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Influence of rising temperature on population growth parameters of *Helicoverpa armigera* (Lepidoptera: Noctuidae)

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Abstract

Temperature-dependent life table studies were performed to evaluate the direct effects of rising temperatures (20, 22.5, 25, 30, 35, 37.5, and 40 °C ± 0.5) on *Helicoverpa armigera* (Hübner) (Lep: Noctuidae). The results indicated that *H. armigera* could successfully survive and reproduce at all temperatures tested except at 37.5 and 40 °C (at 37.5 °C, no adults emerged, and at 40 °C, no eggs hatched). However, a significant difference was observed among the mean life table parameters of *H. armigera* at survived temperatures. The constant temperatures of 22.5 and 25 °C were considered the optimum degree of eggs laid by females of *H. armigera*. The intrinsic rate of rise (*r*) at the specified temperatures ranged from 0.080 day−1 at 35 °C to 0.145 day−1 at 22.5 °C. In addition, the value of the net reproductive rate (*R0*) of *H. armigera* at the different temperatures tested varied from 9.22 offspring at 35 °C to 501.01 offspring at 22.5 °C. Furthermore, the values of the gross reproductive rate (*GRR*) were significantly different at the tested temperatures, and the lowest and highest values of this parameter were obtained at 35 °C (42.18 offspring) and 22.5 °C (1056.44 offspring), respectively. Immature mortality increased with increasing temperature. The results obtained in the present study may provide insight into predicting population dynamics and the efficacy of the subsequent management programs for this pest.

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Introduction

The cotton bollworm, *Helicoverpa armigera* (Hübner) (Lep: Noctuidae), is an important pest of many crops in many parts of the world and is reported to attack more than 60 plant species belonging to more than 47 families such as cotton, chickpea, cowpea, soybean, canola, corn, tomato, and eggplant worldwide (Fathipour & Sedaratian, 2013). Direct damage to flowering and fruiting structures of host plants by larvae of *H. armigera*, together with extensive insecticide spraying, results in low yields and high control costs, respectively (Fathipour & Naseri, 2011). A wide host range, multiple generations, migratory behavior, and high fecundity enable *H. armigera* to survive in unstable habitats and become a difficult pest to control (Subramanian & Mohankumar, 2006).

Life table parameters are an important tool in the measurement of the population growth capacity of a species under specific conditions (Southwood & Henderson, 2000). Based on demographic studies, we can estimate extinction probabilities, predict life history evolution, anticipate outbreaks of pest species, and examine the dynamics of colonizing or invading species (Vargas et al., 1997). A number of factors have been shown to affect the demographic parameters of arthropods, and temperature is known to be a key factor in this regard (Medeiros et al., 2003a, b). Temperature is a critical climatic factor with the greatest effect on the developmental rate of immature poikilotherms, especially arthropods. Insect development occurs within a specific temperature range. The response of insects to temperature can be important in predicting the potential geographical range of a species and in developing phenological models to predict population dynamics and the timing of development, reproduction, and dormancy or migration for planning control or survey programs (Keena, 2006).

Warming of the climate system is unequivocal, as is now evident from observations of increases in global

average air and ocean temperatures (IPCC, 2007). Climate change, as realized through trends of temperature rise and increased CO2 concentration, is a major concern. The Effect of climate change is more pronounced in temperate areas; it can affect range expansion, host and enemy synchrony, and interspecific competition. This increase in temperature will accelerate the development of insect pests, possibly resulting in more generations per year. It influences the activity and seasonal population dynamics of insects and sets the limits of biological activities in arthropods (Huffaker et al., 1999). Global warming may affect insect populations in different ways: by altering developmental times, equilibrium population densities, geographical distributions, and insect-plant-interactions (Cornelissen, 2011). As a result, some of the cultivars that are resistant to insect pests may exhibit susceptible reactions under global warming. In addition, the adverse effects of climate change on the activity and effectiveness of natural enemies will be a major concern in future pest management programs.

Understanding the influence of temperature on the survival and reproduction of *H. armigera* may provide insight into predicting population dynamics and the efficacy of subsequent management programs. Several investigations have been carried out on the effects of different host plants and artificial diets on the life table parameters of *H. armigera* (Naseri et al., 2009; Soleimannejad et al., 2010; Karimi et al., 2012; Safuraie-Parizi et al., 2014), but there is no available data regarding the effect of temperature on the demographic parameters of *H. armigera*. Therefore, the objective of this study is to determine the effects of seven constant temperatures on survival, fecundity and life table parameters of *H. armigera*. The obtained results will provide basic information to accurately describe the relationship between the demographic parameters of *H. armigera* and temperature for the establishment of a pest management program.

Materials and Methods

Insect rearing

A laboratory colony of *H. armigera* was established using larvae collected from tomato fields in the Jiroft region of southeast Iran. The stock culture was initiated on an artificial diet (cowpea powder 205 g, powdered agar 14 g, ascorbic acid 3.5 g, sorbic acid 1.1 g, methyl-p-hydroxybenzoate 2.2 g, yeast 35 g, wheat germ powder 30 g, formaldehyde 37% 2.5 ml, sunflower oil 5 ml and distilled water 650 ml) according to Twine (1971). Adult moths were kept in oviposition containers (14 cm diameter and 19 cm height). The open end of the containers was covered with a fine mesh net. A small cotton wick soaked in a 10% honey solution was used for moth feeding. Every day, net pieces containing *H. armigera* eggs were carefully collected and replaced. The newly hatched larvae were utilized for further multiplication of the insect culture and experiments. The laboratory colony of *H. armigera* was maintained in a growth chamber at 25 ± 1 °C, relative humidity of 60 ± 5%, and a photoperiod of 16:8 (L:D) h. *Helicoverpa armigera* was reared for one generation at each temperature before the initiation of the experiments.

Estimating life table parameters

To determine how high temperatures affect the basic demographic parameters of *H. armigera*, age-stage life tables were constructed. Measuring life table parameters were performed at seven constant temperatures (20, 22.5, 25, 30, 35, 37.5, and 40 °C ± 0.5), 60 ± 5% RH, and a photoperiod of 16:8 (L: D) h. At the beginning of experiments, to obtain the same-aged eggs of *H. armigera*, 30 pairs of both sexes of the moth that were reared at the related temperature were maintained inside the oviposition containers (14 cm diameter and 19 cm height). After 24h, the deposited eggs were used for demographic studies (200 eggs for each temperature). After egg hatching, the neonate larvae were individually transferred into the plastic containers (8.5 cm diameter and 3 cm height) containing artificial diet by using a fine camel-hair brush. These experimental units were checked once a day, and the duration, mortality, and survivorship of the pre-maturity stage were recorded. The prepupae were kept in plastic containers (3 cm diameter and 5 cm height) for pupation.

After emergence of adults, females were coupled with males obtained in the same experiment or taken from the colony at the same temperature. Each pair was transferred into transparent plastic containers (11 cm diameter and 12 cm height) for oviposition. A piece of small cotton which soaked in a 10% honey solution, was placed in the oviposition containers to provide a food source of carbohydrates for the moths. The couple was kept together until the end of the study, and the dead males were replaced by new ones. In daily observations, the fecundity, mortality and survivorship of adult females were recorded until the death of all individuals.

Data analysis

The life table data obtained from daily observations of experimental units were used to construct the two-sex life table for *H. armigera*. All life table parameters, including the gross reproductive rate (*GRR*), net

reproductive rate (*R0*), intrinsic rate of increase (*r*), finite rate of increase (λ), and mean generation time (*T*) were computed using the procedure recommended by Chi & Liu (1985) and Chi (1988) using the TWOSEX-MSChart software (Chi, 2023). Bootstrap procedure (with 100,000 samples) was used to estimate the parameters' variances and standard errors. Mean comparisons of the parameters among different temperatures were carried out by the paired bootstrap test using TWOSEX-MSChart software.

Results

Survival and mortality curves

The age specific survivorship (*lx*) (Fig. 1) shows the probability that a new born individual will survive to age *x* and is calculated by pooling of all individuals of both sexes. Age-specific survivorship at the time of adult emergence of *H. armigera* at 20, 22.5, 25, 30 and 35°C was 0.73, 0.70, 0.45, 0.33, and 0.31, respectively, indicating that immature mortality increased with increasing temperature from 20 to 35 °C. And ultimately, there was no adults emerged at 37.5 °C and no eggs hatched at 40 °C.

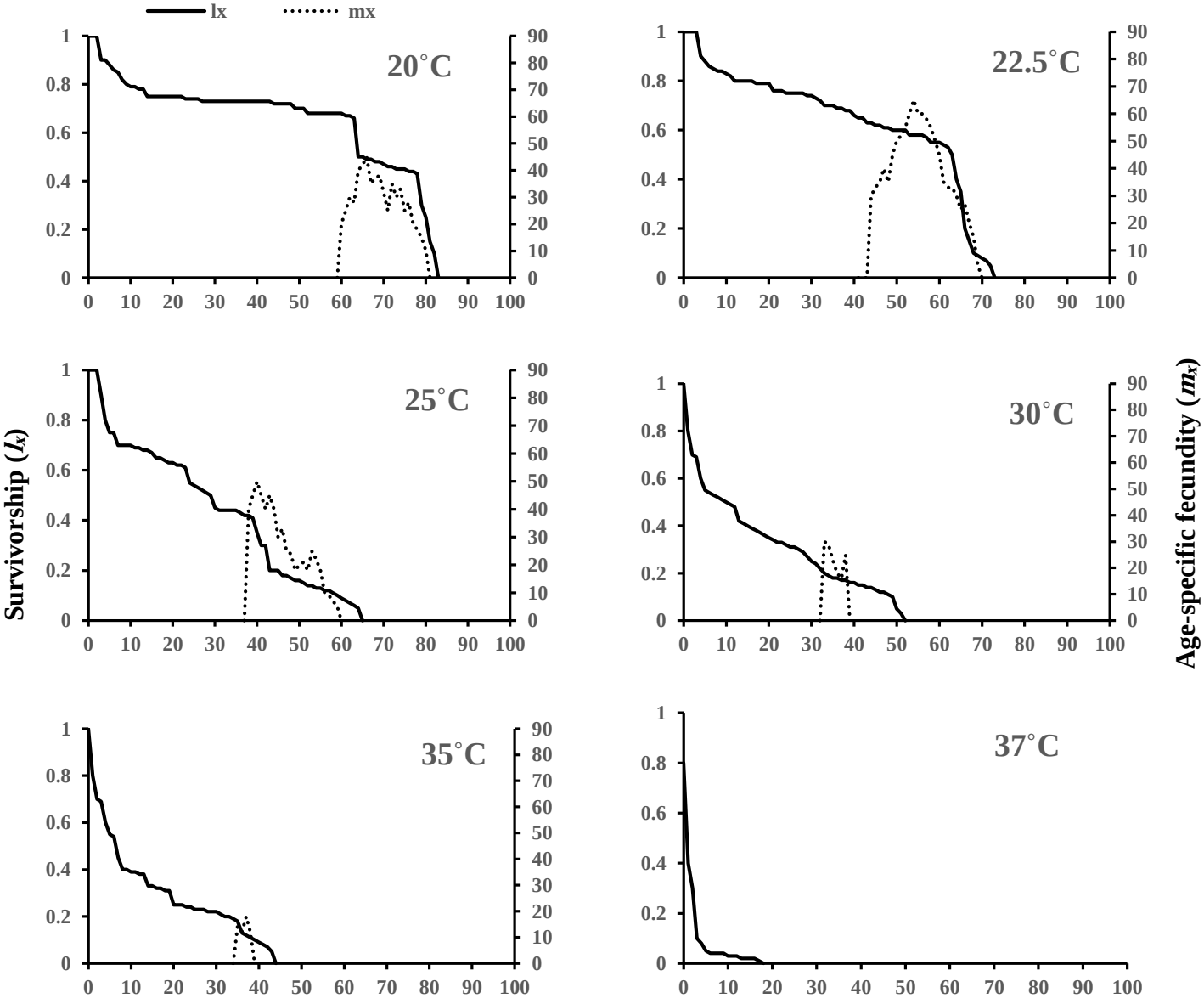

Fig. 1. Age-specific survivorship (*lx*) and age-specific fecundity (*mx*) of *Helicoverpa armigera* at six constant temperatures.

Fecundity curves

Figure 1 shows that age-specific fecundity (*mx*) varied substantially in relation to temperature. The mean daily fecundity (number of eggs per individual) increased from 20 to 22.5 °C but decreased with increasing temperature from 22.5 to 35 °C. The highest peak of female progeny (highest daily fecundity) was at 22.5 °C.

Population growth parameters

Age-stage, two-sex life table parameters were calculated based on data from the entire cohort (Table 1). Development did not reach the adult stage at 37.5 °C, and no eggs hatched at 40 °C; therefore, the population growth parameters were not calculated at these temperatures. However, analysis of the life table parameters of *H. armigera* indicated significant differences among the other five tested temperatures for intrinsic rate of increase (*r*), finite rate of increase (λ), net reproductive rate (*R*0), gross reproductive rate (*GRR*), and mean generation time (*T*).

The intrinsic rate of increase (*r*) at the above-mentioned temperatures varied from 0.080 day−1 at 35 °C to 0.145 day−1 at 22.5 °C. In addition, the value of the net reproductive rate (*R0*) of *H. armigera* at the different temperatures tested varied from 9.22 offspring at 35 °C to 501.01 offspring at 22.5 °C. Furthermore, the values of the gross reproductive rate (*GRR*) were significantly different at the tested temperatures, and the lowest and highest values of this parameter were obtained at 35 °C (42.18 offspring) and 22.5 °C (1056.44 offspring), respectively. In addition, the mean generation time (*T*) decreased with increasing temperature.

Table 1. The mean (±SE) life table parameters of *Helicoverpa armigera* at five constant temperatures.

Parameters	Temperatures				
	20˚C	**22.5˚C**	**25˚C**	**30˚C**	**35˚C**
r (day^{-1})	0.099±0.003^{b}	0.145±0.004^{a}	0.135±0.006^{a}	0.095±0.008^{bc}	0.080±0.008^{c}
λ(day^{-1})	1.104±0.004^{b}	1.156±0.004^{a}	1.144±0.007^{a}	1.099±0.018^{bc}	1.083±0.007^{c}
GRR (offspring)	586.45±60.40^{b}	1056.44±91.48^{a}	590.82±54.63^{b}	170.70±8.19^{c}	42.18±0.51^{d}
R_0 (offspring)	310.10±45.35^{b}	501.01±85.43^{a}	260.32±22.32^{b}	10.80±1.46^{c}	9.22±0.31^{c}
T (day)	57.54±0.47^{a}	43.01±0.39^{b}	41.89±0.30^{b}	25.04±0.54^{c}	27.76±0.27^{c}

*****The means followed by the same letter in each row are not significantly different (Paired bootstrap test, P<0.05).

Discussion

Temperature is the key variable regulating survival, fecundity, and population growth of poikilothermic organisms (Andrewartha, 1970). Information on how temperature can influence life table parameters of an insect pest is essential to develop effective integrated pest management strategies (Diaz & Fereres, 2005). Although insects are not always subject to constant temperatures in nature, a controlled laboratory study can provide valuable insight into the population dynamics of a particular species (Summers et al., 1984).

The obtained results in the current study indicated that the survivorship of *H. armigera* was significantly affected by temperature. According to our results, the survivorship (lx) decreased with increasing temperature from 22.5 to 35 °C, and ultimately, there was no adults emerged at 37.5 °C and no eggs hatched at 40 °C. Mironidis and Savopoulou-Soultani (2008) reported that immature mortality of *H. armigera* increased with increasing temperature from 27.5 to 37.5 °C. And ultimately, there was no development of immature stages at 40°C. This indicated that *H. armigera* reared under higher temperature conditions died faster and earlier, as they were not able to tolerate the higher temperature. Mironidis and Savopoulou-Soultani (2008) indicated that the development time of *H. armigera* decreased with increasing temperature from 17.5 to 32.5 °C, and the shortest development time was recorded 20.91 d (at 32.5°C). Development time is mostly dependent on the metabolic rate of the insects. The metabolic rate of insects' increases linearly with ambient temperature and results in faster development at higher temperatures (Grodzicki & Walentynowicz, 2011).

Zhou et al. (2000) found that the temperature and photoperiod conditions during immature stages significantly affect adult reproductive physiology of *H. armigera*. In this research, the highest total fecundity was at 22.5 °C and after that at 25 °C. Dahi (2010) stated that the constant temperatures of 22 and 27°C

were considered as the optimum degree of eggs laid by female of *H. armigera*, which were 857.4 and 645.5 eggs/ female; respectively. Also, Henneberry and Leal (1979) stated that the reduction in oviposition rate and egg viability at high temperature may due to either killed function sperm or interferes with sperm transfer or both. Generally, the deleterious effect of the high temperature on the adult fecundity are considered as one of the principle factors for the relatively low infestation level during summer season, when temperature is extremely high (Adly et al., 2016).

The life table parameters are powerful tools for analyzing and understanding the impact of an external factor such as temperature (Kheradmand et al., 2007; Jafari et al., 2010; Ganjisaffar et al., 2011; Pakyari et al., 2011; Kouhjani-Gorji et al., 2012), host plant quality (Khanamani et al., 2013; Alipour et al., 2019; Dalir et al., 2021; Khanamani et al., 2021), and pesticide sub-lethal doses (Hamedi et al., 2011; Sedaratian et al., 2014) on growth, survival rate, reproduction, and increase rate of an arthropod population. The intrinsic rate of population increase (*r*) is a good bioclimatic index, in that it reflects the joint influence of temperature on the development, reproduction, and survival characteristics of a population (Messenger, 1964). According to our results, the *r* values of *H. armigera* estimated ranged from 0.080 day−1 (at 35 °C) to 0.145 day−1 (at 22.5 °C). Mironidis & Savopoulou-Soultani (2008) reported that the *r* values of *H. armigera* varied from 0.06 (at 17.5°C) to 0.15 (at 27.5°C). The differences between these findings may be due to the source of *H. armigera* populations in different geographical conditions, different diets, and different rearing techniques.

In conclusion, this study indicated that the survivorship, reproductive, and growth parameters of *H. armigera* were significantly influenced by temperature. In the current study, the optimum temperature for population increase of *H. armigera* was obtained at 22.5°C and after that at 25 °C, even though the highest development rate was at high temperature. At high temperatures, the smaller *r* value was due to low values of fecundity and survivorship (*lx*). Higher temperatures limited the survival and fecundity of *H. armigera*. If global warming continues, it will influence *H. armigera* negatively and the population growth will be severely affected in the future. However, it is necessary to mention that demographic parameters for climatic simulations may differ at constant and natural (alternating) temperatures. Alternating temperature conditions may allow *H. armigera* to complete its life cycle over a much wider range of temperature levels than constant conditions do.

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Conflict of interest

No potential conflict of interest was reported by the author(s).

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M. Khanamani: Conceptualization, methodology, analyzing, reviewing & editing. **M. Roozkhosh:** Writing original draft preparation, reviewing & editing.

References

Adly, A. M., Ibrahim, A. S. M., & Ahmed, A. F. (2016). Thermal units requirements for development of the American bollworm, *Helicoverpa armigera* (HUBNER.). *Journal of Plant Protection and Pathology, 7(2)*, 115–122

Alipour, Z., Fathipour, Y., Farazmand, A., & Khanamani, M. (2019). Resistant rose cultivar affects life table parameters of two-spotted spider mite and its predators *Phytoseiulus persimilis* and *Amblyseius swirskii* (Phytoseiidae). *Systematic & Applied Acarology*, *24*(9), 1620–1630.

Andrewartha, H. G. (1970). *Introduction to the study of animal populations.* The English Language Book. Society and Methuen & Co., Ltd.

Chi, H., (2023). TWOSEX-MSChart: a computer program for the age-stage, two-sex life table analysis. Taichung, Taiwan: National Chung Hsing University. http://140.120.197.173/ Ecology/prod02.htm.

Chi, H. (1988). Life-table analysis incorporating both sexes and variable development rate among individuals. *Environmental Entomology*, *17*, 26–34.

Chi, H., & Liu, H. (1985). Two new methods for the study of insect population ecology. *Bulletin of Institute of Zoology, Academia Sinica*, *24*, 225–240.

Cornelissen, T. (2011). Climate change and its effects on terrestrial insects and herbivory patterns. *Neotropical entomology*, *40*, 155–163.

Dalir, S., Hajiqanbar, H., Fathipour, Y., & Khanamani, M. (2021) A comprehensive picture of foraging strategies of *Neoseiulus cucumeris* and *Amblyseius swirskii* on western flower thrips. *Pest Management Science*, *77(12)*, 5418–5429.

Diaz, B. M., & Fereres, A. (2005). Life table and population parameters of *Nasonovia ribisnigri* (Homoptera: Aphididae) at different constant temperatures. *Environmental Entomology*, *34*, 527–534.

Dahi, H. F. (2010): Lower threshold of development and accumulated heat units requirements for different stages of the American boll worm, *Helicoverpa armigera* (Hub.). *Bulletin of the Entomological Society of Egypt*, *87*, 225–238.

Fathipour, Y., & Naseri, B. (2011). Soybean cultivars affecting performance of *Helicoverpa armigera* (Lepidoptera: Noctuidae). In T. B., Ng (ed.), *Soybean-biochemistry, chemistry and physiology* (pp. 599–630). In Tech, Rijeka, Croatia, , DOI: 10.5772/14838.

Fathipour, Y., & Sedaratian, A. (2013). Integrated management of *Helicoverpa armigera* in soybean cropping systems. In H. El-Shemy (ed.), *Soybean pest resistance* (pp 231–280). In Tech, Rijeka, Croatia.

Ganjisaffar, F., Fathipour, Y., & Kamali, K. (2011). Temperature-dependent development and life table parameters of *Typhlodromus bagdasarjani* (Phytoseiidae) fed on two-spotted spider mite. *Experimental & Applied Acarology, 55*, 259–272.

Grodzicki, P., & Walentynowicz, K. (2011). Hypometabolism in insects. *Research Signpost 37/661 (2)*, 19–37.

Hamedi, N., Fathipour, Y., & Saber, M. (2011). Sublethal effects of abamectin on the biological performance of the predatory mite, *Phytoseius plumifer* (Acari: Phytoseiidae). *Experimental & Applied Acarology*, 53, 29–40.

Henneberry,T. J., & Leal, M. P. (1979). Pink bollworm: Effect of temperature, photoperiod and light intensity, moth age and mating frequency on oviposition and viability. *Journal of Economic Entomology*, *72*, 489–492.

Huffaker, C. B., Berryman, A., & Turchin, P. (1999). *Dynamics and regulation of insectpopulations*. In C. B. Huffaker & A. P. Gutierrez (eds.), *Ecological Entomology*, (pp. 269–305) (2nd ed.) Wiley, New York.

IPCC (Intergovernmental Panel on Climate Change) (2007). *Climate change 2007: Fourth assessment report of the intergovernmental panel on climate change.* Cambridge Univ. Press, Cambridge.

Jafari, S., Fathipour, Y., Faraji, F., & Bagheri, M. (2010). Demographic response to constant temperatures in *Neoseiulus barkeri* (Phytoseiidae) fed on *Tetranychus urticae* (Tetranychidae). *Systematic & Applied Acarology*, *15*, 83–99.

Karimi, S., Fathipour, Y., Talebi, A. A., & Naseri, B. (2012). Evaluation of canola cultivars forresistance of *Helicoverpa armigera* (Lepidoptera: Noctuidae) using demographic parameters. *Journal of Economic Entomology*. *105*, 2172–2179.

Keena, M. A. (2006). Effects of temperature on *Anoplophora glabripennis* (Coleoptera: Cerambycidae) adult survival,reproduction, and egg hatch. *Enviromental Entomology, 35*, 912–921.

Khanamani, M., Basij, M., & Fathipour, Y. (2021). Effectiveness of factitious foods and artificial substrate in mass rearing and conservation of *Neoseiulus californicus* (Acari: Phytoseiidae). *International Journal of Acarology*, *47(4)*, 273–280.

Khanamani, M., Fathipour, Y., & Hajiqanbar, H. (2013). Population growth response of

Tetranychus urticae to eggplant quality: application of female age-specific and age-stage, two-sex life tables. *International Journal of Acarology, 39*, 638–648.

Kheradmand, K., Kamali, K., Fathipour, Y., & Mohammadi-Goltapeh, E. (2007). Development, life table and thermal requirement of *Tyrophagus putrescentiae* (Astigmata: Acaridae) on mushrooms. *Journal of Stored Products Research, 43*, 276–281.

Kouhjani-Gorji, M., Fathipour, Y., & Kamali, K. (2012). Life table parameters of *Phytoseius plumifer* (Phytoseiidae) fed on two-spotted spider mite at different constant temperatures. *International Journal of Acarology*, *38*, 377–385.

Medeiros, R. S., Ramalho, F. S., Zanuncio, J. C., & Serrão, J. E. (2003a). Estimate of *Alabama argillacea* (Hübner) (Lepidoptera: Noctuidae) development with nonlinear models. *Brazilian Journal of Biology*, *63*, 589–598.

Medeiros, R.S., Ramalho, F.S., Zanuncio, J.C., & Serrao, J.E. (2003b). Effect of temperature on life table parameters of *Podisus nigrispinus* (Het. Pentatomidae) fed with *Alabama argillacea* (Lep. Noctuidae) larvae. *Journal of Applied Entomology*, *127*, 209–213.

Messenger, P. S. (1964). Use of life tables in bioclimatic study of an experimental aphid *Braconid* wasp host parasite system. *Ecology, 45*, 119–131.

Mironidis, G. K., & Savopoulou-Soultani, M. (2008). Development, survivorship, and reproduction of *Helicoverpa armigera* (Lepidoptera: Noctuidae) under constant and alternating temperatures. *Environmental Entomology, 37*(1), 16–28.

Naseri, B., Fathipour, Y., Moharramipour, S., & Hosseininaveh, V. (2009). Life table parameters of the cotton bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae) on different soybean cultivars. *Journal of Entomological Society of Iran*, *29*, 25–40.

Pakyari. H., Fathipour, Y., Enkegaard, A., 2011. Effect of temperature on Life table parameters of predatory Thrips *Scolothrips longicornis* (Thysanoptera: Thripidae) fed on two spotted spider mites (Acari: Tetranychidae). *Journal of Economic Entomology, 104*, 799–805.

Safuraie-Parizi, S., Fathipour, Y., & Talebi, A. A. (2014). Evaluation of tomato cultivars to *Helicoverpa armigera* using two-sex life table parameters in laboratory. *Journal of Asia Pacific Entomology, 17*, 837–844.

Sedaratian, A., Fathipour, Y., & Talaei-Hassanloui, R. (2014). Deleterious effects of *Bacillus thuringiensis* on biological parameters of *Habrobracon hebetor* parasitizing *Helicoverpa armigera*. *BioContro, l59*, 89–98.

Soleimannejad, S., Fathipour, Y., Moharramipour, S., & Zalucki, M. P. (2010). Evaluation of potential resistance in seeds of different soybean cultivars to *Helicoverpa armigera* (Lepidoptera: Noctuidae) using demographic parameters and nutritional indices. *Journal of Economic Entomology*, *103(4)*, 1420–1430.

Southwood, T. R. E., & Henderson, P. A. (2000). *Ecological methods.* (3rd ed.). Blackwell, Oxford, United Kingdom.

Subramanian, S., & Mohankumar, S. (2006). Genetic variability of the bollworm, *Helicoverpa armigera*, occurring on different host plants. *Journal of Insect Science*, *6(1)*, 26.

Summers, C. G., Coviello, R.. L, & Gutierrez, A. P. (1984). Influence of constant temperatures on the development and reproduction of *Acyrthosiphum kondori* (Homoptera: Aphididae). *Environmental Entomology*, *13*, 236–242.

Twine, B. H. (1971). Cannibalistic behaviour of *Heliothis armigera* (Hübner). *Queensland Journal of Agricultural & Animal Sciences, 28*, 153–157.

Vargas, R. I., Walsh, W. A., Kanehisa, D., Jang, E. B., & Armstrong, J. W. (1997). Demography of four Hawaiian fruit flies (Diptera: Tephritidae) reared at five constant temperatures. *Annals of the Entomological Society of America*, *90(2)*, 162–168.

Zhou, X., Coll, M., & Applebaum. S. W. (2000). Effect of temperature and photoperiod on juvenile hormone biosynthesis and sexual maturation in the cotton bollworm, *Helicoverpa armigera*: implications for life history traits. *Insect Biochemistry and Molecular Biology, 30*, 863–868.