

Influence of *Aphis gossypii* Glover (Hemiptera: Aphididae) density on life table parameters of *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae) under laboratory conditions

Khadijeh Madahi, Ahad Sahragard* and Reza Hosseini

Department of Plant Protection, Faculty of Agriculture, University of Guilan, Rasht, Iran.

Abstract: Life table gives the most comprehensive explanation of the survivorship, development, and reproduction of a population. The life table parameters of an aphidophagous midge, *Aphidoletes aphidimyza* were studied on different densities (5, 10, 20, 40, 60, 80) of third instar nymphs of *Aphis gossypii* as prey in a growth chamber (25 ± 1 °C, $70 \pm 5\%$ RH and a photoperiod of 16L: 8D h). The pre-ovipositional period of female *A. aphidimyza* was reduced as prey density increased with no significant difference. The oviposition periods were 3.833 ± 0.401 and 5.5 ± 0.463 days in lowest and highest prey density, respectively. Fecundity increased significantly with increasing prey density. The lowest fecundity was obtained at density of 5 preys/day (49.667 ± 6.053 eggs) and the highest was at density of 80 preys/day (104.25 ± 7.78 eggs). Intrinsic rate of increase (r_m) ranged from 0.110 ± 0.016 to 0.166 ± 0.014 d⁻¹ with increasing prey density. Net reproductive rate (R_0) was positively dependent on prey density. The peak reproductive values showed that female aphidophagous midge at ages of 17, 18, 19, 22 and 25 days made the highest contribution to the population when reared on 5 to 80 preys in a day, respectively. However, mean generation time (T) ranged from 22.42 ± 0.55 to 24.47 ± 1.04 days. It was concluded that the increase in the density of third instar nymphs of *A. gossypii* significantly affected the demographic parameters of *A. aphidimyza* and it had a better reproductive performance in higher prey densities.

Keywords: *Aphis gossypii*, intrinsic rate, prey density, reproductive values, *Aphidoletes aphidimyza*

Introduction

The cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), is a cosmopolitan, polyphagous species widely distributed in tropical, subtropical and temperate regions (Kersting *et al.*, 1999; Isikber, 2005). It is a major pest of cotton, cucurbits and citrus, and

principally attacks vegetables in fields and greenhouses (Leclant and Deguine, 1994; Parrella *et al.*, 1999; Baniameri and Nasrollahi, 2003). It can also infest other economically important crops such as melon, zucchini, coffee, vegetables (eggplant, okra, sweet pepper, etc.) as well as ornamental plants (*Lantana*, *Hibiscus*, and *Chrysanthemum*) (Razmjou *et al.*, 2006). The cotton aphid not only reduces fruit quantity and quality through direct feeding and honeydew production but also transmits more than 50 plant viruses (Roistacher *et al.*, 1984; Blackman and Eastop, 2000). The population of *A. gossypii* has

Handling Editor: Dr. Yaghoob Fathipour

*Corresponding author, e-mail: sahragard@guilan.ac.ir
Received: 10 February 2013; Accepted: 16 June 2013

strongly increased in main cotton growing areas of Iran, especially in northern regions (Mojeni and Rezvani, 1997; Razmjou *et al.*, 2002). Outbreaks of this insect have been attributed to the development of resistance to insecticides which are known to have injurious effects on populations of insect's natural enemies as well as changes in nutritional and bioclimatic factors in host plants (Isikber, 2005). Biological control of aphids is being increasingly applied on the greenhouse crops (van Lenteren and Woets, 1988; Parrella *et al.*, 1999). However, studies are needed for evaluating more aphidophagous insects because the availability of additional natural enemies of aphids would lead to an increase in successful biological control of aphids under various situations.

The predacious gall midge, *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae), is a specialist effective predator of many aphid species worldwide in greenhouses, on field crops, and fruit trees (Morse, 1981; Markkula and Tittanen, 1985; Malais and Ravensberg, 1992) and has a wide geographical distribution (Xie *et al.*, 2000). Since 1973, this gall midge has been commercially used in many countries as one of the most effective biological control agents against aphids, particularly on greenhouse crops, and has proven effective (e.g., Asyakin, 1973; Markkula *et al.*, 1979; Adams and Prokopy, 1980; Havelka, 1980, 1982; Meadow *et al.*, 1985; Morse and Croft, 1987; Nijveldt, 1988; Kulp *et al.*, 1989; Solarska, 2004). It shows great promise as a biological control agent because of its high degree of density-dependency (El-Titi, 1973; Stewart and Walde, 1997), its inclination to kill more aphids than it consumes (Uygun, 1971), and its compatibility with many pesticides (Warner and Croft, 1982; Meadow *et al.*, 1985). Larvae of this species feed on a wide variety of aphids, at least 80 species have been recorded as its hosts (Yukawa *et al.*, 1998), e. g. *A. pomi* DeGeer (Adams and Prokopy, 1980; Jokinen, 1980; Morse and Croft 1987); *A. spiraecola* Patch (Brown, 2004), *Dysaphis plantaginea* Pass. (Wyss *et*

al., 1999); *Myzus persicae* Schultzer (Meadow *et al.*, 1985; Choi *et al.*, 2001), *Diuraphis noxia* Kurdjumov (Tóth *et al.*, 2009); *Brevicoryne brassicae* L. (Raworth *et al.*, 1984), as well as the cereal aphids, *Rhopalosiphum padi* Linnaeus, *Sitobion avenae* Fabricius and *Metopolophium dirhodum* Walker (Dixon, 1997; Schmidt *et al.*, 2004).

Among the life table parameters, intrinsic rate of increase (r_m) is a key demographic parameter useful to predict the population growth potential of an animal under a given environmental condition (Ricklefs and Miller, 1999; Southwood and Henderson, 2000) and may help predict the outcomes of pest–natural enemy interactions (Roy *et al.*, 2003). Besides being a measure of population growth, r_m has been widely used to estimate the insect response to resistant plants (Ruggle and Gutierrez, 1995), and in comparison of different food types that predators consume (Engel, 1990). Furthermore, construction of life fertility tables may help improve pest management (Toapanta *et al.*, 2005). Chi and Liu (1985) and Chi (1988) developed an age-stage two-sex life table theory. Age-stage two-sex life table theory has been applied to insect pests (Gabre *et al.*, 2005; Silva *et al.*, 2006; Yin *et al.*, 2009; Bailey *et al.*, 2010; Huang and Chi, 2011); and predator life table and predation rate studies (Chi and Yang, 2003; Yu *et al.*, 2005; Mo and Liu, 2006).

The main objective of this study was to assemble, describe, and analyze life table parameters for *A. aphidimyza* population exposed to different densities of third instar nymphs of *A. gossypii*. We analyzed the data to find out the effect of prey density on life table parameters such as age-stage specific survival and fecundity, reproductive value, expected remaining life time, net reproductive value (R_0), intrinsic rate of increase (r_m), mean generation time (T), and finite rate of increase (λ). These parameters can be used to estimate the rate of increase of a natural or released population (El Hag and Zaitoon, 1996).

Materials and Methods

Rearing prey and predator

Third instar nymphs of *A. gossypii* were collected from cucumber fields in Rasht and Pir-bazaar region, Guilan Province (Northern Iran) and reared on cucumber (cultivar: Super dominus) in a greenhouse at University of Guilan. Larvae of *A. aphidimyza* were collected from the colony of *A. gossypii* in an infested cucumber field. The predators were reared for one generation on different nymphal instars of *A. gossypii* before starting the life table experiments.

Experimental conditions

All aphids and predator stocks were kept in a growth chamber at 25 ± 1 °C, $70 \pm 5\%$ relative humidity (RH), and a photoperiod of 16:8 h. (L: D).

Life table study

Tests were undertaken after rearing the population under constant laboratory conditions as mentioned above for one generation. To obtain eggs of the predator, a stock culture of *A. aphidimyza* were kept in laboratory and visited frequently in a day. Newly hatched 1st instar larvae of *A. aphidimyza* were transferred and placed individually in experimental transparent plastic containers ($15 \times 13 \times 3$ cm) and offered densities of 5, 10, 20, 40, 60 and 80 third instar nymphs of *A. gossypii* every day to study their life table parameters. The duration of the successive developmental stages and the mortality were recorded. The number of prey consumed was counted daily at each prey density level to determine the total number of prey consumed (from 1st instar larva to pupa). Prior to pupation, mature larvae were individually transferred to larger transparent plastic containers ($19 \times 16 \times 6$ cm) to change into pupa in a 2-3 cm layer of moist fine sand which had been sterilized in an autoclave (20 minutes at 120 °C). The pupae were left in the containers until the emergence of adults (Havelka and Zemek, 1988). After adult emergence, the gall midges from the same prey

densities were allowed to mate, and then were transferred to individual experimental arenas as described earlier in pupal stage. Adults were fed on few strips of paper (1×7 cm) soaked in sucrose solution placed on the corners of containers. Then, they were provided with the same densities of prey similar to their immature stages. The *A. aphidimyza* adult females and male mortality and number of eggs laid were recorded daily until all adults died. The number of replicates was 20 for each prey density.

Statistical analysis

Data were analyzed using age-stage, two-sex life table theory. Therefore, developmental time of all individuals and female daily fecundity were analyzed according to the age-stage, two-sex life table theory (Chi and Liu, 1985; Chi, 1988). Data analysis and population parameters were calculated using the TWOSEX-MSChart program designed in visual BASIC for the Windows operation system (Chi, 2005). The TWOSEX-MSChart is available at <http://140.120.197.173/Ecology/prod02.htm> (Chung Hsing University) and <http://nhsbig.inhs.uiuc.edu/wes/chi.html> (Illinois Natural History Survey). The Jackknife method (Meyer *et al.*, 1986; Sokal and Rohlf 1995) was used to calculate the means and standard errors of the life table parameters. We used Duncan procedure to compare the differences among treatments following the description of Sokal and Rohlf (1995).

Results

The adult pre-ovipositional periods (APOP), that is the duration from adult emergence to first oviposition, was higher in females fed on 5 preys per day during their larval stage than those fed on higher prey densities but without any significant differences. The total pre-ovipositional periods (TPOP) in different prey densities, that are the duration from egg to first oviposition, did not differ significantly ($F = 1.85$; $df = 5, 40$; $P = 0.129$). There were also no significant differences in oviposition periods of the female predator on different prey densities

per day ($F = 1.91$; $df = 5, 40$; $P = 0.117$). The density provided to immature stages and adults had also no significant effect on female longevity ($F = 1.17$; $df = 5, 40$; $P = 0.343$). However, the fecundity was affected positively by prey density (Fig. 1). Total fecundity of females fed on 5 preys per day during their larval stage, was significantly lower than those fed on other prey densities per day. Similarly, the highest fecundity was observed in females fed on 80 prey per day during their larval stage ($F = 9.61$; $df = 5, 40$; $P < 0.0001$) (Table 1).

Results showed that increasing prey density affected the intrinsic rate of increase (r_m), the finite rate of increase (λ) and the net reproduction rate (R_0). The intrinsic rate of increase (r_m) increased significantly with increasing prey density ($F = 5.34$; $df = 5, 119$; $P = 0.045$). There was no significant difference in finite rates of increase (λ) with increasing prey density ($F = 1.68$; $df = 5, 119$; $P = 0.144$). The net reproductive rate (R_0) of females increased positively by increasing prey density (Fig. 2). The net reproductive rate of females fed on 5 preys per day during their larval stage, was significantly lower than those fed on other prey densities per day. Likewise, females fed on 60 and 80 preys per day during their larval stage had significantly higher net reproductive rate than those fed on other prey densities per day ($F = 9.51$; $df = 5, 119$; $P < 0.0001$). Increasing prey density had no significant effect on mean generation time (T) ($F = 1.64$; $df = 5, 119$; $P = 0.155$) (Table 2).

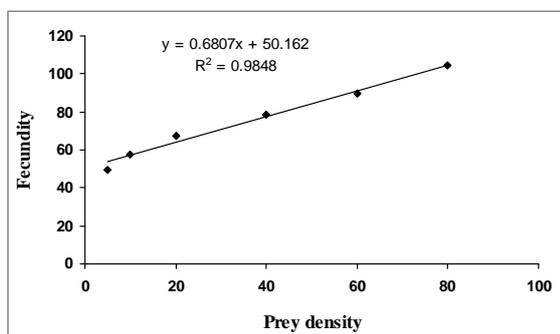


Figure 1 Effect of different densities of *Aphis gossypii* on *Aphidoletes aphidimyza* fecundity at 25 ± 1 °C, $70\% \pm 5\%$ relative humidity, photoperiod 16: 8h (L: D).

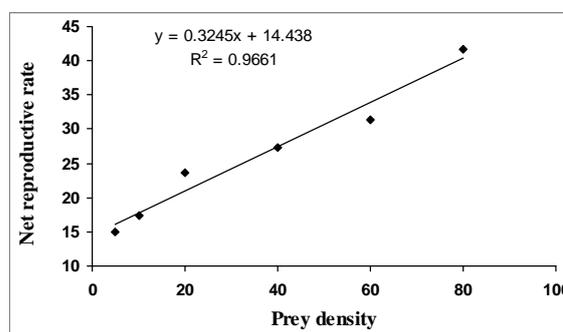


Figure 2 The relationship between net reproductive rate of *Aphidoletes aphidimyza* and different densities of *Aphis gossypii* at 25 ± 1 °C, $70\% \pm 5\%$ relative humidity, photoperiod 16: 8h (L: D).

The contribution of an individual of age x and stage j to the future population is described by the age-stage reproductive value (v_{xj}) (Fig. 3). However, the peak reproductive value appeared at ages of 25 days on 5 preys/day, 22 days on 10 preys/day, 19 days on 20 preys/day, 18 days on 40 preys/day, 17 days on 60 preys/day and 18 days on 80 preys/day. It showed that female aphidophagous midge at ages of 17, 18, 19, 22 and 25 days made the highest contribution to the population when reared on 60, 40 and 80, 20, 10 and 5 prey densities per day, respectively. There was also a positive relationship between the peak reproductive values and prey density ($R^2 = 0.995$) (Fig. 4). The age-specific survival rate (l_x) and fecundity rate (m_x) are shown in Fig. 5. The curve of l_x is a simplified version of the age-stage survival rate (s_{xj}) and describes the change in the survival rate of the cohort with age.

Table 1 Biological parameters, longevity and fecundity of *Aphidoletes aphidimyza* adults reared on different densities of *Aphis gossypii* (Mean \pm SE).

Prey density	APOP*	TPOP*	Oviposition (day)	Female longevity (day)	Fecundity (eggs/female)
5	1.33 \pm 0.211 a	21.83 \pm 0.792 a	3.833 \pm 0.401 a	5.167 \pm 0.307 a	49.667 \pm 6.053 a
10	1.17 \pm 0.167 a	21.5 \pm 0.764 a	4.667 \pm 0.333 a	5.833 \pm 0.401 a	57.833 \pm 5.043 ab
20	1 \pm 0 a	21.29 \pm 0.421 a	5 \pm 0.378 a	6 \pm 0.378 a	67.428 \pm 53.554 bc
40	1 \pm 0 a	21.14 \pm 0.705 a	5.143 \pm 0.404 a	6.143 \pm 0.404 a	78.276 \pm 6.875 bc
60	1 \pm 0 a	19.71 \pm 1.017 a	5.143 \pm 0.404 a	6.285 \pm 0.474 a	89.857 \pm 7.035 cd
80	1 \pm 0 a	19.5 \pm 0.534 a	5.5 \pm 0.463 a	6.5 \pm 0.463 a	104.25 \pm 7.782 d

APOP, adult pre-ovipositional period; TPOP, total pre-ovipositional period (from egg to first oviposition). Within columns, values followed by the same letter do not differ significantly ($P < 0.05$) using Duncan procedure.

Table 2 The population parameters: Intrinsic rate of increase (d^{-1}), finite rate of increase (d^{-1}), net reproductive rate (female offspring/female), mean generation time (day) and gross reproductive rate (female offspring/female) of *Aphidoletes aphidimyza* reared on different densities of *Aphis gossypii*.

Prey density	Intrinsic rate of increase (r)	Finite rate of increase (λ)	Net reproductive rate (R_0)	Mean generation time (T)	Gross reproductive rate (GRR)
5	0.110 \pm 0.016 a	1.117 \pm 0.018 a	14.9 \pm 5.49 a	24.47 \pm 1.04 a	43.9 \pm 20.39 a
10	0.116 \pm 0.015 a	1.123 \pm 0.017 a	17.35 \pm 6.24 ab	24.53 \pm 0.78 a	40.43 \pm 13.52 a
20	0.129 \pm 0.014 b	1.138 \pm 0.016 a	23.6 \pm 7.61 bc	24.37 \pm 0.48 a	53.10 \pm 15.57 b
40	0.138 \pm 0.015 b	1.148 \pm 0.017 a	27.4 \pm 8.87 cd	24.04 \pm 0.72 a	65.15 \pm 18.59 c
60	0.154 \pm 0.016 c	1.166 \pm 0.018 a	31.45 \pm 10.11 d	22.44 \pm 1.06 a	91.6 \pm 45.62 d
80	0.166 \pm 0.014 c	1.181 \pm 0.017 a	41.70 \pm 12.09 d	22.42 \pm 0.55 a	89.25 \pm 45.91 d

Within columns, values followed by the same letter do not differ significantly ($P < 0.05$) using Duncan procedure.

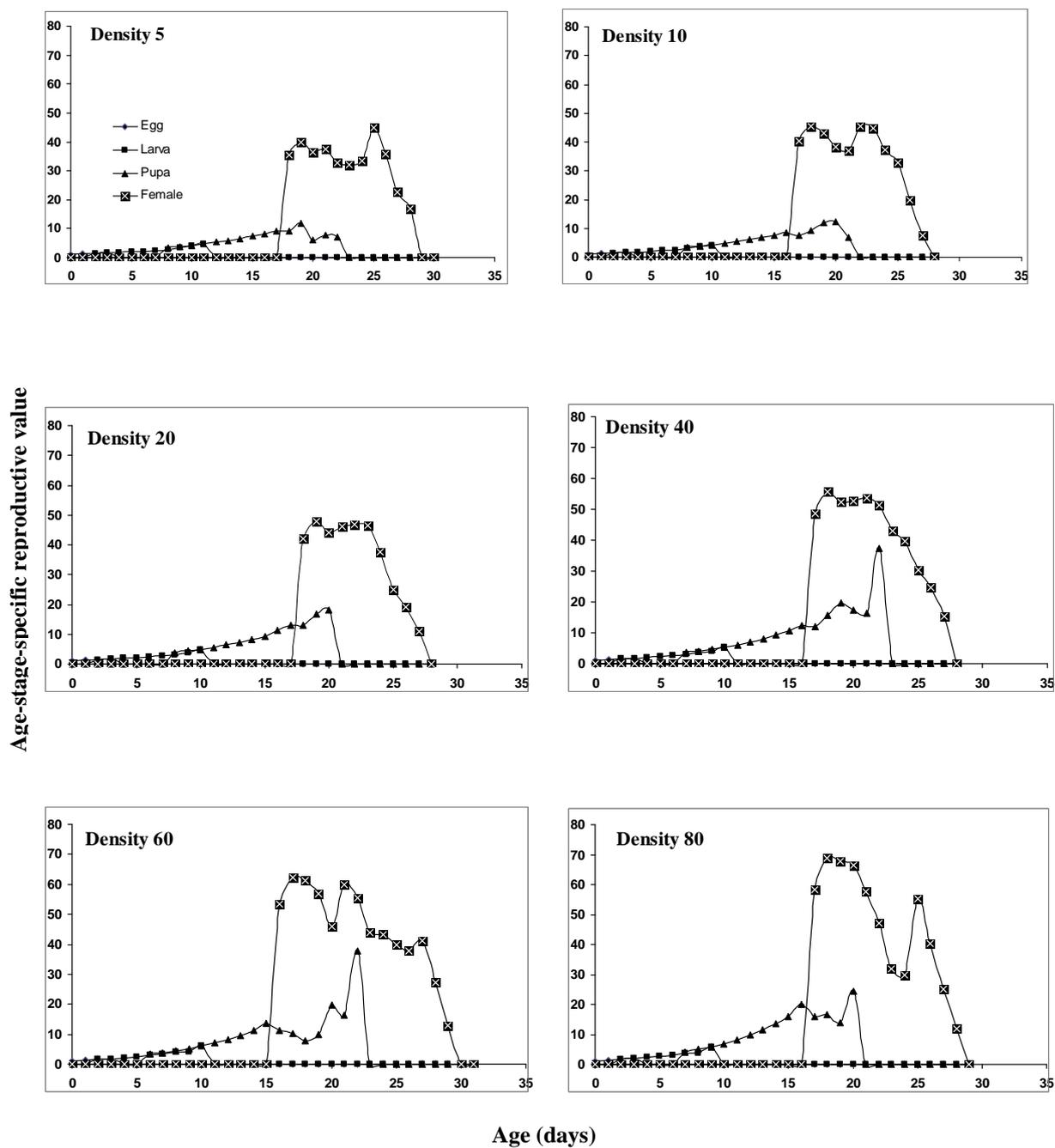


Figure 3. Age-stage-specific reproductive value of *Aphidoletes aphidimyza* fed on different densities of *Aphis gossypii* at 25 ± 1 °C, $70\% \pm 5\%$ relative humidity, photoperiod 16: 8h (L: D).

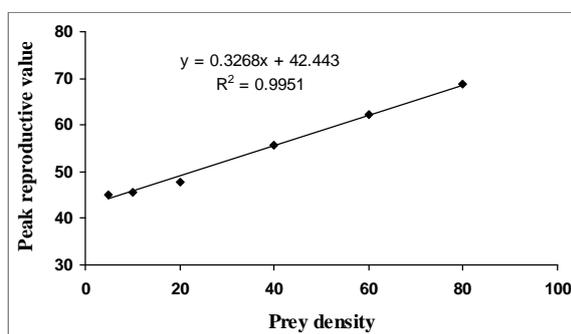


Figure 4 The effect of different densities of *Aphis gossypii* on peak reproductive value of *Aphidoletes aphidimyza* at 25 ± 1 °C, $70\% \pm 5\%$ relative humidity, photoperiod 16: 8h (L: D).

Discussion

In this study, the pre-ovipositional periods (APOP) reduced insignificantly with an increase in prey density. There were also no significant differences in the total pre-ovipositional period (TPOP) of the female predator with increasing prey density. However, Yaşar and Özger (2005) found that increasing prey density resulted in shorter adult pre-ovipositional and total pre-ovipositional periods in *Adalia fasciatopunctata revelierei* (Mulsant). Atlihan and Guldal (2009) also obtained similar results in the study of *Scymnus subvillosus* (Goeze) fed on *Hyalopterus pruni*. The prey density had no significant effect on *A. aphidimyza* oviposition period. Feeding on different prey densities during larval stage had no effects on adults' longevity, but influenced the females fecundity positively. Similar studies showed the effect of prey density on fecundity of predators which are in agreement with the results obtained here (Atlihan and Guldal, 2009, Yaşar and Özger, 2005, Agarwala et al., 2008). The same prey density was offered to *A. aphidimyza* females as in their larval stage, because females strongly prefer to oviposit on plants with high prey density (Messelink et al., 2011). In addition, in previous studies it has been discussed that the variation in fecundity of *A. aphidimyza* might be related to variation in

aphid density, host plant, genetic makeup, larval nutrition and honeydew intake by females (El-Titi, 1973; Mansour, 1975; Havelka and Ruzicka, 1984). The lowest fecundity was obtained at lower prey densities per day, and a rapid increase was found at higher prey density levels. The fecundity ranged between 49.667 to 104.25 eggs at different prey densities and it was nearly close to those reported by Havelka and Zemek (1999) that ranged between 48 and 148 eggs for different populations. According to these results, it can be concluded that an increase in prey density will result in higher reproduction rate. Our results are similar to those of El-Titi (1973); Stewart and Walde (1997) and Lucas and Brodeur (1999), where fecundity of *A. aphidimyza* females increased as a function of aphid density and it was dependent on larval nutrition too. The peak reproductive value of female predator midge was positively density dependent and appeared at ages of 17, 18, 19, 22 and 25 days. It made the highest contribution to the population when reared on 5 preys per day to 80 preys in a day.

The intrinsic rate of increase (r_m), the finite rate of increase (λ) and the net reproduction rate (R_0) were also increased with increasing prey density per day. Atlihan and Guldal (2009) obtained similar trends in demographic parameters of *S. subvillosus* fed on different densities of *H. pruni*. As it was reported by Havelka and Zemek (1999), the values of r_m differed statistically among different populations and ranged between 0.095 and 0.212 d⁻¹, while it ranged from 0.110 to 0.166 at different prey densities in this study. The range of net reproductive rate (R_0) in this study (14.9-41.70 female offspring/female/generation) was somewhat the same as those reported by Havelka and Zemek (1999) (8.57-65.04 offspring). The mean generation time (T) ranged from 22.42 to 24.47 days which was very close to those (18.48 to 23.38 days) found by Havelka and Zemek (1999) on different geographic populations of *A. aphidimyza*.

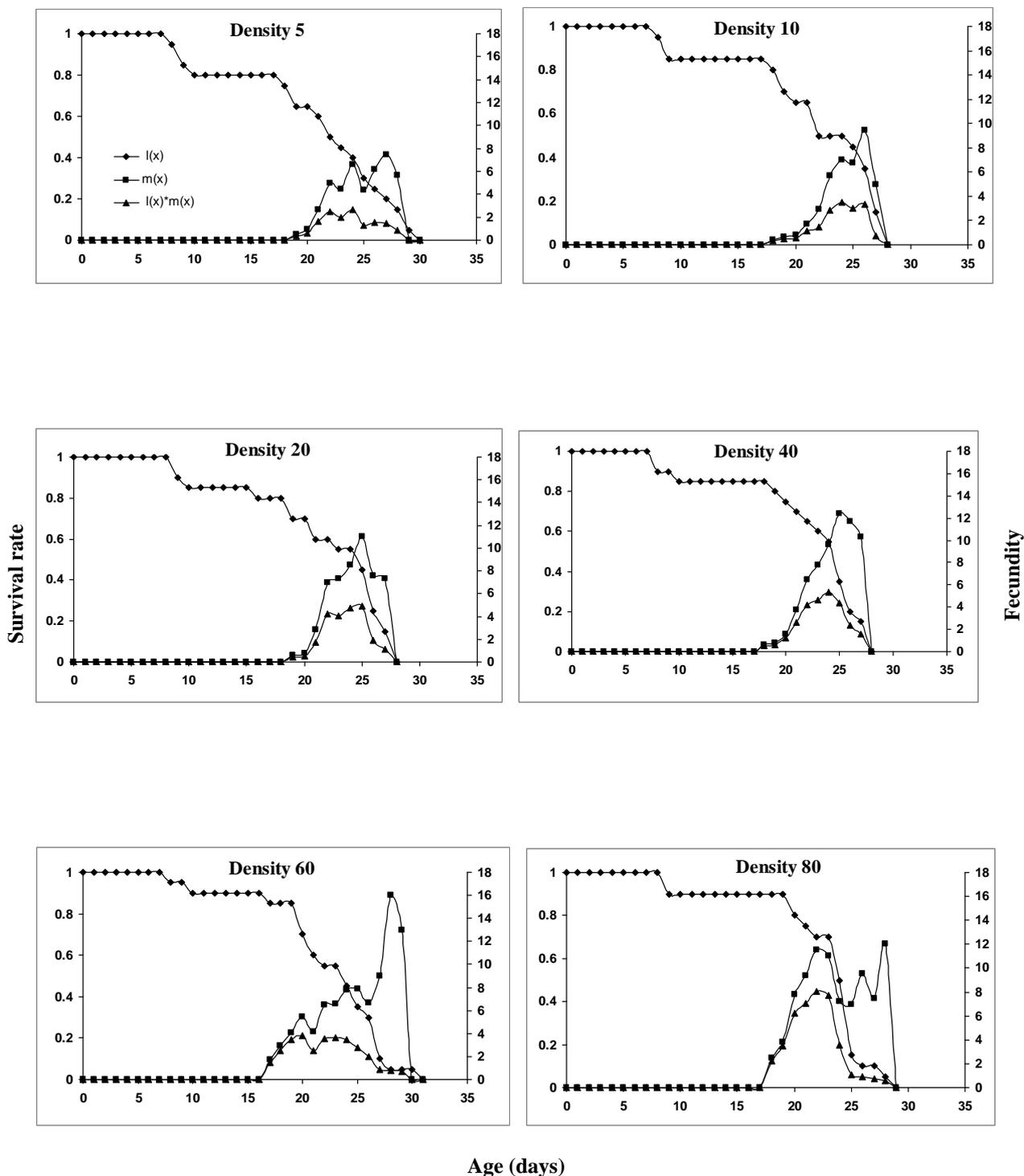


Figure 5 Age-specific survival rate (l_x), age-specific fecundity (m_x) and age-specific maternity ($l_x m_x$) of *Aphidoletes aphidimyza* fed on different densities of *Aphis gossypii* at 25 ± 1 °C, $70\% \pm 5\%$ relative humidity, photoperiod 16: 8h (L: D).

Chi (1988) found that the relationship between the net reproductive rate (R_0) and the mean female fecundity (F) can be described as:

$$R_0 = F * \frac{N_f}{N}$$

where N is the total number of individuals used at the beginning of the life table study and N_f is the number of female adults emerging from these N eggs. It also means $N_f * F = R_0 * N$. In other words, the total number of offspring produced by all females of *A. aphidimyza* equals the net reproductive rate by the cohort size. In our results, the average of $N_f * F$ was 521.321 and $R_0 * N = 521.333$ at different prey densities. This minor difference was due to rounding-off. This relationship showed that the precision is obtainable in the age-stage, two-sex life table analysis (Farhadi et al., 2011). It has also been found some other kind of relationships among life table parameters as Yu et al., (2005) proved a relationship among gross reproduction rate, net reproduction rate, and pre-adult survivorship of *Lemnia biplagiata* (Coleoptera: Coccinellidae) feeding on *A. gossypii*.

Based on the results obtained here, the aphidophagous midge, *A. aphidimyza* can be considered as an effective biological control agent of *A. gossypii*, as it develops successfully to adult stage at all prey densities. However, it is clear that higher prey densities are more favorable than lower ones to rear this predator. It can also be concluded that *A. aphidimyza* is a beneficial natural enemy in the population dynamics of its prey, *A. gossypii*. This study might result in the development of management tactics for the control of aphid pests.

Acknowledgments

We thank the authorities of the College of Agriculture, University of Guilan for providing us research facilities and for their financial support.

References

- Adams, R. G., and Prokopy, R. J. 1980. *Aphidoletes aphidimyza* Rondani (Dip.: Cecidomyiidae): an effective predator of the apple aphid (Hom.: Aphididae) in Massachusetts. Professional Ecology, 2: 27-39.
- Agarwala, B. K., Yasuda, H., and Sato, S. 2008. Life history response of a predatory ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), to food stress. Applied Entomology and Zoology, 43: 183-189.
- Asyakin, B. P. 1973. The use of aphidophagous gall-midge *Aphidoletes aphidimyza* Rondani (Dip.: Cecidomyiidae) in biological control of aphids in glasshouses. Zapiski LSHI, 212.
- Atlihan, R., and Guldal, H. 2009. Prey density-dependent feeding activity and life history of *Scymnus subvillosus*. Phytoparasitica, 37: 35-41.
- Bailey, R., Chang, N. T., Lai, P. Y., and Hsu, T. C. 2010. Life table of cycad scale, *Aulacaspis yasumatsui* (Hemiptera: Diaspididae), reared on Cycas in Taiwan. Journal of Asia-Pacific Entomology, 13: 183-187.
- Baniameri, V., and Nasrollahi, A. A. 2003. Status of IPM program in greenhouse vegetables in Iran. IOBC/WPRS Bulletin, Additional Abstracts/Papers, 26: 1-3.
- Blackman, R. L., and Eastop, V. F. 2000. Aphids on the worlds crops: an identification and information guide, 2nd ed. Wiley, London, United Kingdom.
- Brown, M. W. 2004. Role of aphid predator guild in controlling spirea aphid populations on apple in West Virginia, USA. Biological Control, 29: 189-198.
- Chi, H. 1988. Life-table analysis incorporating both sexes and variable development rate among individuals. Environmental Entomology, 17: 26-34.
- Chi, H. 2005. TWSEX-MSChart: Computer program for age-stage, two-sex life table analysis. Taichung, Taiwan: National Chung Hsing University <http://140.120.197.173/Ecology/prod02.htm>.

- Chi H., Liu H. 1985. Two new methods for the study of insect population ecology. *Bull. Inst. Zool. Acad. Sin.* 24: 225-240.
- Chi, H., and Yang, T. C. 2003. Two-sex life table and predation rate of *Propylaea japonica* Thunberg (Coleoptera: Coccinellidae) fed on *Myzus persicae* (Sulzer) (Homoptera: Aphididae). *Environmental Entomology*, 32: 327-333.
- Choi, M. Y., Lee, G. H., Paik, C. H., and Kim, D. H. 2001. Development and predation of aphidophagous gall midge, *Aphidoletes aphidimyza* (Rondani) (Diptera: Cecidomyiidae) on *Myzus persicae* Sulzer. *Korean Journal of Applied Entomology*, 40: 45-49.
- Dixon, A. F. G. 1997. Role of predators on maize aphid populations, p. 505-511, *Aphids in natural and managed ecosystems*. In: Asin, L., Pons, X., Nieto-Nafria, J. M., (Eds.) *Proceedings of the Fifth International Symposium on Aphids*, Leon, Spain, 15-19 September, 1997, published in 1998.
- El-Hag, E. A., and Zaitoon, A. A. 1996. Biological parameters for four coccinellid species in Central Arabia. *Biocontrol*, 7: 316-319.
- El-Titi, A. 1973. Influences of prey density and food-plant morphology on the oviposition of *Aphidoletes aphidimyza* (Rond.) (Diptera: Itonididae). *Zeitschrift für Angewandte Entomologie*, 72: 400-415.
- Engel, R. 1990. Alternative prey and other food resources of the phytoseiid mite *Typhlodromus pyri* (Scheuten). In: Schmid, A., (Ed.), *Integrated Control in Viticulture*. IOBC/WPRS Bulletin, 13: 124-127.
- Farhadi, R., Allahyari, H., and Chi, H. 2011. Life table and predation capacity of *Hippodamia variegata* (Coleoptera: Coccinellidae) feeding on *Aphis fabae* (Homoptera: Aphididae). *Biological Control*, doi:10.1016/j.biocontrol.2011.07.013.
- Gabre, R. A., Adham, F. K., and Chi, H. 2005. Life table of *Chrysomya megacephala* (Fabricius) (Diptera: Calliphoridae). *Acta Oecologica*, 27: 179-183.
- Havelka, J. 1980. Effect of temperature on the developmental rate of preimaginal stages of *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae). *Entomologia Experimentalis et Applicata*, 27: 83-90.
- Havelka, J. 1982. Predatory gallmidge *Aphidoletes aphidimyza* (R.). method of mass rearing and use for biological control in the greenhouse. *Proc. IOBC East Palearctic Regional Section "Methods of Integrated Pest Management"*, Poznan, Poland pp. 89-121 (in Russian).
- Havelka, J., and Ruzicka, Z. 1984. Selection of aphid species by ovipositing females and effects of larval food on the development and fecundity in *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae). *Journal of Applied Entomology*, 98: 432-437.
- Havelka, J., and Zemek, R. 1988. Intraspecific variability of aphidophagous gall-midge *Aphidoletes aphidimyza* (Rondani) (Dipt., Cecidomyiidae) and its importance for biological control of aphids. *Journal of Applied Entomology*, 105: 280-288.
- Havelka, J., and Zemek, R. 1999. Life table parameters and oviposition dynamics of various population of the predacious gall-midge *Aphidoletes aphidimyza*. *Entomologia Experimentalis et Applicata* 91: 481-484.
- Huang, Y. B., and Chi, H. 2011. Age-stage, two-sex life tables of *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) with a discussion on the problem of applying female age-specific life tables to insect populations. *Insect Science*, 19: 263-273.
- Isikber, A. A. 2005. Functional Response of Two Coccinellid Predators, *Scymnus levaillanti* and *Cycloneda sanguinea*, to the Cotton Aphid, *Aphis gossypii*. *Turkish Journal of Agriculture and Forestry*, 29: 347-355.
- Jokinen, D. P. 1980. Spatial distribution of *Aphis pomi* (DeGeer) and the predator *Aphidoletes aphidimyza* (Rondani) relative to growth of the apple tree. M. Sc. Thesis, Michigan State Univ., E. Lansing, Michigan.
- Kersting, U., Satar, S., and Uygun, N. 1999. Effect of temperature on development rate fecundity of apterous *Aphis gossypii* Glover

- (Homoptera: Aphididae) reared on *Gossypium Hirsutum*. Journal of Applied Entomology, 123: 23-27.
- Kulp, D., Fortmann, M., Hommes, M., and Plate, H. P. 1989. Die räuberische Gallmücke *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae)-Ein bedeutender Blattlausprädator Nachschlagewerk zur Systematik, Verbreitung, Biologie, Zucht und Anwendung. Mitteilungen aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft Berlin-Dahlem, 250: 1-126.
- Leclant, F., and Deguine, J. P. 1994. Aphids (Hemiptera: Aphididae), p. 285-323 In Matthew G. A., Tunstall J. P. (Eds), Insect Pests of Cotton., Wallingford, UK. CAB International.
- Lucas, E., and Brodeur, J. 1999. Oviposition site selection by the predatory midge *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae). Environmental Entomology, 28: 622-627.
- Malais, M., and Ravensberg, W. J. 1992. Knowing and recognizing. The biology of glasshouse pests and their natural enemies. Koppert B. V., Berkel en Rodenrijs, The Netherlands, 109 pp.
- Mansour, M. H. M. 1975. The role of plants as a factor affecting oviposition by *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae). Entomologia Experimentalis et Applicata, 18: 173-179
- Markkula, M., Hamalainen, M., Forsberg, A., 1979. The aphid midge, *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae) and its use in biological control of aphids. Annals Entomology of Fennicia, 45; 89- 98.
- Markkula, M., and Tittanen, K. 1985. Biology of the midge *Aphidoletes* and its potential for biological control. Biological Pest Control: the Glasshouse Experience (ed. by Hussey, N. W., Scopes, N.), pp. 74-81. Cornell University Press, Ithaca, NY.
- Meadow, R. H., Kelly, C., and Shelton, A. M. 1985. Evaluation of *Aphidoletes aphidimyza* (Dip.: Cecidomyiidae) for control of *Myzus persicae* (Hom.: Aphididae) In greenhouse and field experiments in the United States. Entomophaga, 30: 385-392.
- Messelink, G. J., Bloemhard, Ch. M. J., Cortes, J. A., Sabelis, M. W., and Janssen, A. 2011. Hyperpredation by generalist predatory mites disrupts biological control of aphids by the aphidophagous gall midge *Aphidoletes aphidimyza*. Biological Control, 57: 246-252.
- Meyer, J. S., Ingersoll, C. G., McDonald, L. L., & Boyce, M. S. (1986). Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. *Ecology*, 67, 1156–1166.
- Mo, T. L., and Liu, T. X. 2006. Biology, life table and predation of *Feltiella acarisuga* (Diptera: Cecidomyiidae) feeding on *Tetranychus cinnabarinus* eggs (Acari: Tetranychidae). Biological Control, 39: 418-426.
- Mojeni, D. T., and Rezvani, A. 1997. Biology and population fluctuating *A. gossypii* in the cotton fields of Gorgan. Journal of Entomological Society of Iran, 16: 1-10.
- Morse, J. G. 1981. Biological studies on *Aphidoletes aphidimyza* (Rondani) [Diptera: Cecidomyiidae] and its use in the biological control of the apple aphid *Aphis pomi* DeGeer [Homoptera: Aphididae]. Ph. D. Thesis. Mich. State Univ., East Lansing, MI, 166 pp.
- Morse, J. G., and Croft, B. A. 1987. Biological control of *Aphis pomi* (Hom.: Aphididae) by *Aphidoletes aphidimyza* (Dip.: Cecidomyiidae); A predator- prey model. Entomophaga, 32: 339-356.
- Nijveldt, W. 1988. Cecidomyiidae. In "Aphids Their Biology, Natural Enemies and Control". Vol. 2B (A. K. Minks and P. Harrewijn, Eds.), pp. 271-277. Elsevier, Amsterdam.
- Parrella, M. P., Hansen, L. S., and van Lenteren, J. C. 1999. Glasshouse environments. In: Fisher, T. W., Bellows, T. S., Caltagirone, L. E., Dahlstein, D. L., Huaker, C. B., Gordh, G. (Eds.), Handbook of Biological Control. Academic Press, New York, pp. 819-839.
- Raworth, D. A., Frazer, B. D., Gilbert, N., and Wellington, W. G. 1984. Population dynamics of the cabbage aphid, *Brevicoryne*

- brassicae* (Homoptera: Aphididae) at Vancouver, British Columbia. I. Sampling methods and population trends. *Canadian Entomologist*, 116: 861-870.
- Razmjou, J., Hajizadeh, J., and Asadi, A. 2002. Investigation of important natural enemies of cotton aphid in Moghan area, pp. 61-62. In Proceedings, 15th Iranian Plant Protection Congress. Agricultural Education, Karaj Publication Unit, Kermanshah, Iran.
- Razmjou, J., Moharrampour, S., Fathipour Y., and Mirhoseini, S. Z. 2006. Demographic Parameters of Cotton Aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) on Five Cotton Cultures. *Insect Science*, 13: 205-210.
- Ricklefs, R. E., and Miller G. L. 1999. *Ecology*, 4th ed. W. H. Freeman, New York.
- Roistacher C. N., Bar-Joseph M., and Gumpf D. J. 1984. Transmission of tristeza and seedling yellows tristeza virus by small populations of *Aphis gossypii*. *Plant Diseases*, 68: 494-496.
- Roy, M., Brodeur, J., and Cloutier, C. 2003. Effect of temperature on intrinsic rates of natural increase (r_m) of a coccinellid and its spider mite prey. *Biocontrol*, 48: 577-582.
- Ruggle, P., and Gutierrez, A. P. 1995. Use of life tables to assess host plant resistance in alfalfa to *Therioaphis trifolii f. maculata* (Homoptera: Aphididae): Hypothesis for maintenance of resistance. *Environmental Entomology*, 24: 313-325.
- Schmidt, M. H., Thewes, U., Thies, C., and Tschardtke, T. 2004. Aphid suppression by natural enemies in mulched cereals. *Entomologia Experimentalis et Applicata*, 113: 87-93.
- Silva, A. A. E., Varanda, E. M., and Barosela, J. R. 2006. Resistance and susceptibility of alfalfa (*Medicago sativa* L.) cultivars to the aphid *Therioaphis maculata* (Homoptera: Aphididae): insect biology and cultivar evaluation. *Insect Science*, 13: 55-60.
- Sokal, R. R., and Rohlf, F. J. 1995. *Biometry*. W. H. Freeman, San Francisco, CA.
- Solarska, E. 2004. The use of *Aphidius colemani* and *Aphidoletes aphidimyza* to control damson-hop aphid (*Phorodon humuli* Schrank) on hop. *J. Plant Protect. Res.* 44: 85-90.
- Southwood, T. R. E., and Henderson, P. A. 2000. *Ecological methods*, 3rd ed. Blackwell, Oxford, United Kingdom.
- Stewart, H. C., and Walde, S. J. 1997. The dynamics of *Aphis pomi* De Geer (Homoptera: Aphididae) and its predator, *Aphidoletes aphidimyza* (Rondani) (Diptera: Cecidomyiidae), on apple in Nova Scotia. *Canadian Entomologist*, 129: 627-636.
- Toapanta, M. A., Schuster, D. J., and Stansly, P. A. 2005. Development and life history of *Anthonomus eugenii* (Coleoptera: Curculionidae) at constant temperatures. *Environmental Entomology*, 34: 999-1008.
- Tóth, P., Tóthová, M., and Lukáš, J. 2009. Natural enemies of *Diuraphis noxia* (Sternorrhyncha: Aphididae) in Slovakia. *Journal of Central European Agriculture*, 10: 159-166.
- Uygun, N. 1971. Der Einfluss der Nahrungsmenge auf Fruchtbarkeit und Lebensdauer von *Aphidoletes aphidimyza* Rond. (Diptera: Itonididae). *Zeitschrift für Angewandte Entomologie*, 69: 234-258.
- Van Lenteren, J. C., and Woets, J. 1988. Biological and integrated pest control in greenhouses. *Annual Review of Entomology*, 33: 239-369.
- Warner, L. A., and Croft, B. A. 1982. Toxicities of azinphosmethyl and selected orchard pesticides to an aphid predator, *Aphidoletes aphidimyza*. *Journal of Economic Entomology*, 75: 410-415.
- Wyss, E., Villiger, M., and Scharer, M. 1999. The potential of three native insect predators to control the rosy apple aphid, *Dysaphis plantaginea*. *Biocontrol*, 44: 171-182.
- Xie, M., Cheng, H. K., and Qiu, W. L. 2000. The efficiency evaluation of the mass propagation system of *Aphidoletes aphidimyza* by life table. *Acta Entomologica Sinica*, 43: 151-155.
- Yaşar B., Özger S. 2005. Development, feeding and reproduction responses of *Adalia fasciatopunctata revelierei* (Mulsant) (Coleoptera: Coccinellidae) to *Hyalopterus*

- pruni* (Geoffroy) (Homoptera: Aphididae). J. Pest Sci. 78: 199-203.
- Yin, J., Sun, Y., Wu, G., Parajulee, M. N., and Ge, F. 2009. No effects of elevated CO₂ on the population relationship between cotton bollworm, *Helicoverpa armigera* Hu' bner (Lepidoptera: Noctuidae), and its parasitoid, *Microplitis mediator* Haliday (Hymenoptera: Braconidae). Agriculture Ecosystem and Environment, 132: 267-275.
- Yu, J. Z., Chi, H., and Chen, B. H. 2005. Life table and predation of *Lemnia biplagiata* (Coleoptera: Coccinellidae) fed on *Aphis gossypii* (Homoptera: Aphididae) with a proof on relationship among gross reproduction rate, net reproduction rate and preadult survivorship. Annals of the Entomological Society of America, 98: 475-482.
- Yukawa, J., Yamaguchi, D., Mizota, K., and Setokuchi, O. 1998. Distribution and host range of an aphidophagous species of Cecidomyiidae, *Aphidoletes aphidimyza* (Diptera), in Japan. Applied Entomology and Zoology, 33: 185-193.

تأثیر تراکم *Aphis gossypii* Glover (Hemiptera: Aphididae) بر پارامترهای جدول زندگی *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae) در شرایط آزمایشگاه

خدیدجه مداحی، احد صحراگرد* و رضا حسینی

گروه گیاه‌پزشکی، دانشکده علوم کشاورزی، دانشگاه گیلان، رشت، ایران

* پست الکترونیکی نویسنده مسئول مکاتبه: sahragard@guilan.ac.ir

دریافت: ۲۲ بهمن ۱۳۹۱؛ پذیرش: ۲۶ خرداد ۱۳۹۲

چکیده: جدول زندگی جامع‌ترین توضیح بقاء، رشد و نمو و تولید مثل یک جمعیت را ارائه می‌دهد. در این بررسی پارامترهای جدول زندگی پشه شته‌خوار *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae) روی تراکم‌های مختلف (۵، ۱۰، ۲۰، ۴۰، ۶۰ و ۸۰) پوره‌های سن سوم شته *Aphis gossypii* Glover به‌عنوان طعمه در یک اتاقک رشد (۱ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۵ ± ۷۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی) مطالعه شد. داده‌های مربوط به رشد و نمو، بقاء، باروری و نرخ شکارگری با استفاده از جدول زندگی سن-مرحله دو جنسی تجزیه و تحلیل شدند. دوره پیش از تخم‌ریزی ماده *A. aphidimyza* بدون تفاوت معنی‌دار با افزایش تراکم طعمه کاهش پیدا کرد. دوره تخم‌ریزی به‌ترتیب ۰/۴۰۱ ± ۳/۸۳۳ و ۰/۴۶۳ ± ۵/۵ روز در پایین‌ترین و بالاترین تراکم طعمه بود. باروری به‌طور معنی‌داری با افزایش تراکم طعمه افزایش پیدا کرد. پایین‌ترین باروری در تراکم ۵ طعمه (۶/۰۵۳ ± ۴۹/۶۶۷ تخم) و بالاترین آن در تراکم ۸۰ طعمه (۷/۷۸ ± ۱۰۴/۲۵ تخم) به‌دست آمد. نرخ ذاتی افزایش جمعیت (r_m) با افزایش تراکم طعمه از ۰/۱۰۶ ± ۰/۱۱۰ تا ۰/۱۴ ± ۰/۱۶۶ بر روز در نوسان بود. نرخ خالص تولید مثل (R_0) به‌طور مثبت وابسته به تراکم طعمه بود. اوج مقادیر تولید مثل نشان داد که ماده پشه شته‌خوار هنگامی که روی ۵ تا ۸۰ طعمه در روز پرورش یافت به‌ترتیب در سنین ۱۷، ۱۸، ۱۹، ۲۲، و ۲۵ روزگی بالاترین نقش را در جمعیت ایفا کرد. به هر حال، متوسط مدت زمان نسل (T) از ۰/۵۵ ± ۲۲/۴۲ تا ۱/۰۴ ± ۲۴/۴۷ روز در نوسان بود. نتیجه‌گیری شد که افزایش تراکم پوره‌های سن سوم *A. gossypii* اثرات معنی‌داری بر پارامترهای دموگرافی *A. aphidimyza* داشتند و این شکارگر عملکرد تولید مثلی بهتری در تراکم‌های بالاتر طعمه نشان داد.

واژگان کلیدی: *Aphis gossypii* نرخ ذاتی افزایش جمعیت، تراکم طعمه، مقادیر تولیدمثل، *Aphidoletes aphidimyza*