. At 40% RH it was 45.2, 32.8 and 27.5 days, and at 65% RH it was 55.3, 44.2 and 32.9 days at 20, 25 and 30°C, respectively (Table 6). The $r_m$ values of *A. minki* differed significantly among the different temperatures and RHs tested. The highest $r_m$ were found at 30°C and 65% RH. The net reproductive rate at all temperatures was lower at 40% RH than at 65% RH. Under high-RH conditions, the net reproductive rate was approximately similar at 20 and 25°C, but decreased at 30°C.

The maximum oviposition rate per female per day ($m_x$) at 65% RH was 3.2 eggs at 20°C (24th day), 3.4 eggs at 25°C (40th day), 3.6 eggs at 30°C (27th day), and at 40% RH was 1.2 eggs at 20°C (18th day), 1.5 eggs at 25°C (12th day), and 1.7 eggs at 30°C (10th day), gradually decreasing thereafter (Fig. 1). The highest survival at the same RH was found at to occur at 20°C and decreased with increasing temperature. Adult survival dropped rapidly towards the end of the oviposition period under all tested regimes.

## Discussion

Temperature, RH and their interactions are considered to be important factors affecting the population growth of insects (Odum 1983; Emana et al. 2004). The present study showed that temperature, RH and their interaction significantly affected the adult longevity, fecundity and prey consumption of *A. minki*, as did the temperature at each humidity level or the humidity level at each temperature; however, the interaction term was not statistically significant for the preoviposition period.

Anderson (1962) reported a preoviposition period of 9–22 days for *A. minki* fed on *Psyllopsis fraxinicola* (Förster) (Homoptera: Psyllidae), 4.8 days for *Anthocoris sarothamni* Douglas and Scott (Heteroptera: Anthocoridae) fed on *Arytaina genistae* (Latr.) (Homoptera: Psyllidae), and 6.5 days for *A. sarothamni* fed on *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae), respectively, at 23 ± 2°C. Horton et al. (2000) stated that *Anthocoris tomentosus* Péricart (Heteroptera: Anthocoridae) females began laying eggs about 8 d (7.8–8.3 days) after mating at 22°C and a photoperiod of 16L8D. According to various studies, the preoviposition period of *A. nemoralis* fed on *Cacopsylla pyricola* (Först.) (Homoptera: Psyllidae) was 5 days at 21°C (Brunner and Burts, 1975), 14–15 days on *E. kuehniella* eggs, 3–6 days on *Cacopsylla pyri* (L.) (Homoptera: Psyllidae) at 26 ± 1°C and 70% RH (Fauvel et al. 1984), 4.3 days on *C. pyricola* at 22°C (Horton et al. 2000), and 3–5 days on *C. pyri* at 25 ± 1°C and 75 ± 5% RH (Yanik and Ugur 2005). In the current study, the preoviposition period of *A. minki* females (7–10 days) was intermediate between the previous research findings on anthocorid species. In mass production, the preoviposition period will ensure the faster production of predators.

Most eggs were laid during the early and middle portions of the oviposition period, and adult female longevity was almost the same as in males (Fig. 1; Table 3). These results are similar to those reported by Brunner and Burts (1975) for *A. nemoralis.* The fecundity results are in agreement at 40% RH with those presented by Anderson (1962), who found that *A. minki* fed on *Aulacorthum circumflexum* (Buckt.) (Hemiptera: Aphididae) and *Psylla mali* Schmid (Homoptera: Psyllidae) laid an average of 53.7 (25–106) and 77.8 (47–100) eggs at 23 ± 2°C, respectively. The same author recorded that the average fecundities of *Anthocoris confusus* Reut. (Heteroptera: Anthocoridae) and *A. sarothamni* fed on different species of aphids were 119.5 and 98.7 eggs, respectively. These results are slightly lower than our findings at 30°C and 65% RH, and considerably lower than the number of eggs at 20 and 25°C with 65% RH. Our results (obtained at 25°C and 65% RH) are similar to those of Fauvel et al. (1984), who reported that *A. nemoralis* laid an average of 197.7 eggs in about 46 days at 26 ± 1°C and 70% RH with a long-day photoperiod when fed on *E. kuehniella* eggs. A similar experiment reported the adult longevity and fecundity of *A. nemoralis* on *C. pyricola* to be 30 days and 138 eggs, respectively, at 21°C (RH not reported) (Brunner and Burts 1975). Because the results of the present study were considerably lower than those of *A. minki* at 20°C and 65% RH, these discrepancies are possibly due to the lower RH than in our study; however, the present study showed that low RH significantly decreased the adult longevity and fecundity of *A. minki*.

Yanik and Ugur (2005) reported that the adult longevity, oviposition period and fecundity of *A. nemoralis* females fed on *E. kuehniella* eggs at 25 ± 1°C and 75 ± 5% RH under 16L8D were 65.5, 169.5 days and 296.4 eggs, respectively. The oviposition period, adult female longevity and fecundity of *A. minki* in the present study were 60.4, 115.1 days and 208.3 eggs, respectively, at 25°C and 65% RH. A comparison of our findings with those of Yanik and Ugur (2005) showed a similar oviposition period and different adult female longevity and fecundity. These differences in adult female longevity and fecundity are likely related to different predator species. In our study, non-ovipositing females were found under all tested conditions. Kakimoto et al. (2005) reported that the proportion of ovipositing females ranged from 63.2 to 88.5% for *Orius sauteri* (Poppius) (Heteroptera: Anthocoridae) on *E. kuehniella* eggs at different temperatures and for a photoperiod of 16L8D; however, our study shows that the proportions of ovipositing females were lower under low-RH conditions. A higher proportion of ovipositing females is important in the mass production of *A. minki* for commercial use.

In our experiment, adult females consumed more prey than males. Similar findings were also reported by Isenhour and Yeargan (1981) for *Orius insidiosus* (Say) (Heteroptera: Anthocoridae) and Yanik and Ugur (2004) for *A. nemoralis.* Yanik and Ugur (2004) showed that the total and daily average numbers of *E. kuehniella* eggs consumed by *A. nemoralis* (average of females and males) were 1936.0 ± 157.4 and 12.0 eggs, respectively, during its life span (which, for females, is 169.5 days, and for males 195.2 days), at 25 ± 1°C and 75 ± 5% RH with a photoperiod of 16L8D. Peet (1973) reported that about 1059 *E. kuehniella* eggs were consumed by one female *Nidicola marginata* Harris and Drake (Heteroptera: Anthocoridae) during the adult life span (average of 160 days), at 26 ± 3°C and 60% RH. Under similar conditions in the present study, the average total egg consumption of *A. minki* was lower than in previous studies. Differences in the study results may be attributed to the higher longevity than in our study, the rearing conditions and the number of predators tested. Knowing how much food is consumed is an important parameter in the mass rearing of predators. *E. kuehniella* egg consumption of immature stages of *A. minki* at 40 and 65% RH was recorded by Yanik and Unlu (2010) as 98.2 and 123.1 eggs at 20°C, 113.2 and 94.1 eggs at 25°C, and 86.4 and 99.4 eggs at 30°C, respectively.

The intrinsic rate of natural increase is the most decisive data for estimating population dynamics (Southwood 1978). In this study, the highest $r_m$ (0.112) was observed at 30°C and 65% RH. Yanik (2006) reported that the values of $r_m$ for *A. nemoralis* fed on *E. kuehniella* eggs + *Tetranychus urticae* Koch. (Acarina: Tetranychidae) and *E. kuehniella* eggs + *C. pyri* were 0.368 and 0.400, respectively, at 25 ± 1°C and 60 ± 10% RH with a photoperiod of 16L8D. In the present study, $r_m$ values were lower than those in Yanik (2006). The main reason for the difference could be the use of the longevity and fecundity (immature stage excluded) of *A. nemoralis* to calculate $r_m$ values. Various *Orius* species have been produced commercially and used in the biological control of small insect pests in several countries. In the present study, $r_m$ values of *A. minki* were similar to those of *O. insidiosus* ($r_m$: 0.116), *Orius majusculus* (Reuter) (Heteroptera: Anthocoridae) ($r_m$: 0.080) (Tommasini et al. 2004), *Orius strigicollis* (Poppius) (Heteroptera: Anthocoridae) ($r_m$: 0.102), *O. sauteri* ($r_m$: 0.110) and *Orius minutus* (L.) (Heteroptera: Anthocoridae) ($r_m$: 0.107) (Kakimoto et al. 2005) on *E. kuehniella* eggs at 26°C and with a photoperiod of 16L8D. These similarities in the life table parameters of the above anthocorid species show that *A. minki* is a suitable biological control agent; however, $r_m$ values of *O. sauteri* fed on *Thrips palmi* Karny (Thysanoptera: Thripidae) at 30°C and 75% RH with a photoperiod of 16L8D (Nagai and Yano 1999) were higher than those of *A. minki* at 30°C and 65% RH. The major factor in the high $r_m$ is most likely the use of natural prey.

An efficient mass-rearing technique will be necessary for a suitable mass-production method of *A. minki* for commercial use. When the adult longevity, fecundity and life history parameters are taken into account, 30°C and 65% RH are recommended for the mass production of *A. minki* based on this study, because a greater population is obtained in a shorter period of time.

The results of the current study confirmed that *A. minki* can be reproduced normally when reared on factitious prey, *E. kuehniella* eggs. The findings obtained here provide information about the biology of *A. minki* that might be useful for the utilization of these predators for mass rearing and release for the biological control of *A. pistaciae* in pistachio orchards. Further investigation is needed to determine the predatory ability of this species against pistachio psylla, *A. pistaciae*, in both the laboratory and the field.

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