Archive of SID

JOURNAL OF ENTOMOLOGICAL SOCIETY OF IRAN
2018, 38(2), 151–172
نامه انجمن حشره‌شناسی ایران ۱۷۲– ۱۵۱ ,(۲)۳۸ ,۱۳۹۷
JESI
DOI: 10.22117/JESI.2018.121466.1216

Life history performance of *Aphis gossypii* (Hemiptera: Aphididae) on six different host plants under microcosm condition

Khadijeh Madahi[1], Ahad Sahragard[1&*], Reza Hosseini[1] & Valiollah Baniameri[2]

1- Department of Plant Protection, Faculty of Agricultural Sciences, University of Guilan, Rasht, Iran & 2- Agricultural Entomology Research Department, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Organization (AREEO), Tehran, Iran.
*Corresponding author, E-mail: ahad.sahragard@gmail.com

Abstract
Aphis gossypii Glover is considered as the most important polyphagous pest of a wide range of economically important plants in fields and greenhouses. In this study, the demography of cotton aphid, reared on six different host plants, including cucumber (*Cucumis sativus* L. var. Beith Alpha), tomato (*Solanum lycopersicum* var. Falat111), eggplant (*Solanum melongena* var. Yummy), okra (*Abelmoschus esculentus* var. Clemson Spineless), squash (*Cucurbita pepo* var. Hybrid Rajai), and pepper (*Capsicum annuum* var. Bertene) was investigated using the age-stage, two-sex life table under microcosm conditions (23±2°C and 70±5% RH and a photoperiod of 16L:8D h). The results revealed the differential effect of host plants on developmental duration, fecundity, and life table parameters of *A. gossypii*. The shortest nymphal duration (4.57±0.177 days), the longest adult longevity (21.87±0.184 days), the highest fecundity (73.6±0.85 offspring/female), the highest intrinsic rate of increase (r) (0.369±0.006 day^{-1}) and the lowest mean generation time (T) (11.646±0.202 days) of the aphid were obtained on squash. Furthermore, the results of the population projection revealed that the population growth of cotton aphid was higher on squash, compared to other host plants. These findings suggested that squash as the most suitable host plant for *A. gossypii* among the tested hosts.
Key words: cotton aphid, life table, trichome, host plant, population projection

عملکرد زیستی شته جالیز *Aphis gossypii* (Hemiptera: Aphididae) روی شش گیاه میزبان مختلف در شرایط میکروکازم

خدیجه مداحی[۱]، احد صحراگرد[۱و*]، رضا حسینی[۱] و ولی‌الله بنی‌عامری[۲]

۱- گروه گیاه‌پزشکی، دانشکده علوم کشاورزی، دانشگاه گیلان، رشت، ایران و ۲- بخش تحقیقات حشره‌شناسی کشاورزی، موسسه تحقیقات گیاه‌پزشکی کشور، سازمان تحقیقات، آموزش و ترویج کشاورزی، تهران، ایران
* مسئول مکاتبات، پست الکترونیکی: ahad.sahragard@gmail.com, sahragard@guilan.ac.ir

چکیده
شته جالیز، *Aphis gossypii* Glover به عنوان مهم‌ترین آفت چندین‌خوار طیف وسیعی از گیاهان اقتصادی مهم در مزارع و گلخانه‌ها محسوب می‌شود. در این تحقیق، دموگرافی شته جالیز روی شش گیاه میزبان مختلف، از جمله خیار (*Cucumis sativus* L. var. Beith Alpha)، گوجه‌فرنگی (*Solanum lycopersicum* var. Falat111)، بادمجان (*Solanum melongena* var. Yummy)، بامیه (*Abelmoschus esculentus* var. Clemson Spineless)، کدو (*Cucurbita pepo* var. Hybrid Rajai) و فلفل (*Capsicum annuum* var. Bertene) با استفاده از جدول زندگی سن-مرحله رشدی، دو جنسی در شرایط میکروکازم (۲±۲۳ درجهٔ سلسیوس، رطوبت نسبی ۵±۷۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی) بررسی شد. نتایج، اثر گیاهان میزبان مختلف را بر طول دوره رشدی، باروری و پارامترهای جدول زندگی *A. gossypii* نشان داد. کمترین طول دوره پورگی (۰/۱۷۷±۴/۵۷ روز)، بیشترین طول عمر بلوغ (۰/۱۸۴±۲۱/۸۷ روز)، بیشترین باروری (۰/۸۵±۷۳/۶ نتاج/ماده)، بیشترین مقدار نرخ ذاتی افزایش جمعیت (r) (۰/۰۰۶±۰/۳۶۹ بر روز) و کمترین

Received: 19 April 2018, *Accepted:* 3 September 2018
Subject Editor: Yaghoub Fathipour

www.SID.ir

Archive of SID

میانگین طول یک نسل (*T*) (۰/۲۰۲± ۱۱/۶۴۶ روز) شته مذکور روی کدو به دست آمد. علاوه بر این، نتایج پیش‌بینی جمعیت نشان داد که رشد جمعیت شته جالیز روی کدو، بیشتر از سایر گیاهان میزبان بود. این یافته‌ها نشان داد که از بین میزبان‌های مورد بررسی، کدو به عنوان مناسب‌ترین گیاه میزبان برای شته جالیز است.

واژگان کلیدی: شته جالیز، جدول زندگی، تریکوم، گیاه میزبان، پیش‌بینی جمعیت

دریافت: ۱۳۹۷/۰۱/۳۰، پذیرش: ۱۳۹۷/۰۶/۱۲.

Introduction

Aphids are an extremely successful group of insects which are distributed all over the world (Žanić *et al.*, 2013). The cotton or melon aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) is considered as a polyphagous pest on a wide range of economically important plants, such as several cucurbitaceous crops, cotton, potato, and ornamental plants in fields and greenhouses (Blackman & Eastop, 2006). This pest is widely distributed in temperate, tropical, and subtropical regions of the world including Iran (Satar *et al.*, 1999; van Steenis, 1992; Baniameri & Nasrollahi, 2003; Razmjou *et al.*, 2012; Torkamand *et al.*, 2013). It can damage plants directly by feeding on lower surface of leaves, sucking up nutrients, distorting and curling leaves and consequently reducing fruit quality and yield. Moreover, transmission of several plant pathogenic viruses is considered as the indirect damage of this pest (Kennedy *et al.*, 1962; Pinto *et al.*, 2008).

Among all the ecological data, demographic studies provide basic and comprehensive information about the birth, survival, death, reproduction, and growth capacity of pest populations (Southwood & Henderson, 2000). Assessing the suitability of host plants to various pest insects has been conducted using life table method (Vargas *et al.*, 1997; Southwood & Henderson, 2000; Fathi *et al.*, 2011). Life table parameters represent the potential of population growth in the present and future generations (Frel *et al.*, 2003; Sauvion *et al.*, 2005) and are one of the most critically important tools to perform ecology-based integrated pest management programs (Vargas *et al.*, 1990; Jha *et al.*, 2012; Tuan *et al.*, 2014).

Host plant quality plays an important role on the growth, survival, fecundity, and population growth of phytophagous insects (Scriber & Slansky, 1981; Slansky, 1993; Browne & Raubenheimer, 2003). The study of pest performance on different host plants is an effective strategy to manage the insect populations (Painter, 1951, Fathipour & Naseri, 2011; Li *et al.*, 2006; Takalloozadeh, 2010). Host plant effects may be physical (such as trichomes, tissue roughness) or chemical (such as toxins and digestibility reducers) (Price *et al.*, 1980; Schoonhoven *et al.*, 2005). Studying the effect of food quality on pest population development and investigating the interaction between pest and its host plants are important for understanding their host suitability (Greenberg *et al.*, 2001; Safuraie-Parizi *et al.*, 2014). High quality plants may increase insect survival, size or weight, longevity and reproduction

www.SID.ir

Archive of SID

or indirectly decrease their exposure to the natural enemies as a result of diminished developmental period (Dent, 2000; Greenberg *et al.,* 2001; Awmack & Leather, 2002).

Several studies have been done on the performance of *A. gossypii* on cotton (Razmjou *et al.,* 2006), pepper (Satar *et al.,* 2008; Alizadeh *et al.*, 2016; Tazerouni *et al.*, 2016), eggplant (Alim *et al*., 2015; Yazıcı & Akça, 2016), squash (Leite *et al.,* 2008; Baldin *et al.,* 2009), okra (Shannag *et al.*, 2007), cucumber (van Steenis & El-Khawass, 1995; Zamani *et al.,* 2006; Mollashahi & Tahmasbi, 2009; Takalloozadeh, 2010; Rahsepar *et al.*, 2016; Darvishzadeh & Jafari, 2016) and tomato (Bugti 2016). Despite many articles dealing with the effect of different plants on biological traits and life table parameters of *A. gossypii* under laboratory conditions, determining the suitable host plant for *A. gossypii* under microcosm conditions has not been considered so far. Therefore, the aim of this study was to evaluate the effect of six different host plants on biological parameters of *A. gossypii*.

Materials and methods

Host plant culture

The six different host plants including cucumber (*Cucumis sativus* L. var. Beith Alpha), tomato (*Solanum lycopersicum* var. Falat111), eggplant (*Solanum melongena* var. Yummy), okra (*Abelmoschus esculentus* var. Clemson Spineless), squash (*Cucurbita pepo* var. Hybrid rajai), and pepper (*Capsicum annuum* var. Bertene) were grown in plastic pots (20 cm diameter) filled with a mixture of soil, sand and manure (2: 2: 1). All plants were grown in a greenhouse (23± 5°C, 70± 10% RH and 16L: 8D h photoperiod). No insecticides were applied to the plants. Plants with 3-5 leaves were used for the experiments.

Insect culturing

Rose mallow shrub, *Hibiscus syriacus* (L.), cucumber, eggplant, watermelon, and cucurbit fields in Guilan Province, Rasht (from Gil Sq 37° 21' 15.48" N,49° 25' 3.30" E to Manzarieh Blvd (37° 15' 35.46" N,49° 36' 11.34" E) and fields around Pir Bazaar villages; Sheykh Mahalleh (37° 21' 16.08" N,49° 25' 54.72" E) and Lakesar (37° 21' 15.48" N,49° 25' 3.30" E) were visited every week and the colonies of *A. gossypii* were collected. They were individually reared on each mentioned host plants for three generations in greenhouse conditions.

Experimental Design

To study demographic parameters of cotton aphid, a wingless female of *A. gossypii* was randomly selected from the stock culture, transferred and placed individually on the

www.SID.ir

Archive of SID

microcosm consisted of a host plant leaf, placed in a plastic petri dish (9 cm diameter and 1 cm height) covered with mesh for ventilation. To avoid aphid escape from microcosm, the entrance of leaves to petri dishes was covered by cotton, moistened with distilled water (Figure 1). One newly born nymph was maintained in each leaf and other nymphs and the adult were removed after 12 hours. The developmental stage and survival of each individual were checked daily. The presence of discarded exuviates was used to determine time of molting. As soon as adults reached reproductive stage, all newly-born offspring were counted and removed from each microcosm in order to calculate daily fecundity. This was continued to the death of adults. Every 4-5 days, host plants were replaced to reduce the effects of plant age on aphid development and survivorship (McCornack *et al.*, 2004). The number of replicates was 30 on each host plant. All microcosms were maintained in greenhouse conditions (23±5 °C, 70±5% relative humidity and a photoperiod of 16:8h. (L:D)).

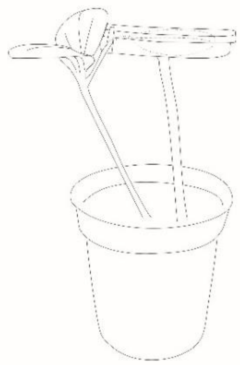

Fig. 1. Experimental unit used in this study (microcosm condition)(Original)

Statistical analysis

Data were analyzed using age-stage, two-sex life table theory (Chi and Liu, 1985) and the method described by Chi (1988). To facilitate the tiresome procedure, data analysis and population parameters were calculated using the TWOSEX-MSChart program (Chi 2016a).

The means and standard errors of the life table parameters were estimated by bootstrap procedure with 10,000 resampling (Erfon & Tibshirani, 1993; Brandstatter, 1999; Huang and Chi, 2012). A paired bootstrap test procedure was used to detect the difference among treatments based on the confidence interval of differences (Chi, 2016a). Curves were drawn by SigmaPlot v. 12.0 software (Polat-Akköprü *et al.*, 2015).

Population projection

According to Chi (1990) and Chi & Liu (1985), population growth of *A. gossypii* was predicted based on life table data, using TIMING-MSChart program (Chi, 2016b). Thirty first-instar nymphs of aphid were used as initial population to start the population projection

www.SID.ir

Archive of SID

and it was projected 60 days to obtain the total size of the population on each host plant under a scenario without suppression by biotic and abiotic factors.

Assessment of trichome

The presence or absence, density and length of trichomes on lower surface of each host plant leaves were determined, owing to preferred feeding of *A. gossypii* on the lower surface of the host plants. An Olympus TM SZX9 stereomicroscope equipped with a Cannon EOS Kiss X5 (600D) digital camera (Scale: X65) was used for taking images. Furthermore, SEM photos of lower leaf surface of each host plants were prepared by using a Su3500 Hitachi scanning electron microscope.

Results

Development time and survival of *A. gossypii*

Data describing the duration of each nymphal stage, total pre-adult and adult stage of *A. gossypi*, reared on six different host plants, are presented in Table 1. The mean duration of nymphal stages as well as total pre-adult of cotton aphid varied significantly on different host plants. The pre-adult longevity was the lowest on squash (4.57±0.177 days) and cucumber (5.07±0.253 days) differ significantly from others ($p<0.05$). Moreover, adult longevity was significantly different for aphids reared on various host plants; the shortest and longest adults longevity was shown on tomato (16.5±0.133 days) and squash (21.87±0.184 days), respectively.

Table 1. Comparative duration (day, mean ± SE) of immature and adult stages of *Aphis gossypii* reared on different host plants under microcosm condition.

Stages	Squash	Cucumber	Eggplant	Okra	Pepper	Tomato
N1	1.33±0.088 d	1.43±0.092 cd	1.5±0.093 cd	1.63±0.089 bc	1.87±0.104 ab	2.07±0.095 a
N2	1.13±0.063 c	1.37±0.089 b	1.47±0.093 b	1.53±0.093 ab	1.57±0.092 ab	1.77±0.079 a
N3	1.07± 0.046 b	1.2±0.074 ab	1.27±0.082 a	1.4±0.091 a	1.43±0.092 a	1.4±0.091 a
N4	1.03±0.033 c	1.07±0.46 bc	1.13±0.063 abc	1.2±0.074 ab	1.3±0.085 a	1.27±0.082 a
Preadult	4.57±0.177 d	5.07±0.253 cd	5.37±0.282 bc	5.77±0.294 abc	6.17±0.307 ab	6.5±0.262 a
Adult	21.87±0.184 a	20.13±0.202 b	18.53±0.124 c	17.8±0.074 d	17.37±0.162 e	16.5±0.133 f

The age-stage-specific survival rate (s_{xj}) of *A. gossypii* which represents the probability of a newborn surviving to age x and stage j, was shown in Figure 2 for six different host plants. The significant overlaps among various stages attributed to the variation in the developmental rates of individuals within cohort. The survival rate of *A. gossypi* on squash was relatively higher than others.

www.SID.ir

Archive of SID

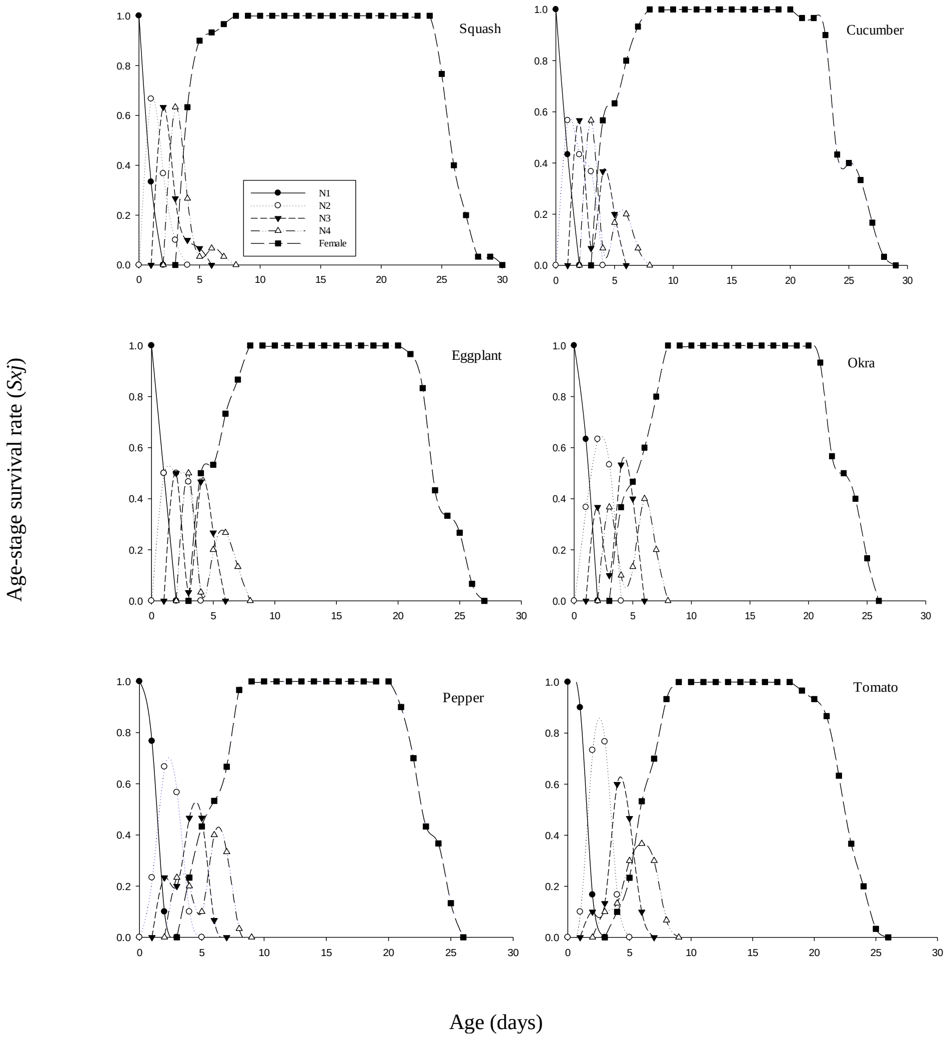

Fig. 2. Age-stage specific survival rate (s_{xj}) of *Aphis gossypii* on different host plants under microcosm condition

Reproduction and life table parameters of *A. gossypii*

Reproduction parameters are summarized in Table 2. It is apparent that different host plants had significant effect on APOP (adult pre-oviposition period), TPOP (total pre-oviposition period), reproductive period, as well as fecundity (Table 2). Rearing *A. gossypii* on squash led to the highest fecundity (73.6±0.85 offspring/female) and rearing on pepper (54.63±0.88 offspring/female) and tomato (52.17±0.92 offspring/female) resulted in the lowest fecundity ($p<0.05$). Moreover, the longest reproductive period (19.33±0.21 days) of *A. gossypii* was on squash, whereas the shortest duration was observed on tomato (14.67±0.17 days).

www.SID.ir

Archive of SID

Table 2. Reproductive attributes of *Aphis gossypii* reared on different host plants under microcosm condition.

	Squash	Cucumber	Eggplant	Okra	Pepper	Tomato
Fecundity	73.6±0.85 a	65.27±0.73 b	57.8±1 c	56.83±0.79 cd	54.63±0.88 de	52.17±0.92 e
TPOP	5.07±0.21 a	5.77±0.28 b	6.27±0.31 bc	6.8±0.33 cd	7.130.29 de	7.7±0.3 e
APOP	0.5±0.11 a	0.7±0.13 b	0.9±0.13 bc	1.03±0.12 bc	0.97±0.11 bc	1.2±0.11 c
Oviposition day	19.33±0.21 a	18.07±0.23 b	16.43±0.26 c	16±0.18 cd	15.47±0.18 e	14.67±0.17 f

Table 3 represented the effect of six different host plants on population parameters of *A. gossypii*. Paired bootstrap test indicated that the highest intrinsic rate of increase (r), the finite rate of increase (λ) and the net reproductive rate (R_0) of *A. gossypii* were observed on squash. The highest value for r was found on squash (0.369±0.006 day^{-1}), whereas the lowest values was on tomato (0.292±0.008 day^{-1}). Also, the lowest and the highest value of R_0 of *A. gossypii* was observed on tomato (52.167±0.913 offspring) and squash (73.6± 0.84 offspring), respectively ($p<0.05$). Moreover, rearing the aphids on squash and tomato resulted in the highest (1.446±0.009 day^{-1}) and lowest (1.339±0.01 day^{-1}) finite rate of increase, respectively ($p<0.05$). In addition, the mean generation time of *A. gossypii* differed among various host plants ($p<0.05$).

Table 3. Life table parameters (Means ± SE) of *Aphis gossypii* reared on different host plants under microcosm condition.

Parameters	Squash	Cucumber	Eggplant	Okra	Pepper	Tomato
r	0.369±0.006 a	0.348±0.009 b	0.329±0.008 bc	0.317±0.008 cd	0.305±0.008 d	0.292±0.008 e
λ	1.446±0.009 a	1.416±0.012 b	1.39±0.011 bc	1.373±0.012 cd	1.356±0.011 d	1.339±0.01 e
R_0	73.6± 0.84 a	65.267±0.724 b	57.8±0.982 c	56.833±0.767 cd	54.633±0.873 de	52.167±0.913 e
T	11.646±0.202 d	12.021±0.29 ab	12.313±0.311 bcd	12.732±0.353 abc	13.124±0.338 ab	13.544±0.345 a

Based on our results, age-specific survivorship rate (l_x), age-specific fecundity (m_x), and age-specific maternity ($l_x m_x$) of *A. gossypii* on six different host plants are plotted in Figure 3. The survival rate (l_x) on squash is relatively higher than those on other host plants. The maximum value of age-specific fecundity (m_x) on squash, cucumber, eggplant, okra, pepper and tomato were 6.867, 5.1, 4.733, 4.567, 4.667 and 4.367 offspring, respectively. The value of cotton aphid life expectancy (e_{xj}) on all host plants were very close to each other and the highest and the lowest value were shown on squash (26.433 days) and tomato (23 days), respectively (Figure 4). The results revealed that female made the highest contribution (v_{xj}) to the population growth and there were no significant difference between reproductive values of *A. gossypii* reared on various six host plants (Figure 5).

www.SID.ir

Archive of SID

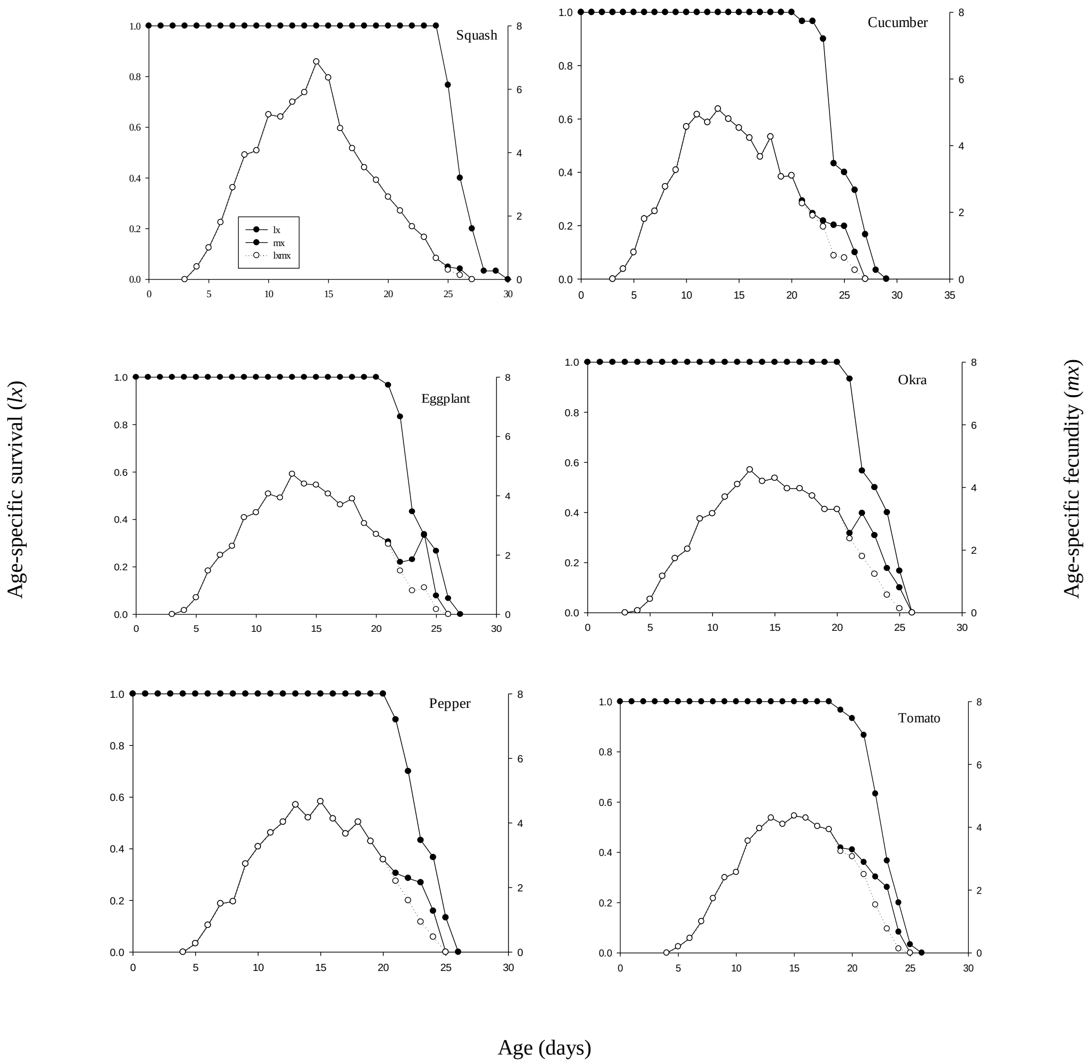

Fig. 3. Age-specific survival (l_x), age-specific fecundity (m_x) and age-specific maternity ($l_x m_x$) of *Aphis gossypii* on different host plants under microcosm condition

www.SID.ir

Archive of SID

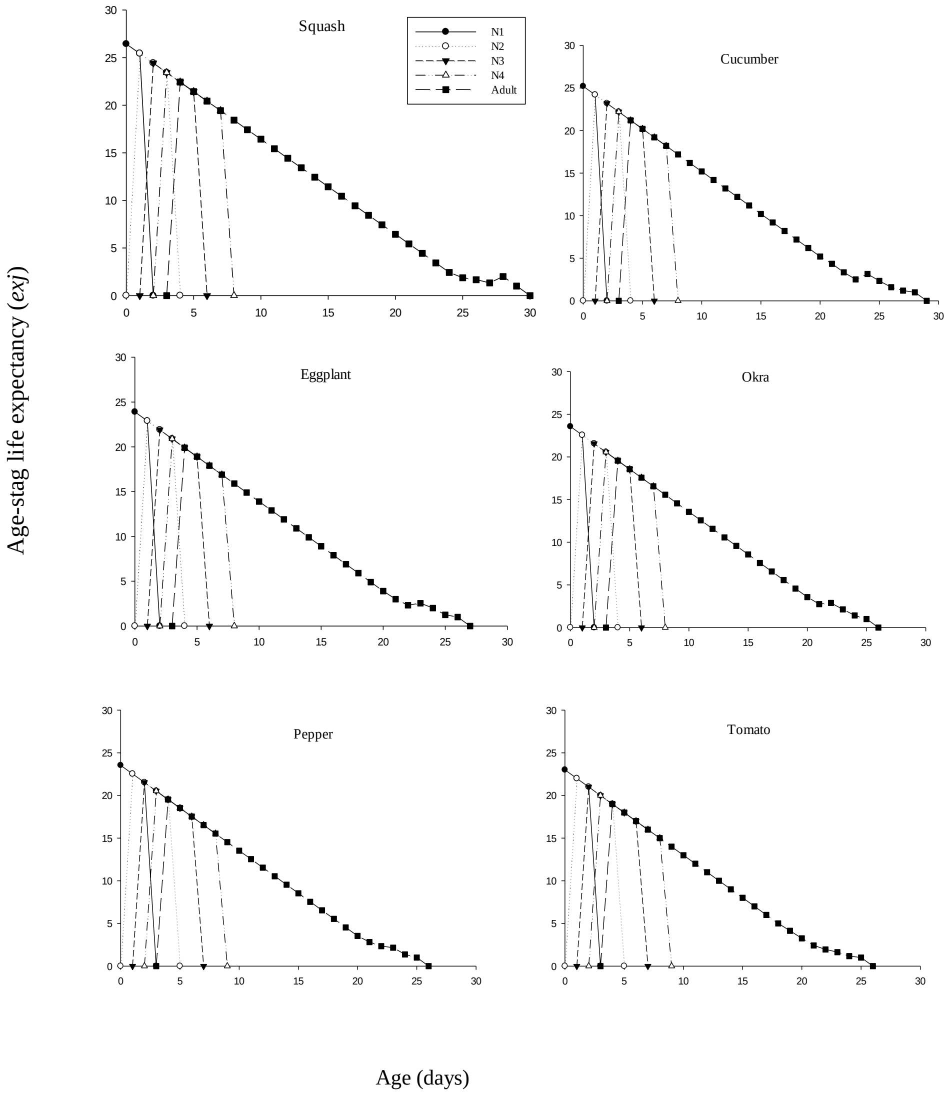

Fig. 4. Age-stage specific life expectancy (e_{xj}) of *Aphis gossypii* on different host plants under microcosm condition

www.SID.ir

Archive of SID

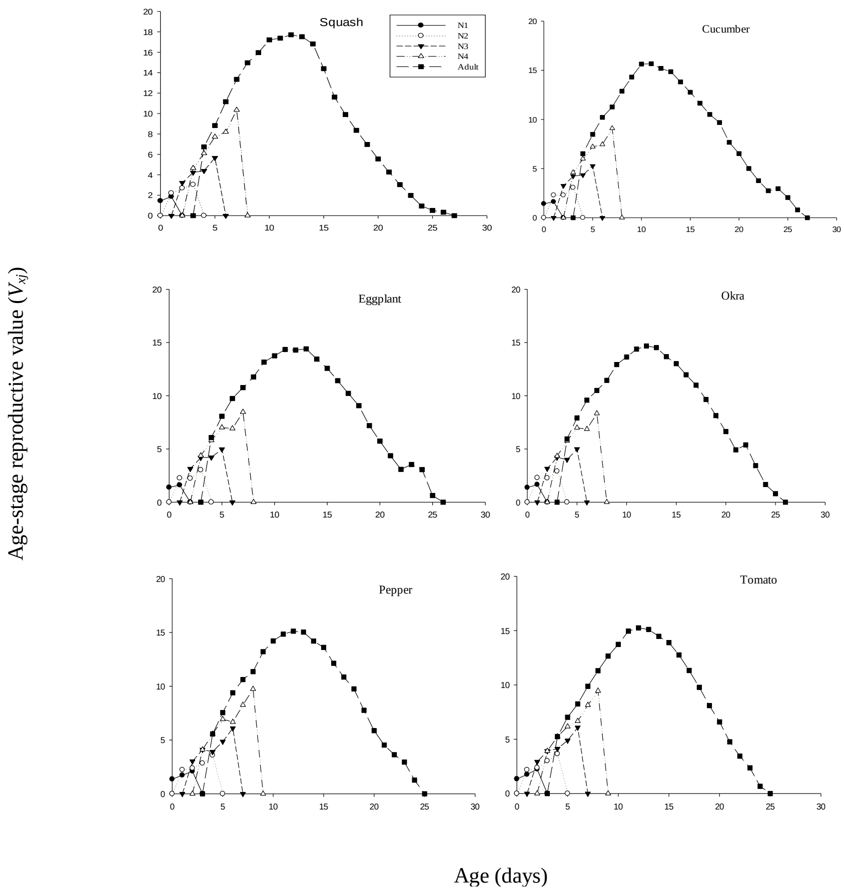

Fig. 5. Age-stage-specific reproductive value (V_{xj}) of *Aphis gossypii* on different host plants under microcosm condition

Population Projection of *A. gossypii*

Figure 6 illustrates the projected population growth levels of *A. gossypii* on different host plants. The highest total population size was shown on squash, while tomato yielded the lowest population size at the end of 60 days.

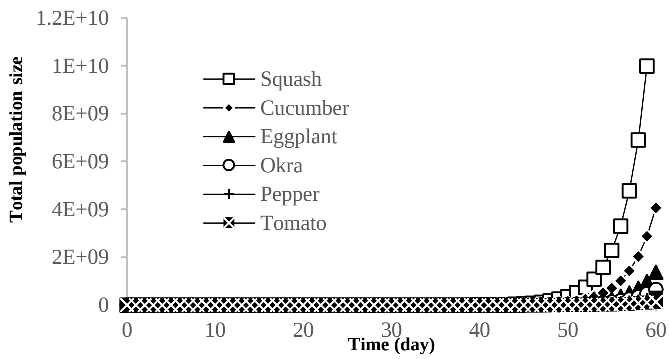

Fig. 6. Projection of population growth potential of *A. gossypii* on different host plants under microcosm condition

www.SID.ir

Archive of SID

Leaf trichomes density and status

Figure 7 presents SEM and stereomicroscopic photos of lower leaf surface of each host plant, showing their trichome status. Considerable differences was observed in terms of presence or absence and density of trichomes among host plants. As it can be seen from photos, multicellular unbranched stinging trichomes were found on squash, cucumber and okra. The type of trichomes of eggplant and tomato leaves were stellate and multicellular glandular, respectively. The lower surface of okra leaves has only few trichomes and no trichome was found on underneath of pepper leaves. The results showed that density and trichome type had remarkable influence on demographic and life table parameters of *A. gossypii.*

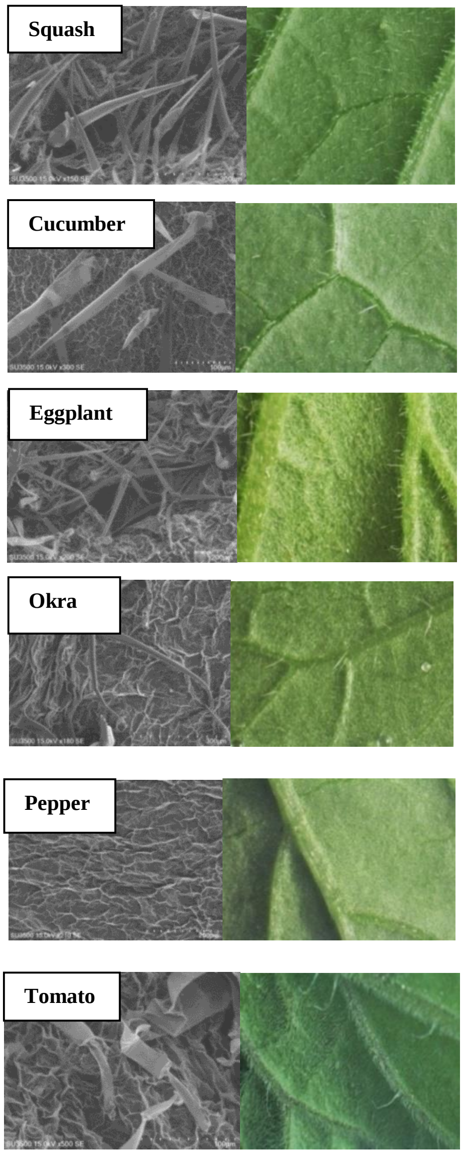

Fig. 7. The lower leaf surface of different host plants: photo taken by Stereomicroscope (scale= X65) (right) and SEM (left)

www.SID.ir

Archive of SID

Discussion

Host plants characteristics can have substantial effects on the growth, survival and reproduction of herbivorous insects (Bellows *et al.,* 1992; Žnidarčič *et al.*, 2008; 2011). Numerous studies have shown the effect of host plant on biological parameters of cotton aphid (e.g. pepper: Alizadeh *et al.,* 2016, Tazerouni *et al.*, 2016, cucumber: van Steenis and El-Khawass, 1995; Takalloozadeh, 2010; Darvishzadeh and Jafari, 2016; Rahsepar *et al.,* 2016; Tazerooni *et al.,* 2016, eggplant: Yazıcı and Akça, 2016, and squash: Baldin *et al.,* 2009). The results of our research showed the obvious effect of different host plants on developmental periods of *A. gossypii*. Similarly, the effect of different host plants on developmental and adult longevity of cotton aphid was also reported by Takalloozadeh (2010) and Tazerouni *et al*. (2016) who studied the difference of biological parameters of *A. gossypii* on cucumber vs. pepper and cucumber vs. cotton, respectively. Darvishzadeh and Jafari (2016) reared cotton aphid on seven different varieties of cucumber and showed the significant effect of different varieties on duration of first, second and fourth instars, but no effect on third instar and total pre-adult duration of *A. gossypii* was reported. Moreover, Baldin *et al.* (2009), Rahsepar *et al.* (2016), and Alizadeh *et al.* (2016), demonstrated that different varieties of host plants (squash, cucumber and pepper, respectively) had significant effect on total developmental time of *A. gossypii*. Jawal *et al.* (1998) stated that developmental duration of fist instar to 4th instar nymph of cotton aphid on pepper were 2.33±0.26, 2.29±0.34, 2.36±0.31 and 2.38±0.38 days, respectively. Satar *et al.* (1999; 2008) studied the development of *A. gossypii* at 22.5°C (somehow relative to the temperature in our research, 23°C) and reported that developmental duration of cotton aphid was 5.5 ± 0.09 and 6 days on pepper (var. Kandil Dolma) and okra, respectively. According to Mollashahi and Tahmasebi (2009), nymphal and adult longevity on the cucumber (Negin var.) were 4.98± 0.1 and 22 days, respectively. Moreover, the nymphal duration of cotton aphid was recorded 5.6, 5.2, and 4.5 days on cucumber, pumpkins and squash, respectively (Shirvani and Hosseini Naveh, 2004). Overall, our results are in agreement with the results reported by above mentioned researchers for the effect of different host plants on development duration of *A. gossypii*. Only few differences were observed, due to differences in plant varieties, temperature, experimental conditions (previous studies were conducted in laboratory conditions, in contrast to our microcosm condition).

Based on the results of this study, rearing cotton aphid on different host plant, lead to different adult longevity. This finding has been also reported by other researchers (e.g. Alizadeh *et al*., 2016 on pepper; Darvishzadeh & Jafari, 2016 and Rahsepar *et al.,* 2016 on cucumber; Tazerouni *et al.,* 2016 on cucumber and pepper). The adult longevity of *A. gossypii* on cucumber (20.13±0.202 days) was in accordance with the finding of Mollashahi

www.SID.ir

Archive of SID

& Tahmasebi (2009) who reported 22 days (Negin var.). Little differences are likely related to various experimental conditions (laboratory vs. microcosm) and plant varieties (Negin variety vs. Beith Alpha). Golizadeh *et al.* (2009) mentioned that host plant availability and quality, may play an significant role on pest population by affecting immature and adult preference.

Furthermore, concerning the reproductive parameters (TPOP, APOP, fecundity and reproduction period), our results revealed the significant effect of different host plants. Darvishzadeh & Jafari (2016) stated that the fecundity of cotton aphid ranged from 44.66 to 69.89 on different cucumber varieties which is nearly close to our results (62.27 offspring/female on cucumber). Moreover, our results are somehow in agreement with those reported by Hafiz (2002) that ranged between 40.2 and 59.3 nymphs on cucumber varieties. van Lenteren & Noldus (1990) demonstrated that shorter development times and greater total reproduction on a host, reflect the host plant suitability. Other studies have shown that the fecundity of *A. gossypii* vary on different host plants (van Steenis & El-Khawass, 1995; Mojeni *et al.*, 1997; Bethke *et al.*, 1998; Du *et al.*, 2004; Razmjou *et al.*, 2006).

Estimation of the life table parameters is typically used to compare the suitability of host plant for herbivorous insects (for example aphids) (Sa´nchez & Pereyra, 1995; Sa´nchez *et al.*, 1997; Yang & Chi, 2006; Fathi *et al.*, 2011). The suitable host plant will result in higher population growth parameters. The most popular parameter to describe the capacity of a population to increase under given climatic and food conditions is *r*. Due to its potential to reflect survival, stage differentiation, and reproduction of pest populations, *r* can be used as the most comprehensive parameter to evaluate the effect of different host plant on phytophagous insects (Carey, 1993; Southwood & Handerson, 2000; Murai, 2001).

In our study, the life table parameters of *A. gossypii* were influenced by different host plants, which was in accordance with previous reports (Satar *et al.*, 1999; Xia *et al.*, 1999; Razmjou *et al.*, 2006a,b; Takalloozadeh, 2010; Tazerouni *et al.*, 2016; Yazıcı & Akça, 2016). According to obtained results, the highest *r* value was found on squash (0.369±0.006 day-1). Satar *et al*. (2008) reported that the value of *r* on pepper (Kandil Dolma var.) was 0.427±0.007 day^{-1}) at 22.5°C (close to the temperature of current study). Moreover, Mollashahi & Tahmasbi (2009) found 0.471 day^{-1} on cucumber (Negin var.), Tazeouni *et al*. (2016) 0.493±0.008 day^{-1} and 0.250±0.006 day^{-1} on cucumber and pepper, respectively. Moreover, the *R*0 is another important life table parameter, was used to compare population in different conditions and different host plants (Liu *et al*., 2004). The highest value of *R*0 (73.6±0.84 offspring) and λ (1.446±0.009 day^{-1}) were observed on squash in current research. Alizadeh *et al.* (2016) reported that the value of *R*0 was ranged from 25.79 to 41.46 offspring on five pepper varieties which was relatively lower than our result on pepper (54.633±0.873 offspring). In a study conducted by Satar *et al.* (2008), the net reproductive rate (R_0) of *A.*

www.SID.ir

Archive of SID

gossypii on pepper (Kandil Dolma var.) at 22.5°C was 68.38 offspring, that is higher than what obtained in our study. Generally, difference between our results and others can be related to the experimental methodology (laboratory versus microcosm condition) and different host plant varieties. Mehrkhou *et al.* (2012) claimed that in addition to *r*, *T* is also an important parameter reflecting the suitability of host plant. This parameter was also influenced by different host plants as reported by other authors. Baldin *et al.* (2009) demonstrated that the life cycle of cotton aphid takes 11.67 to 22.25 days on different varieties of squash, which is comparable to our results (11.646±0.202 days). It was shown that the suitability of our squash variety is somehow close to Sandy variety in their study. The mean generation time of cotton aphid obtained on cucumber (12.021±0.29 days) concurs with that reported by Takalloozadeh (2010) at 23°C (11.85 days). Overall, the influence of different host plant on *R*0, *λ*, as well as *T* parameters of cotton aphid was observed, which was similar to the finding of previous researches in this field (Baldin *et al.*, 2009; Takalloozdeh, 2010; Alizadeh *et al.*, 2016; Darvishzadeh & Jafari, 2016; Tazerouni *et al*., 2016; Yazıcı & Akça, 2016).

The suitability of host plant species differs greatly for insects with respect to survival, development and reproductive rates of the pest, due to presence/absence, density and type of leaf trichome, chemical composition and presence of secondary metabolites, as well as nutritional value of host plants (Berenbaum, 1995; Dixon, 1998; Goundoudaki et *al.*, 2003; Zarpas *et al.*, 2006; Tazerouni *et al.*, 2016). The results showed the positive effect of trichomes on *A. gossypii* reproduction, in agreement with many other previous researches done on herbivorous insects.

The fecundity of *Bemisia tabaci* (Gennadius) was significantly influenced by higher density of trichome of some soybean varieties (McAuslane 1996) and different tomato genotypes (Oriani & Vendramim, 2010). Moreover, Srinivasan & Uthamasamy (2005) reported the influence of trichome of tomato leaves on *Helicoverpa armigera* (Hübner) and *B. tabaci*. Also, the positive effect of wheat cultivars with higher density of trichomes on the population of *Sipha maydis* (Passerini) was already reported by Gholami Moghadam *et al.* (2013). Similarly, Tazerouni *et al.* (2016) showed the suitably of cucumber (with higher trichome density) on developmental and life table parameters of *A. gossypii*, compared to pepper (with no trichome on the lower surface of leaves). On the other hand, numerous studies have shown the negative effect of trichomes on ovipositional parameters and population of phytophagous insects (Eisner *et al.*, 1998; Khan *et al.*, 2000; Lam & Pedigo, 2001; Pompon *et al.*, 2010; Žnidarčič *et al.*, 2008, 2011). It seems that the effect of trichomes on herbivores insects is species specific.

In this study, the higher density of trichome in squash and cucumber, together with stellate form of the eggplant's trichome, may provide a better environment for *A. gossypii*

www.SID.ir

Archive of SID

which led to more suitability of these three host plants compared to pepper and okra. Also, the suitability of squash as host plant can be attributed to the higher amount of nitrogen content (Madahi *et al*. unpublished data). Indeed, nitrogen is one of the major nutrients required by insect herbivores and in most cases is the main limiting factor for optimal growth of insects (Mattson, 1980; White, 1993). The relationship between the presences of some elements like nitrogen and the effect of host plant on developmental parameters of herbivorous insects has been widely identified in previous researches (Scriber & Slansky, 1981; Awmack & Leather, 2002; Du *et al.*, 2004; Soufbaf *et al.*, 2012). Despite high trichome density of tomato leaves, the results indicated the lowest suitability of tomato as a host for *A. gossypii*, in respect of the longest developmental time and the lowest fecundity of cotton aphid. This suggests the other determinant factors such as the presence of tubular glands and secreted secondary metabolites, which negatively affect the development and reproductive performance of the aphid on tomato (Howe & Jander, 2008).

In addition to life table, population projection is also an important tool in population growth trends, describing stage structure, and for scheduling the pest management strategies (Huang & Chi, 2014). Recently, a number of research has been done, using population projection to forecast population growth (Huang & Chi, 2014; Tuan *et al.*, 2015; Güncan & Gümüs, 2017). The results suggested the effect of different host plants on population size of *A. gossypii*, and showed higher population size on squash, compare to other host plants, after 60 days.

In conclusion, our study revealed the differential effect of host plants on development and life table parameters of *A. gossypii*, as well as its population size, which may be due to differences in density and trichomes type, secondary metabolites and nitrogen content of host plants. Considering the shortest developmental duration and higher intrinsic rate of increase, squash is the most suitable host plant for *A. gossypii*, among others. However, further physicochemical investigations are required to better understand bottom-up effects of mentioned host plants on the life history of *A. gossypii*.

Acknowledgement

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

www.SID.ir

Archive of SID

References

Alim, M. A., Naher, H., Habib, A. Sh. & Islam, M. A. (2015) Integrated management of cotton aphid, aphis gossypii on roof-planted eggplant, *Solanum melongena*. *Bangladesh Journal of Zoology* 43(1), 19-26.

Alizadeh, Z., Haghani, M. & Sedaratian, A. (2016) Biology and reproduction parameters of *Aphis gossypii* Glover, 1877 (Hemiptera, Aphididae) on five sweet pepper cultivars under laboratory conditions. *Entomofauna* 37, 617-628.

Awmack, C. S. & Leather, S. R. (2002) Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology* 47, 817–844.

Baldin, E. L. L., Marchi, L. S. & Schlick, E. C. (2009) Resistance of squash cultivars to *Aphis gossypii*. *Horticultura Brasileira* 27, 366-370.

Baniameri, V. & Nasrollahi, A. A. (2003) Status of IPM program in greenhouse vegetables in Iran. *IOBC/WPRS bulletin* 26, 1–3.

Berenbaum, M. R. (1995) Turnabout is fair play: Secondary roles for primary compounds. *Journal of Chemical Ecology* 21, 925–940.

Bethke, J. A., Redak, R. A. & Schuch, U. (1998) Melon aphid performance on chrysanthemum as mediated by cultivar, and differential levels of fertilization and irrigation. *Entomologia Experimentalis et Applicata* 88, 41-47.

Blackman, R. L. & Eastop, V. F. (2000) Aphids on the World's Crops: An Identification and Information Guide, 2nd ed, John Wiley and Sons, Chichester, UK.

Brandstatter, E. (1999) Confidence intervals as an alternative to significance testing. MPR-Online 4, 33–46.

Browne, L. B. & Raubenheimer, D. (2003) Ontogenetic changes in the rate of ingestion and estimates of food consumption in fourth and fifth instar *Helicoverpa armigera* caterpillars. *Journal of Insect Physiology* 49, 63–71.

Carey, J. R. (1993) *Applied Demography for Biologists, with Special Emphasis on Insects.* Oxford University Press, UK.

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

Chi, H. (1990) Timing of control based on the stage structure of pest populations: A simulation approach. *Journal of Economic Entomology* 83, 1143–1150.

Chi, H. (2016a) TWOSEX-MSChart: A computer program for the age–stage, two-sex life table analysis. (http://140.120.197.173/ecology/Download/TWOSEX-MSChart.rar, accessed 15 November 2016)

www.SID.ir

Archive of SID

Chi, H. (2016b) TIMING-MSChart: A computer program for the population projection based on age–stage, two-sex life table. (http://140.120.197.173/Ecology/Download/ TIMING- MSChart. rar, accessed 15 November 2016)

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

Darvishzadeh, S. & Jafari, Sh. (2016) Life history performance of *Aphis gossypii* Glover (Aphididae) on seven cucumber cultivars. *International Journal of Pest Management* 62(3), 245-250.

Dent, D. (2000) Host plant resistance. In: *Insect pest management*, Dent, D. (ed.). 2nd ed. p 410. CABI Publishing, Wallingford.

Dixon, A. F. G. (1998) *Aphid Ecology*. Chapman and Hall, London.

Du, L., Ge, F., Zhu, S. & Parajulee, M. N. (2004) Effect of cotton cultivars on development and reproduction of *Aphis gossypii* (Homoptera: Aphididae) and its predator *Propylaea japonica* (Coleoptera: Coccinellidae). *Journal of Economic Entomology* 97, 1278-1283.

Efron, B. & Tibshirani, R. J. (1993) *An introduction to the bootstrap*. Volume 57 of Monographs on Statistics and Applied Probability. Chapman & Hall, NY.

Eisner, T., Eisner, M. & Hoebeke, E. R. (1998) When defense backfires: detrimental effect of a plant's protective trichomes on an insect beneficial to the plant. *Proceedings of the National Academy of Sciences* 95, 4410-4414.

Fathi, S. A. A., Gholami, F., Nouri-Ganbalani, G. & Mohiseni, A. (2011) Life history parameters of *Thrips tabaci* (Thysanoptera: Thripidae) on six commercial cultivars of canola. *Applied Entomology and Zoology* 46, 505-510.

Fathipour, Y. & Naseri, B. (2011) Soybean cultivars affecting performance of *Helicoverpa armigera* (Lepidoptera: Noctuidae). In: Ng TB (ed.) S*oybean biochemistry, chemistry and physiology*. pp 599-630. Rijeka: In Tech.

Frel, A., Gu, H., Cardona, C. & Dorn, S. (2003) Antixenosis and antibiosis of common beans to *Thrips palmi*. *Journal of Economic Entomology* 93, 1577-1584.

Gholami Moghadam, S., Hosseini, M. & Modares Awal, M. (2013) Does leaf pubescence of wheat affect host selection and life table parameters of *Sipha maydis* (Hemiptera: Aphididae)? *Journal of Crop Protection* 2(1), 81-92.

Golizadeh, A., Kamali, K., Fathipour, Y. & Abbasipour, H. (2009) Life table of the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae) on five cultivated Brassicaceous host plants. *Journal of Agricultural Science and Technology* 11, 115-124.

Goundoudaki, S., Tsitsipis, J. A., Margaritopoulos, J. T., Zarpas, K. D. & Divanidis, S. (2003) Performance of the tobacco aphid *Myzus persicae* (Hemiptera: Aphididae) on oriental and virginia tobacco varieties. *Agricultural and Forest Entomology* 5, 285–291.

www.SID.ir

Archive of SID

Greenberg, S. M., Sappington, T. W., Legaspi, B. C., Liu, T. X. & Setamou, M. (2001) Feeding and life history of *Spodoptera exigua* (Lepidoptera: Noctuidae) on different host plants. *Annals of the Entomological Society of America* 94, 566–575.

Güncan, A. & Gümüs, E. (2017) Influence of different hazelnut cultivars on some demographic characteristics of the filbert aphid (Hemiptera: Aphididae). *Plant Research* (doi: 10.1093/jee/tox087).

Hafiz, N. A. (2002) Effect of certain cucumber varieties on the biology of *Aphis gossypii* (Hom.: Aphididae). *17th Symposium of the International Farming Systems Association*, pp. 17-20.

Howe GA, Jander G. (2008) Plant immunity to insect herbivores. *Annual Review of Plant Biology* 59, 41–66.

Huang, Y. B. & Chi, H. (2014) Fitness of *Bactrocera dorsalis* (Hendel) on seven host plants and an artificial diet. *Türkiye Entomoloji Dergisi* 38 (4), 401-414.

Huang, Y. B. & Chi, H. (2012) 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.

Jawal, R., Kannoria, J. L. & Singh, G. (1998) Biology of *Aphis gossypii* Glover on chilli in the Punjab. *Journal of Insect Science* 1(1), 60-65.

Jha, R. K., Chi, H. & Tang, L.C. (2012) A Comparison of artificial diet and hybrid sweet corn for the rearing of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) based on life table characteristics. *Environmental Entomology* 41, 30–39.

Kennedy, J. S., Day, M. F. & Eastop, V. F. (1962) *A Conspectus of Aphids as Vectors as Plant Viruses.* Commonwealth Agricultural Bureaux, London.

Khan, M. M., Kundu, R. & Alam, M. Z. (2000) Impact of trichome density on the infestation of *Aphis gossypii* Glover and incidence of Virus dsease in Ashgourd *Benincasa hispida* (Thunb.). *International Journal of Pest Management* 46, 201-204.

Lam, W. K. F. & Pedigo, L. P. (2001) Effect of trichome density on soybean pod feeding by adult bean leaf beetles (Coleoptera: Chrysomelidae). *Journal of Economic Entomology* 94, 1459-1463.

Leite, M. V., Santos, T. M., Souza, B., Calixto, A. M. & Carvalho, C. F. (2008) Biologia de *Aphis gossypii* Glover, 1877 (Hemiptera: Aphididae) em abobrinha cultivar Caserta (*Cucurbita pepo* L.) em diferentes temperaturas. *Ciência e Agrotecnologia* 32, 1394-1401.

Li, Y., Hill, C. B. & Hartman, G. L. (2004) Effect of three resistant soybean genotypes on the fecundity, mortality, and maturation of soybean aphid (Homoptera: Aphididae). *Journal of Economic Entomology* 97, 1106-1111.

www.SID.ir

Archive of SID

Mattson, W. J. J. (1980) Herbivory in relation to plant nitrogen content. *Annual Review of Ecology and Systematics* 11, 119–161.

McCornack, B. P., Ragsdale, D. W. & Venette, R. C. (2004) Demography of soybean aphid (Hom.: Aphididae) at summer temperatures. *Journal of Economic Entomology* 97, 854–861.

Mehrkhou, F., Talebi, A. A., Moharamipour, S. & Hosseininaveh, V. (2012) Demographic parameters of *Spodoptera exigua* (Lepidoptera: Noctuidae) on different soybean cultivars. *Environmental Entomology* 41, 326-332.

Mojeni, D. T., Tariki, T. & Rezvani, A. (1997) Final report of study of infestation measurement of different cotton cultivars to Aphis gossypii. Tehran: Department of Plant Pests and Diseases of Gorgan and Gonbad Research Institute, Ministry of Agriculture.

Mollashahi, M. & Tahmasebi, A. (2009) Demographic parameters of *Aphis gossypii* Glover (Hom.: Aphididae) on greenhouse cucumber under laboratory conditions. *Journal of Agricultural Science and Natural Resorces* 16(3), 100-109.

Murai, T. (2001) Development and reproductive capacity of *Thrips hawaiiensis* (Thysanoptera: Thripidae) and itspotential as a major pest. *Bulletin of the Entomological Research* 91, 193 -198.

Oriani, M. A. D. G. & Vendramim, J. D. (2010) Influence of trichomes on attractiveness and ovipositional preference of *Bemisia tabaci* (Genn.) B Biotype (Hemiptera: Leyrodidae) on tomato Genotypes. *Neotropical Entomology* 39, 1002-1007.

Painter, R. H. (1951) Insect Resistance in Crop Plants. Macmillan, New York.

Pinto, Z. V., Rezende, J. A. M., Valdir Atsushi Yuki, V. A. & Piedade, S. M. S. (2008) Ability of *Aphis gossypii* and *Myzus persicae* to transmit cucumber mosaic virus in single and mixed infection with two Potyviruses to zucchini squash. *Summa Phytopathologica Botucatu* 34(2), 183-185.

Polat Akköprü, E., Atlıhan, R., Okut, H. & Chi, H. (2015) Demographic assessment of plant cultivar resistance to insect pests: A case study of the dusky-veined walnut aphid (Hemiptera: Callaphididae) on five walnut cultivars. *Journal of Economic Entomology* 108, 378–387.

Pompon, J., Quiring, D., Giordanengo, Ph. & Pelletier, Y. (2010) Role of host-plant selection in resistance of wild solanum species to *Macrosiphum euphorbiae* and *Myzus persicae*. *Entomologia experimentalis et applicata* 137, 73-85.

Price, P. W., Bouton, E., Gross, P., McPheron, B. A., Thompson, J. N. & Weis, A. E. (1980) Interactions among three trophic levels: Influence of plants on interactions between insect herbivores and natural enemies. *Annual Review of Ecology and Systematics* 11, 41–65.

www.SID.ir

Archive of SID

Rahsepar, A., Haghani, M., Sedaratian-Jahromi, A., Ghane-Jahromi, M. & Farrar, N. (2016) Different cucumber (*Cucumis sativus*) varieties could affect biological performance of cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), a case study at laboratory condition. *Entomofauna* 37, 353-364.

Razmjou, J., Vorburger, C., Mohammadi, M. & Hasanpour, M. (2012) Influence of vermicompost and cucumber cultivar on population growth of *Aphis gossypii* Glover. *Journal of Applied Entomology* 136 (8), 568-575.

Razmjou, J., Moharramipour, S., Fathipour, Y. & Mirhoseini, S. Z. (2006a) Demographic parameters of cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) on five cotton cultivars. *Insect Science* 13, 205-210.

Razmjou, J., Moharramipour, S., Fathipour, Y. & Mirhoseini, S. Z. (2006b) Effect of cotton cultivar on performance of *Aphis gossypii* (Homoptera: Aphididae) in Iran. *Journal of Economic Entomology* 99, 1820-1825.

Sa´nchez, N. E. & Pereyra, P. C. (1995) Life table of the soybean looper *Rachiplusia nu* (Lepidoptera: Noctuidae) in the laboratory. *Revista de la Sociedad Entomológica Argentina* 54, 89–96.

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.

Sánchez, N. E., Pereyra, P. C. & Gentile, M. V. (1997) Population parameters of *Epinotia aporema* (Lepidoptera: Tortricidae) on soybean. *Revista de la Sociedad Entomológica Argentina* 56, 151-153

Satar, S., Kersting, U. & Uygun, N. (1999) Development and fecundity of *Aphis gossypii* Glover (Homoptera: Aphididae) on three Malvaceae hosts. *Turkish Journal of Agriculture and Forestry* 23, 637-643.

Satar, S., Kersting, U. & Uygun, N. (2008) Effect of temperature on population parameters of *Aphis gossypii* Glover and *Myzus persicae* (Sulzer) (Homoptera: Aphididae) on pepper. *Journal of Plant Diseases and Protection* 115(2), 69–74.

Sauvion, S., Mauriello, V., Renard, B. & Boissot, N. (2005) Impact of melon accessions resistant to aphids on the demographic potential of silver leaf whitefly. *Journal of Economic Entomology* 98, 557-567.

Schoonhoven, L. M., van Loon, J. J. A. & Dicke, M. (2005) Insect-Plant Biology. Oxford University press, New York.

Scriber, J. M. & Slansky, F. (1981) The nutritional ecology of immature insects. *Annual Review of Entomology* 26, 183-211.

www.SID.ir

Archive of SID

Shannag, H. K., Al-Qudah, J. M., Makhadmeh, I. M. & Freihat, N. M. (2007) Differences in growth and yield responses to *Aphis gossypii* Glover between different okra varieties. *Plant Protection Science* 43(3), 109–116

Shirvani, A. & Hoseini-Naveh, V. (2004) Fertiltiy life table parameters estimation of *Aphis gossypii* Glover. *Iranian Journal of Agricultural Science* 35 (1), 23-29.

Slansky, F. (1993) Nutritional ecology: The fundamental quest for nutrients. In: Caterpillars. Ecological and evolutionary constrains on foraging, Stamp, N. E. & Casey, T. M. (eds.). pp 191-229. Chapman and Hall, New York.

Soufbaf, M., Fathipour, Y., Zalucki, M. P. & Hui, C. (2012) Importance of primary metabolites in canola in mediating interactions between a specialist leaf-feeding insect and its specialist solitary endoparasitoid. *Arthropod Plant Interact* 6, 241–250.

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

Srinivasan, R. & Uthamasamy, S. (2005) Trichome density and antibiosis affect resistance of tomato to fruitborer and whitefly under laboratory conditions. *Journal of Vegetation Science* 11, 3-17.

Takalloozadeh, H. M. (2010) Effect of host-plants and various temperatures on population growth parameters of *Aphis gossypii* Glover (Hom.: Aphididae). *Middle-East Journal of Scientific Research* 6(1), 25-30.

Tazerouni, Z., Talebi, A. A., Fathipour, Y. & Soufbaf, M. (2016) Bottom-up effect of two host Plants on life table parameters of *Aphis gossypii* (Hemiptera: Aphididae). *Journal of Agricultural Science and Technology* 18(1), 179-190.

Torkamand, M., Heidari, A., Ghajarieh, H. & Faravardeh, L. (2013) Comparison of susceptibility of melon aphid, *Aphis gossypii* G lover (Hemiptera: Aphididae), to pirimicarb and malathion in seven regions in Iran. *Journal of Crop Protection* 2 (2), 183-192.

Tuan, S. J., Lee, C. C. & Chi, H. (2014) Population and damage projection of *Spodoptera litura* (F.) on peanuts (*Arachis hypogaea* L.) under different conditions using the age-stage, two-sex life table. *Pest Management Science* 70, 805–813.

Tuan, S. J., Li, N. J. & Yeh, C. C. (2015) Growth performance and biometric characteristics of *Spodoptera litura* (F.) reared on different host plants. *Journal of Economic Entomology* 108, 2242–2249.

van Lenteren, J. C. & Noldus, L. P. J. J. (1990) Whitefly–Plant relationships: Behavioral and ecological aspects. In: *Whiteflies: Their Bionomics, Pest Status and Management,* Gerling D. (ed.). pp. 47–89. Intercept, Hants, United Kingdom.

www.SID.ir

Archive of SID

van Steenis, M. J. (1992) Biological control of the cotton aphid, *Aphis gossypii* Glover (Hom., Aphididae): pre-introduction evaluation of natural enemies. *Journal of Applied Entomology* 114, 362-380.

van Steenis, M. J. & El-Khawass, K. A. M. H. (1995) Life history of Aphis gossypii on cucumber: influence of temperature, host plant and parasitism. *Entomologia Experimentalis et Applicata* 76**,** 121-131.

Vargas, R. I., Stark, J. D. & Nishida, T. (1990) Population dynamics, habitat preference, and seasonal distribution patterns of oriental fruit fly and melon fly (Diptera: Tephritidae) in an agricultural area. *Environmental Entomology* 19, 1820-1828.

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, 162-168.

White, T. C. R. (1993) The Inadequate Environment: Nitrogen and the Abundance of Animals. Springer, New York.

Xia, J. Y., van der Werf, W. & Rabbinge, R. (1999) Influence of temperature on bionomics of cotton aphid, *Aphis gossypii*, on cotton. *Entomologia Experimentalis et Applicata* 90, 25–35.

Yang, T. C. & Chi, H. (2006) Life tables and development of *Bemisia argentifolii* (Homoptera: Aleyrodidae) at different temperatures. *Journal of Economic Entomology* 99, 691–698.

Yazıcı, E. & Akça, I. (2016) Determination of some biological parameters of *Aphis gossypii* Glover (Hemiptera: phididae) on different eggplant cultivars. *Journal of Agricultural Science* 31, 33-39

Zamani, A. A., Talebi, A. A., Fathipour, Y. & Baniameri, V. (2006) Effect of temperature on biology and population growth parameters of *Aphis gossypii* Glover (Homoptera, Aphididae) on greenhouse cucumber. *Journal of Applied Entomology* 130, 453-460.

Zarpas, K. D., Margaritopoulos, J. T., Stathi, L. & Tsitsipis, J. A. (2006) Performance of cotton aphid *Aphis gossypii* (Hemiptera: Aphididae) lineages on cotton varieties. *International Journal of Pest Management* 52(3), 225-232.

Žnidarčič, D., Marković, D., Vidrih, R., Bohinc, T. & Trdan, S. (2011) Which biophysical and biochemical factors may contribute to higher resistance of cabbage (*Brassica oleraceae* L. var. Capitata) to attack of the most important pests. *Acta Agriculturae Slovenica* 97(2), 151-158.

Žnidarčič, D., Valič, N. & Trdan, S. (2008) Epicuticular wax content in the leaves of cabbage (*Brassica oleracea* L. var. Capitata) as a mechanical barrier against three insect pests. *Acta Agriculturae Slovenica* 91(2), 361-370.

www.SID.ir