Journal of Asia-Pacific Entomology 18 (2015) 501–505

Contents lists available at ScienceDirect

Journal of Asia-Pacific Entomology

journal homepage: www.elsevier.com/locate/jape

Demography of pistachio fruit hull borer moth, *Arimania komaroffi* (Lepidoptera: Pyralidae) under different constant temperatures

Mehdi Basirat, Ali Golizadeh *, Seyed Ali Asghar Fathi, Mahdi Hassanpour

Department of Plant Protection, Faculty of Agricultural Science, University of Mohaghegh Ardabili, P.O. Box, 179, Ardabil, Iran

ARTICLE INFO

Article history:
Received 21 April 2015
Revised 21 June 2015
Accepted 25 June 2015
Available online 3 July 2015

Keywords:
Temperature
Life table
Demography
Pistachio
Arimania komaroffi

ABSTRACT

Recently, the pistachio fruit hull borer moth, *Arimania komaroffi* Ragonot (Lepidoptera: Pyralidae) has been emerged as a major pest of pistachio in Iran. Temperature is the most effective ecological factors on demography and life cycle of arthropods. The effect of temperature on the reproduction and population growth parameters of this pest was investigated in current study. Experiments were conducted at four constant temperatures 25, 27.5, 30 and 32.5 (±1) °C, on Ohadi cultivar in the laboratory. Based on the results, the immature development times were calculated as 56.37 ± 0.53, 47.72 ± 0.70, 42.03 ± 0.39 and 39.10 ± 0.46 days at 25, 27.5, 30 and 32.5 °C, respectively. The highest net fecundity rate was 25.34 eggs/female at 27.5 °C, although no significant difference was observed between 27.5 and 30 °C. Mean daily number of eggs laid by a female was the greatest at 30 °C. The gross reproductive rate (*GRR*) and net reproductive rate (R_0) of *A. komaroffi* were higher at 30 and 27.5 °C. The highest intrinsic rate of increase (r_m) was calculated as 0.056 at 30 °C. Similarly no significant difference was observed in r_m values between 27.5 and 30 °C. The higher finite rates of increase (λ) ware achieved at 27.5 and 30 °C. The longest mean generation time (*T*) was 59.9 days at 25 °C. Pest generation time decreased significantly with increasing temperature from 25 °C to 30 °C. Regarding the results, development and population increase of *A. komaroffi* at 27.5 and 30 °C were more rapidly performed and this knowledge could be valuable in its monitoring and control.

Introduction

Pistachio trees (*Pistacia vera* L.) have great economic value in Iran. It is cultivated mainly in the eastern and central region of Iran. In 2009, about 255,000 mt of pistachio nuts, approximately 50% of the world's pistachio production was produced in Iran (FAO, 2013). Iranian pistachio exports included about 40% of agricultural exports and the total export revenue from pistachio nuts is about 500,000,000 US$ annually (Hokmabadi, 2011). Pistachio nuts are a rich source of some essential and important nutrients including linoleic and linolenic fatty acids (Garcia et al., 1992). The proper temperature for pistachio growth is 25–35 °C during the growing season; however it could tolerate up to 42 °C (Hokmabadi, 2011).

Pistachio trees are attacked by a large number of pests (more than 50 species) during its growth period (Moderraes Awal, 1997; Mehrnejad, 2001).The pistachio fruit hull borer moth, *Arimania komaroffi* Ragonot (Lepidoptera: Pyralidae) was first collected by light trap from Fars province in Iran in 1939 by Brandt (Amsel, 1954). It was later collected from cultivated pistachio trees, in Rafsanjan, south eastern Iran, in 1972 by Samet (1974; 1985). It was not considered an important pest until early 2000. The most recent investigation by Mehrnejad and Speidel (2011) showed that the status of *A. komaroffi* has been gradually changing during the present decade and nowadays it is considered as an important pest of pistachio trees in Rafsanjan, the main pistachio production area of Iran (Mehrnejad, 2012; Hashemi-Rad and Alavi, 2014). This moth has 3–4 generations per year. The larvae feed on pistachio fruit hull within the pistachio fruit clusters and caused drying and falling of fruits. This pest causes damage at all stages of fruit growth and the injury level is higher and it is enough to destroy the entire fruit. The larvae spin silk and pistachio fruit nuts are linked to each other (Mehrnejad, 2001, 2010; Mehrnejad and Speidel, 2011). Organophosphorous pesticides currently are frequently used to control this pest.

Insects are poikilothermic animals that are affected by various climatic factors. Among the all climatic factors, temperature is one of the most critical abiotic factors affecting insect demographic parameters. It directly affects the seasonal occurrence and population dynamics, by affecting the natality, mortality and growth rates of individuals (Sharpe and DeMichele, 1977; Taylor, 1979, 1981; Pedigo, 1989). Demographic population analysis has diverse applications: predicting life history traits, analyzing population stability and structure, estimating extinction probabilities, predicting outbreaks in pest species, and examining the dynamics of colonizing or invading species (McPeek and Kalisz, 1993; Vargas et al., 1997).

* Corresponding author. Tel.: +98 451 5510140; fax: +98 451 5512204.
E-mail address: golizadeh@uma.ac.ir (A. Golizadeh).

http://dx.doi.org/10.1016/j.aspen.2015.06.007

Despite the importance of *A. komaroffi* as an important pest of pistachio, any information has been published on its temperature-dependent biology and life table. The current study was conducted to investigate the influence of temperature on development, survival and demography of *A. komaroffi*. This information is important to understand population dynamics of *A. komaroffi* and to develop sound and effective integrated pest management strategies, in particular monitoring and sampling in areas which are infested with pest.

Materials and methods

Insect rearing

Insect larvae were collected in pistachio orchards located at Rafsanjan region eastern of Iran. To accomplish this, fresh pistachio fruit clusters containing *A. komaroffi* larvae were cut and transferred to the laboratory in Pistachio Research Institute and placed in containers with pistachio fruits, until adults emerged. The insect colony was maintained in the laboratory conditions, 27 ± 1 °C, with a relative humidity (RH) of 65 ± 5%, and a photoperiod of L16:D8 h on pistachio fruit, Ohadi cultivar. The relative humidity was maintained at 65 ± 5% using a saturated magnesium nitrate salt solution (Mehrnejad et al., 2015). The pistachio fruits and test containers were replaced with new one every 2 days in order to prevent mold growth and contamination of pistachio fruits. The insects were reared for one generation before the studies were carried out. After adult emergence, laid eggs were used in experiments.

Development and mortality

Development and survival of *A. komaroffi* were determined at four constant temperatures (25, 27.5, 30 and 32.5 °C) with ±1 °C in growth chambers, with 65 ± 5% relative humidity and a photoperiod of L16:D8 h on Ohadi pistachio cultivar. Based on a primary test, female adults failed in oviposition at 35 °C and this temperature point was excluded from experimental design. To obtain the same aged eggs, about 20 pairs of male and female moth were placed in a cage at each temperature treatment. Eggs were collected within 24 h of oviposition using a moistened fine camel's hair brush, then placed on surface of fresh pistachio fruits in a transparent containers covered with fine mesh gauze for ventilation. The total number of eggs used for each temperature was 150 eggs. The eggs were checked twice daily, and the numbers of larvae that hatched were recorded. Eggs were checked until they hatched or collapsed. The new emerged larvae (neonate) at each temperature treatment were transferred individually using a fine camel's hair brush into cups (200 cc capacity) containing two fresh pistachio fruits. The experiment cups were covered with fine mesh gauze for ventilation. The larvae were feeding with pistachio fruit clusters (Ohadi cultivar) and fresh pistachio fruits were provided every 2–3 days during the experiment. Moreover, the experimental cups were replaced with new one for avoiding of any fungal infections. Larval and pupal developments were checked daily, and their developmental stages were recorded. The sex of new emerged adults was determined.

Reproduction and life table parameters

The adults eclosed from the pupae at each temperature were used to measure the pre-oviposition, oviposition, post-oviposition periods, longevity and fecundity. For this purpose, each newly eclosed, 0–24-h-old female was paired with a new emerged male, and then each pair was placed into transparent plastic box (17 × 10 × 7 cm) with lids containing ventilation openings covered with fine mesh gauze. The inside of container was covered with filter paper and containing fresh pistachio fruits. The pistachio fruits were replaced with fresh ones and the number of eggs laid on pistachio fruits and filter paper was counted daily. The number of adult pairs used for each experiment was between 11 and 16. The experiments were terminated when all of the adult moths died. The experimental design was completely randomized with four treatments (temperatures). The fertility and survivorship schedules were used to calculate the population growth parameters using formula suggested by Carey (1993) such as intrinsic rate of increase (r_m), mean generation time (T), finite rate of increase (λ), net reproductive rate (R_0), doubling time (DT) and other reproduction parameters.

Data analysis

Data concerning development time, survival rate, adult fecundity and longevity at each temperature were analyzed using the one-way ANOVA. The variables were tested for normality using the Kolmogorov–Smirnov test before subjecting them to analysis. Statistical analysis was performed using the SPSS v.16.0 statistical software (SPSS, 2007). If significant differences were detected, multiple comparisons were made using the Duncan's procedure ($P < 0.05$). The means, variances, and standard errors of population growth parameters (R_0, T, λ, DT, r_m) and reproduction parameters were estimated with Jackknife technique (Meyer et al., 1986; Sokal and Rohlf, 1995). In this procedure, after calculating the n pseudo-values for each parameter, the jackknife estimate of the mean and standard error was calculated by equations in Maia et al. (2000). The mean values of ($n - 1$) jackknife pseudo-values for each temperature were subjected to analysis of variance using the SPSS statistical programs.

Results

Developmental times and mortality rates

The developmental times of various stages of *A. komaroffi* at four temperatures 25, 27.5, 30 and 32.5 °C are presented in Table 1. The egg incubation period was significantly decreased as the temperature increased in the tested temperature range ($P < 0.001$). The longest and shortest incubation period was recorded at 25 and 32.5 °C. The similar trend was observed for larval and pupal periods in the experimental temperatures. The total developmental time from egg to adult was decreased significantly with increasing in temperature ($P < 0.001$, $F = 140.16$, $df = 3{,}203$). The longest and shortest developmental time from egg to adult was 56.37 ± 0.53 days at 25 °C and 39.10 ± 0.46 days at 32.5 °C, respectively. At each temperature from 25 to 30 °C, more than 92% of the eggs hatched, and the higher egg mortality was occurred at 32.5 °C (17.92%) (Table 2). Mortality rates from egg to adult were ranged between 47.29% at 25 °C and 72.64% at 32.5 °C. Age-specific survival rate of *A. komaroffi* reared at four constant temperatures is presented in Fig. 1. The life cycle duration decreased with increasing in temperature. The lowest survivorship period of *A. komaroffi* was at 32.5 °C and complete mortality for moth reared at 25, 27.5, 30 and 32.5 °C was observed after 64, 56, 50 and 48 days, respectively. There was a sharp decline in the survival rate of *A. komaroffi* adults immediately after the reproduction period at all temperatures.

Adult longevity and fecundity

Adult moth longevity (both male and female) was not significantly affected by temperature ($P > 0.05$). Moreover, the oviposition and post-oviposition period did not show significant differences among the four temperature treatments ($P > 0.05$). The pre-oviposition period was significantly differed between temperature points ($P = 0.033$, $F = 3.12$, $df = 3{,}56$) and this period at 32.5 °C was significantly higher than at 27.5 and 30 °C (Table 1). There was no significant difference in the time spent for producing offspring between four temperatures (Table 1). The first oviposition occurred on days 56, 48, 42 and 43 at 25, 27.5, 30 and 32.5 °C, respectively (Fig. 1). The m_x (age-specific

Table 1
Immature developmental times, adult longevities and reproduction periods (days) of *A. komaroffi* at four constant temperatures.

Stage	Temperature °C			
	25.0	27.5	30.0	32.5
Egg	4.92 ± 0.03 [a]	4.35 ± 0.03 [b]	3.91 ± 0.04 [c]	3.59 ± 0.04 [d]
Larva	35.21 ± 0.41 [a]	30.12 ± 0.48 [b]	26.95 ± 0.30 [c]	26.33 ± 0.45 [c]
Pupa	16.23 ± 0.20 [a]	13.34 ± 0.33 [b]	10.90 ± 0.11 [c]	9.48 ± 0.12 [d]
Egg-to-adult	56.37 ± 0.53 [a]	47.72 ± 0.70 [b]	42.03 ± 0.39 [c]	39.10 ± 0.46 [d]
Male longevity	9.09 ± 0.79 [a]	7.83 ± 0.46 [a]	8.76 ± 0.32 [a]	7.44 ± 0.93 [a]
Female longevity	9.00 ± 0.98 [a]	7.90 ± 0.47 [a]	8.86 ± 0.44 [a]	8.67 ± 0.44 [a]
Pre-oviposition period	3.90 ± 0.72 [ab]	2.85 ± 0.41 [b]	3.48 ± 0.35 [b]	5.22 ± 0.88 [a]
Oviposition period	4.10 ± 0.87 [a]	4.05 ± 0.45 [a]	4.67 ± 0.49 [a]	2.89 ± 0.77 [a]
Post-oviposition period	1.00 ± 0.37 [a]	1.00 ± 0.35 [a]	0.71 ± 0.33 [a]	0.56 ± 0.29 [a]

Mean values followed by the same letter in the each row are not significantly different ($P < 0.05$; Duncan after one-way ANOVA).

fecundity rate) showed a clear peak at all temperatures and peaked on days 60 (6.7 eggs), 50 (6.9 eggs), 48 (6.1 eggs) and 46 (4.9 eggs), respectively.

The reproduction parameters of *A. komaroffi* at four constant temperatures were calculated and results have been represented in Table 3. Among related parameters, fecundity is indicating total eggs and fertility is showing only hatched eggs. Gross fecundity rate (the average of produced offspring by females during their lifetimes) of *A. komaroffi* differed significantly among temperatures ($P = 0.017$, $F = 3.69$, $df = 3{,}56$) and the lowest and highest was 21.89 ± 8.08 and 56.05 ± 5.51 eggs per female at 32.5 and 30 °C, respectively. Similarly, significant difference was observed for gross fertility rate (the number of hatched eggs during female life time) between four temperatures ($P = 0.011$, $F = 4.04$, $df = 3{,}56$). Two net reproduction rates inclusive net fecundity and fertility rate were significantly different between four tested temperatures ($P = 0.001$, $F = 6.00$, $df = 3{,}56$; $P = 0.001$, $F = 6.16$, $df = 3{,}56$, respectively). Both parameter values were higher at 27.5 and 30 °C than two others. These parameters are showing the average of produced and hatched eggs for effective females in reproduction during life cycle, respectively. The daily number of eggs laid per female was the greatest at 30 °C, however no significant differences were observed between 27.5 and 30 °C. The mean number of fertile eggs per female per day was the greatest at 30 °C (Table 3).

Population growth parameters

Population growth parameters of *A. komaroffi* at four temperatures are presented in Table 4. Most calculated parameters were significantly affected by temperature. The gross reproductive rate (*GRR*) was highest at 30 °C followed by 27 °C. The net reproductive rate (R_0) at 27.5 and 30 °C was significantly higher than 25 and 32.5 °C ($P = 0.017$, $F = 3.69$, $df = 3{,}56$). The lowest R_0 value (3.19 ± 1.18) was observed at 32.5 °C without significant difference with 25 °C. The intrinsic rate of increase (r_m) increased as temperature increased from 25 to 30 °C and then decreased at 32.5 °C ($P < 0.001$, $F = 10.35$, $df = 3{,}56$). The highest values of r_m was observed at 30 (0.056) and 27.5 °C (0.052) that were significantly higher than its values at 25 °C (0.032) and 32.5 °C (0.028). No significant difference was observed in r_m values between 30 and 27.5 °C; moreover the difference between 25 and 32.5 °C was not significant. The intrinsic rate of increase is a function of insect fecundity, survival rate and mean generation time. The highest intrinsic rate of birth (b) was achieved at 30 °C, which was significantly different from others. The intrinsic rate of birth at 25 °C was significantly lowest than other temperatures. The lowest and highest intrinsic rates of death (d) were observed at 27.5 and 32.5 °C, respectively. The finite rates of increase (λ) showed significant differences between four constant temperatures and similar trend like r_m values was observed for this parameter ($P < 0.001$, $F = 10.45$, $df = 3{,}56$). The mean generation time (T) decreased significantly with increasing in temperature form 25 to 30 °C ($P < 0.001$, $F = 162.35$, $df = 3{,}56$). Its value decreased at higher temperature point (32.5 °C), however no significant difference was observed between 30 and 32.5 °C. Among the measured population growth parameters, only doubling time (*DT*) did not show significant differences among the four experimental temperatures.

Discussion

The optimal temperature range for pistachio's trees growth is 25–35 °C during the growing season (Hokmabadi, 2011). The data achieved in this study provide more realistic information on the development and survival of *A. komaroffi* under laboratory conditions at an optimum temperature range for pistachio trees growing. The results provide a basis for understanding the biology and ecology of this pest and development of control measures. Temperature is one of the most important factors that influence the life cycle of insects (Roy et al., 2003). Estimation of life history parameters under a constant temperature range when including the total life cycle such as developmental and survival rates and reproduction, allows estimation of temperature-dependent growth potential of the insect pests (Greenberg et al., 2005; Dong et al., 2007). In this research, the variations in *A. komaroffi* fertility life table statistics were investigated at different constant temperatures.

Table 2
Immature mortality rate (%) of *A. komaroffi* at four constant temperatures.

Temperature °C	Mortality percentage							
	Larva						Pupa	Egg-to-adult
	Egg	1st instar	2nd instar	3rd instar	4th instar	5th instar		
25.0	2.99 ($n = 134$)	17.16 ($n = 130$)	11.19 ($n = 107$)	5.97 ($n = 92$)	5.22 ($n = 84$)	10.45 ($n = 77$)	2.24 ($n = 63$)	55.22 ($n = 134$)
27.5	6.20 ($n = 129$)	9.30 ($n = 121$)	6.20 ($n = 109$)	2.33 ($n = 101$)	3.88 ($n = 98$)	11.63 ($n = 93$)	7.75 ($n = 78$)	47.29 ($n = 129$)
30.0	7.14 ($n = 140$)	21.43 ($n = 130$)	3.57 ($n = 100$)	3.57 ($n = 95$)	2.14 ($n = 90$)	8.57 ($n = 87$)	8.57 ($n = 75$)	55.00 ($n = 140$)
32.5	17.92 ($n = 106$)	16.98 ($n = 87$)	4.72 ($n = 69$)	4.72 ($n = 64$)	12.26 ($n = 59$)	12.26 ($n = 46$)	3.77 ($n = 33$)	72.64 ($n = 106$)

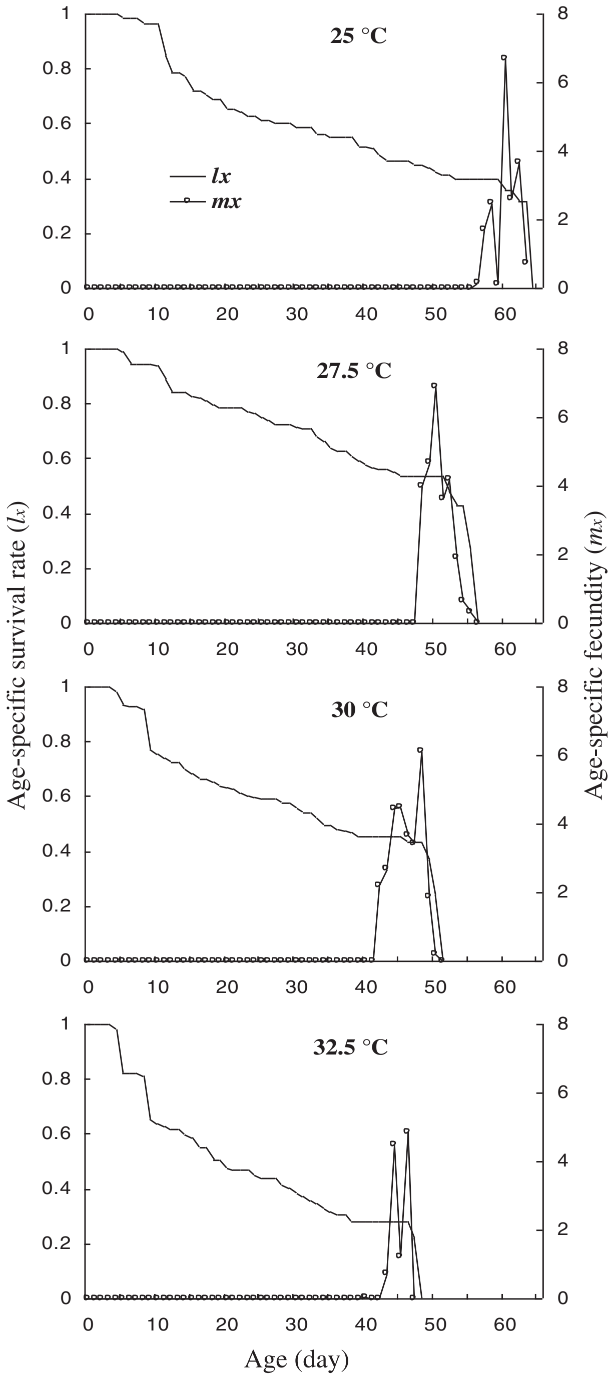

Fig. 1. Age-specific fecundity and survival rate of *A. komaroffi* at four constant temperatures.

The temperatures encountered by *A. komaroffi* played a critical role in its survival, development and adult reproductive success. Developmental time of all immature life stages of *A. komaroffi* is significantly influenced by temperature which is in agreement with those collected by different authors on different insect pests (Tsai and Liu, 1998; Kersting et al., 1999; Wang et al., 2000; Roy et al., 2002; Zamani et al., 2006; Liu and Meng, 2007; Golizadeh et al., 2009). In this study, the total developmental time decreased as temperature increased from 25–32.5 °C, and the developmental period among examined temperatures was the shortest at 32.5 °C. This result suggested that 32 °C is within the suitable temperature range, and it seems to be the optimal temperature for development of *A. komaroffi* among the examined temperatures. However, the mortality rate of the whole immature stage from egg to adult was the highest at 32.5 °C. The survival rate was extremely low at extreme examined temperature indicating that higher temperature retards survivorship.

Although the temperature had not significant effect on the male and female adults longevity, but reproductive parameters were significantly affected by temperature. In the net reproduction parameters, the probability of insect survival is considered while this probability is ignored in gross reproduction parameters. Most reproductive parameters including net fecundity and fertility rates, daily numbers of total egg and fertile egg per female were significantly higher at 27.5 and 30 °C than other temperatures. These parameters were significantly lower at two extreme temperatures. This indicates that its reproductive parameters were negatively affected by the relative warm and cold temperatures. This finding suggests that two temperature points (27.5 and 30 °C) are optimum for *A. komaroffi* reproduction.

The effects of temperature on reproductive parameters showed similar pattern for fertility life table parameters and most of these parameters were severely influenced by temperature. Among the fertility life table parameters, the intrinsic rate of increase (r_m) is a good indicator of the temperature at which the growth of population is most favorable, because it reflects the overall effects of temperature on development, survival rate and reproduction characteristics of a population (Southwood, 1978). This parameter is the only statistic which is able to suitably present the physiological qualities of an insect pest relative to its capacity of increase (Andrewartha and Birch, 1954; Wang et al., 2000). Intrinsic rate of increase has been considered as the most perfect parameter to compare the growth differences of a population under various conditions (Aldyhim and Khalil, 1993; Tsai and Liu, 1998; Wang and Tsai, 2001; Kuo et al., 2006; Golizadeh et al., 2012). Although development rate (reciprocal of development time) of *A. komaroffi* was highest at 32.5 °C however the populations kept at 27.5 and 30 °C showed the highest r_m value among the tested temperatures (r_m = 0.052 and 0.056, respectively). The result obtained due to its relative faster development, the higher survivorship of immature stages and as well as high net reproductive rate (R_0) and daily rate of progeny at 27.5 and 30 °C. The population exposed to 32.5 °C had a higher immature stage mortality rate (72.64%) and statistically lower fertility rate, resulting in a much smaller intrinsic rate of increase (0.028 female/

Table 3
Reproduction parameters of *A. komaroffi* at four constant temperatures.

Parameters	Temperature °C			
	25.0	27.5	30.0	32.5
Gross fecundity rate	35.00 ± 8.05 [ab]	50.65 ± 7.63 [a]	56.05 ± 5.51 [a]	21.89 ± 8.08 [b]
Gross fertility rate	34.51 ± 7.94 [ab]	48.62 ± 7.33 [a]	53.81 ± 5.29 [a]	19.04 ± 7.03 [b]
Net fecundity rate	12.06 ± 3.48 [b]	25.34 ± 4.09 [a]	23.65 ± 2.41 [a]	5.82 ± 2.08 [b]
Net fertility rate	11.90 ± 3.43 [b]	24.32 ± 3.93 [a]	22.70 ± 2.32 [a]	5.06 ± 1.81 [b]
Eggs/female/day	0.31 ± 0.09 [b]	0.63 ± 0.10 [a]	0.75 ± 0.08 [a]	0.24 ± 0.09 [b]
Fertile eggs/female/day	0.31 ± 0.09 [b]	0.61 ± 0.10 [a]	0.72 ± 0.07 [a]	0.21 ± 0.07 [b]

Mean values followed by the same letter in the each row are not significantly different ($P < 0.05$; Duncan after one-way ANOVA).

Table 4
Population growth parameters of *A. komaroffi* at four constant temperatures.

Parameters	Temperature °C			
	25.0	27.5	30.0	32.5
Gross reproductive rate (*GRR*)	18.20 ± 4.19 [ab]	26.34 ± 3.97 [a]	29.14 ± 2.87 [a]	11.38 ± 4.20 [b]
Net reproductive rate (R_0)(female offspring)	6.45 ± 1.83 [b]	13.48 ± 2.14 [a]	12.69 ± 1.24 [a]	3.19 ± 1.18 [b]
Intrinsic rates of increase (r_m) (day^{-1})	0.032 ± 0.005 [b]	0.052 ± 0.003 [a]	0.056 ± 0.002 [a]	0.028 ± 0.009 [b]
Finite rates of increase (λ) (day^{-1})	1.032 ± 0.005 [b]	1.053 ± 0.003 [a]	1.058 ± 0.002 [a]	1.028 ± 0.009 [b]
Mean generation time (*T*) (day)	59.90 ± 0.50 [a]	50.14 ± 0.36 [b]	45.49 ± 0.47 [c]	44.96 ± 0.52 [c]
Doubling time (*DT*) (day)	21.31 ± 3.36 [a]	13.24 ± 0.86 [a]	12.37 ± 0.52 [a]	20.99 ± 11.69 [a]

Mean values followed by the same letter in the each row are not significantly different ($P < 0.05$; Duncan after one-way ANOVA).

female/day). The higher immature stage mortality rate at 32.5 °C is reflected by a sharp decline in age-specific survival rates (l_x) comparing with other temperatures (Fig. 1). Female moths produced their eggs over a period of approximately 1 week and the oviposition peak of most females occurred about in their mid-age (Fig. 1).

Arimania komaroffi has emerged as an important pest in the pistachio cultivation areas in Iran, recently. In the current study, we were able to make direct comparisons of some life history features of *A. komaroffi* related rearing temperature at an optimal temperature range for pistachio trees. In conclusion, our results clearly show that temperature has the strong effect on the development and survival rate and reproduction potential of *A. komaroffi*, which plays an important role in regulating the phenology, seasonal abundance and growth of populations. However, other abiotic and biotic effective factors on population growth of *A. komaroffi* should be evaluated for full understanding. Although insects are not always subject to constant temperatures in nature, a controlled laboratory studies can provide crucial detailed information about the population dynamics of *A. komaroffi*. The highest intrinsic rate of increase (r_m) and net reproductive rate (R_0) were observed at 27.5 and 30 °C, indicating a high capita growth rate within this temperature range. This information could be valuable in contribution and improvement of an integrated pest management programs. Future studies should include an evaluation of temperature effects on performance of *A. komaroffi* under field conditions in order to fully assess temperature effect on its life history.

Acknowledgments

We thank the Pistachio Research Institute of Iran, for valuable cooperation and available facilities. This project is part of a PhD dissertation of the senior author that was funded by University of Mohaghegh Ardabili.

References

Aldyhim, Y.N., Khalil, A.F., 1993. Influence of temperature on population development of *Aphis gossypii* on *Cucurbita pepo*. Entomol. Exp. Appl. 67, 167–172.
Amsel, H.G., 1954. Die Microlepidopteren der Brandt'schen Iran Ausbeute, 4 Teil. Ark. Zool. 2, 255–326.
Andrewartha, H.G., Birch, L.C., 1954. The Distribution and Abundance of Animals. The University of Chicago Press, Chicago.
Carey, J.R., 1993. Applied Demography for Biologists with Special Emphasis on Insects. Oxford University Press, New York.
Dong, P., Wang, J.J., Jia, F.X., Hu, F., 2007. Development and reproduction of the psocid *Liposcelis tricolor* (Psocoptera: Liposcelididae) as a function of temperature. Ann. Entomol. Soc. Am. 100, 228–235.
FAO, 2013. Annual report Available at: http://www.fao.org.
Garcia, J.M., Agar, I.T., Streif, J., 1992. Fat content and fatty acid composition in individual seeds of pistachio varieties grown in Turkey. Gartenbauwissenschaft 57, 130–133.
Golizadeh, A., Kamali, K., Fathipour, Y., Abbasipour, H., 2009. Effect of temperature on life table parameters of *Plutella xylostella* (Lepidoptera: Plutellidae) on two brassicaceous host plants. J. Asia Pac. Entomol. 12, 207–212.
Golizadeh, A., Razmjou, J., Rafiee-Dastjerdi, H., Hassanpour, M., 2012. Effect of temperature on demographic parameters of potato tuberworm, *Phthorimaea operculella* (Lepidoptera: Gelechiidae) on potato tuber. Am. J. Potato Res. 89, 150–158.
Greenberg, S.M., Setamou, M., Sappington, T.W., Liu, T.X., Coleman, R.J., Armstrong, J.S., 2005. Temperature-dependent development and reproduction of the boll weevil (Coleoptera: Curculionidae). Insect Sci. 12, 449–459.
Hashemi-Rad, H., Alavi, S.H., 2014. Study on the biology and damage of pistachio borer moth, (*Arimania komaroffi* Rag.) in Kerman province. Proceeding of 1st Iran's Pistachio Conference, 31 August - 1 September, Kerman, Iran, pp. 266–278 (in Persian).
Hokmabadi, H., 2011. Diagnostic of Environmental and Non-environmental Damaging Factors Incoming to Pistachio Product. Agricultural Research and Education Organization, Tehran, Iran (in Persian).
Kersting, U., Satar, S., Uygun, N., 1999. Effect of temperature on development rate fecundity of apterous *Aphis gossypii* Glover (Homoptera: Aphididae) reared on *Gossypium hirsutum* L. J. Appl. Entomol. 123, 23–27.
Kuo, M.H., Lu, W.N., Chiu, M.C., Kuo, Y.H., Hwang, S.H., 2006. Temperature-dependent development and population growth of *Tetraneura nigriabdominalis* (Homoptera: Pemphigidae) on three host plants. J. Econ. Entomol. 99, 1209–1213.
Liu, S.S., Meng, X.D., 2007. Modelling development time of *Lipaphis erysimi* (Hemiptera: Aphididae) at constant and variable temperatures. B. Entomol. Res. 90, 337–347.
Maia, A.H.N., Luiz, A.J.B., Campanhola, C., 2000. Statistical influence on associated fertility life table parameters using jackknife technique, computational aspects. J. Econ. Entomol. 93, 511–518.
McPeek, M.A., Kalisz, S., 1993. Population sampling and bootstrapping in complex designs: demographic analysis. In: Scheiner, S.M., Gurevitch, J. (Eds.), Design and Analysis of Ecological Experiments. Chapman and Hall, New York, pp. 232–252.
Mehrnejad, M.R., 2001. The current status of pistachio pests in Iran. Cah. Options Mediterr. 56, 315–322.
Mehrnejad, M.R., 2010. The parasitoids of the pistachio hull borer moth, *Arimania komaroffi*, short report. Appl. Entomol. Phytopathol. 77, 131–133.
Mehrnejad, M.R., 2012. Biological parameters of *Elasmus nudus* (Hymenoptera, Eulophidae), a parasitoid of the pistachio fruit hull borer moth, *Arimania komaroffi* (Lepidoptera, Pyralidae). Biocontrol Sci. Tech. 22, 659–670.
Mehrnejad, M.R., Speidel, W., 2011. The pistachio hull borer moth *Arimania komaroffi* Ragonot (Lepidoptera, Pyralidae). Entomofauna 32, 5–16.
Mehrnejad, M.R., Vahabzadeh, N., Hodgson, C.J., 2015. Relative suitability of the common pistachio psyllid, *Agonoscena pistaciae* (Hemiptera: Aphalaridae), as prey for the two-spotted ladybird, *Adalia bipunctata* (Coleoptera: Coccinellidae). Biol. Control 80, 128–132.
Meyer, J.S., Ingersoll, C.G., McDonald, L.L., Boyce, M.C., 1986. Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. Ecology 67, 1156–1166.
Moderraes Awal, M., 1997. List of Agricultural Pests and Their Natural Enemies in Iran. Ferdowsi University Press, Mashhad, Iran.
Pedigo, L.P., 1989. Entomology and Pest Management. Macmillan Publishing Company.
Roy, M., Brodeur, J., Cloutier, C., 2002. Relationship between temperature and developmental rate of *Stethorus punctillum* (Coleoptera: Coccinellidae) and its prey *Tetranychus mcdanieli* (Acarina: Tetranychidae). Environ. Entomol. 31, 177–187.
Roy, M., Brodeur, J., Cloutier, C., 2003. Effect of temperature on intrinsic rates of natural increase (r_m) of a coccinellid and its spider mite prey. Biocontrol 48, 57–72.
Samet, K., 1974. Three injurious butterflies of pistachio trees in Kerman Province. Proceedings of the 5th Plant Protection Congress of Iran. The University of Azar-abadegan, Tabriz, Iran, pp. 11–12.
Samet, K., 1985. The life cycle of *Arimania komaroffi*, a new pest of *Pistachio vera* in Iran. Entomol. Gaz. 36, 113–115.
Sharpe, P.J.H., DeMichele, D.W., 1977. Reaction kinetics of poikilotherm development. J. Theor. Biol. 64, 649–670.
Sokal, R.R., Rohlf, F.J., 1995. Biometry. 3rd ed. W.H. Freeman and Company, New York.
Southwood, T.R.E., 1978. Ecological Methods. Chapman and Hall, London.
SPSS, 2007. SPSS Base 16.0 User's Guide. SPSS Incorporation, Chicago.
Taylor, F., 1979. Convergence to the stable age distribution in populations of insects. Am. Nat. 113, 511–530.
Taylor, F., 1981. Ecology and evolution of physiological time in insects. Am. Nat. 117, 1–23.
Tsai, J.H., Liu, Y.H., 1998. Effect of temperature on development, survivorship, and reproduction of rice root aphid (Homoptera: Aphididae). Environ. Entomol. 27, 662–666.
Vargas, R.I., Walsh, W.A., Kanehisa, D.T., Jang, E.B., Armstrong, J.W., 1997. Demography of four Hawaiian fruit flies (Diptera: Tephritidae) reared at five constant temperatures. Ann. Entomol. Soc. Am. 90, 162–168.
Wang, J.J., Tsai, J.H., 2001. Development, survival and reproduction of black citrus aphid, *Toxoptera aurantii* (Hemiptera: Aphididae), as a function of temperature. B. Entomol. Res. 91, 477–487.
Wang, J.J., Tsai, J.H., Zhao, Z.M., Li, L.S., 2000. Development and reproduction of the psocid *Liposcelis bostrychophila* (Psocoptera: Liposcelididae) as a function of temperature. Ann. Entomol. Soc. Am. 93, 261–270.
Zamani, A.A., Talebi, A.A., Fathipour, Y., Baniameri, V., 2006. Effect of temperature on biology and population growth parameters of *Aphis gossypii* Glover (Hom., Aphididae) on greenhouse cucumber. J. Appl. Entomol. 130, 453–460.