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A laboratory and field condition comparison of life table parameters of *Aphis gossypii* Glover (Hemiptera: Aphididae)

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Abstract: Life table studies are essential tools for understanding population dynamics. The life table parameters of *Aphis gossypii* Glover (Hemiptera: Aphididae) feeding on the host plant, *Hibiscus syriacus* L. were studied under laboratory (25±1°C and relative humidity of 65±5% and a photoperiod of 16L : 8D h) and field conditions (23–43°C, and relative humidity of 27–95%). The data were analysed using the age-stage, two-sex life table theory. The life table studies were started with 50 and 40 nymphs in laboratory and field conditions, respectively. Under laboratory conditions, *A. gossypii* reared on *H. syriacus* had a higher survival rate, fecundity, and longevity than those reared under field conditions. When reared under field conditions, *A. gossypii* had a longer nymphal developmental time, shorter adult longevity, and lower fecundity than those reared under laboratory conditions. The intrinsic rate of increase (r), net reproductive rate (R_0), and the finite rate of increase (λ) under laboratory conditions, were higher than those obtained under field conditions. Nevertheless, there were no significant differences in the mean generation time T (days) between field and laboratory conditions. In the present study, the results clearly showed that life table parameters of *A. gossypii* were significantly different under field and laboratory conditions. These results could help us to understand the *A. gossypii* population dynamics under field conditions. The results could also help us make better management decisions for economically important crops.

Key words: cotton aphid, life table parameters, natural conditions, net reproductive rate, the intrinsic rate of increase

Introduction

The cotton-melon aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), is a cosmopolitan, polyphagous species which is widely distributed in tropical, subtropical, and temperate regions. This aphid feeds on a wide range of dicotyledonous plants including members of the Cucurbitaceae. The cotton-melon aphid is a pest of cotton and citrus. In temperate zones this aphid mainly attacks vegetables in fields and greenhouses (Leclant and Deguine 1994; Klingler *et al*. 1998; Kersting *et al*. 1999; Capinera 2001; Baniameri and Nasrollahi 2003; Isikber 2005). *Aphis gossypii* is a polymorphic species. It is variable in its morphology (colour and dwarf forms) (Wall 1933; Setokuchi 1981) and in its life cycle (holocyclic, anholocyclic, and mixed populations) (Takada 1988). Damage caused includes a reduction in yield and fruit quality through direct feeding and honeydew production as well as damage incurred from the transmission of more than 50 plant viruses (Roistacher *et al*. 1984; Blackman and Eastop 2000).

In areas with rigorous winters, *A. gossypii* has been described as a holocyclic species, showing a sexual reproduction event on a limited number of primary hosts. *Hibiscus syriacus* L., *Catalpa bignoïdes* Walter and some other ligneous plants act as hosts (Carletto *et al*. 2009). Rose of Sharon, *H. syriacus*, is a common garden hibiscus. It is a flowering shrub of the Malvaceae family, native to Asia. In temperate regions, it is among the most commonly grown ornamental species, widely planted in areas with hot summers. It is a deciduous and fast growing species, reaching 2–4 m in height, with very attractive white, pink, red, lavender, or purple flowers (Capinera 2001; Paoletti *et al*. 2009).

Life table studies are essential tools for understanding population dynamics and estimating the growth parameters and reproduction potential of insect populations (Chi and Su 2006). Life table studies are often used by scientists as a method of projecting the growth of populations and predicting the size of a population. The life table provides an integrated and comprehensive description which includes the details of development times, the survival rates of each growth stage, and the fecundity and life expectancy of a population (Istock 1981; Chi 1990; Carey 1993; Medeiros *et al*. 2000; Southwood and Henderson 2000; Yang *et al*. 2013).

The intrinsic rate of increase (r) is the most useful life table parameter to predict the population growth potential of different species under a given environmental condition (Southwood 1966; Ricklefs and Miller 1999; Southwood and Henderson 2000). The daily fecundity data generated by life tables allow prediction of the population size and age structure of a natural enemy at any time (Southwood 1966). The intrinsic rate of increase has been widely used as a bioclimatic index (Hulting *et al*. 1990), and in estimation of insect response to resistant plants

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(Ruggle and Gutierrez 1995), and in comparison of different food types that predators consume (Engel 1990). Although a large number of factors affect the components of *r*, there is a close and positive association between the mean relative growth rate and *r* (Guldemond *et al*. 1998).

Chi and Liu (1985) and Chi (1988) developed the age-stage, two-sex life table theory and data analysis. This method has been used to describe the population characteristics of many insect and mite species.

Many studies have examined the effect of temperature on the biology and population growth parameters, development, and fecundity of *A. gossypii* reared on cucumber and *Cucurbita pepo* L. under laboratory conditions (Wyatt and Brown 1977; Aldyhim and Khalil 1993; Kocourek *et al*. 1994; Satar *et al*. 2005; Zamani *et al*. 2006). However, nothing has been done under field conditions.

Identifying the differences between life tables collected in the laboratory and those actual life tables under field conditions is necessary to construct precise predictions of the dynamics of populations in the field (Huang and Chi 2013). We intended to find such differences between the life table parameters of *A. gossypii* reared on *H. syriacus* such as age-stage specific survival and fecundity, reproductive value, net reproductive value, intrinsic rate of increase, and finite rate of increase, under field and laboratory conditions.

Materials and Methods

Insect culture

Leaves bearing *A. gossypii* were collected from *H. syriacus* at the College of Agricultural Sciences in the University of Guilan (Northern Iran). The leaves were kept in a growth chamber at 25±1°C, 65±5% relative humidity (RH) and a photoperiod of 16L : 8D h. The colony was maintained for two generations before the beginning of the life table study. Then, newly born nymphs of *A. gossypii* were placed, separately, on a *H. syriacus* apical leaf in plastic Petri dishes (10 cm in diameter). Each dish had a hole in the center of the lid, and was covered with muslin for aeration. A layer of wet cotton padding, 0.5 cm-thick, lined the Petri dish, and the leaf was on the bottom of the Petri dish (Madahi and Sahragard 2012). Whenever leaves appeared discolored, they were replaced with fresh ones.

A similar methodology was used to study the life table of *A. gossypii* in leaf cages in the field. Each Petri dish had a hole in the center of the lid, and was covered with muslin for aeration. A hole was made through both the lid and body of the Petri dish. The leaf cage was placed over the leaf with the stem of the plant passing through the side hole of the cage. The aphids' development was checked every 24 h; from the first instars to the death of the adults. A magnifier 55× was used. Daily temperature and humidity were measured with Digital hygro-thermometer. The temperature ranged from 23–43°C, and the relative humidity was 27–95%.

The aphid first instar nymphs were placed in their natural position under the leaf surface (Liu and Meng 1999). Nymphs were observed every 24 h until the adult stage. After adult appearance, the survival, mortality, and number of nymphs produced by each female, was recorded daily. The life table studies were started with 50 and 40 nymphs in the laboratory and field, respectively.

Data analysis

The life table data were analysed according to the age-stage, two-sex life table theory (Chi and Liu 1985) and the method described by Chi (1988).

To facilitate the tedious process of raw data analysis, a computer program TWOSEX-MSCHART for the age-stage, two-sex life table analysis (Chi 2013) in VISUAL BASIC (version 6, service pack 6) for the Windows system was used and is available at http://140.120.197.173/Ecology/ (Chung Hsing University) and at http://nhsbig.inhs.uiuc.edu/wes/chi.html (Illinois Natural History Survey).

The age-stage specific survival rate (s_{xj}) (where x means age and j – stage), the age-stage specific fecundity (f_{xj}), the age-specific survival rate (l_x), the age-specific fecundity (m_x), and the population parameters (r – the intrinsic rate of increase; λ – the finite rate of increase; R_0 – the net reproductive rate; T – the mean generation time) were calculated accordingly.

The means, variances and standard errors of the life table parameters were estimated with the bootstrap (m = = 10,000) method (Efron and Tibshirani 1993).

Results

The developmental times for each stage are listed in table 1. The development time of the pre-adult stage of *A. gossypii* on *H. syriacus* was generally faster under laboratory conditions. Development time was 6.32±0.155 days under laboratory conditions and 8.075±0.18 days under field conditions. First instar *A. gossypii* developed faster under field conditions than under laboratory conditions but the development time from the second to the fourth instars was shorter in the laboratory than in the field conditions. *Aphypis gossypii* adult longevity was shorter under the field conditions than under laboratory conditions. Mean fecundity (F) (nymphs/female/day) under the laboratory conditions was significantly higher than in the field.

The life table parameters of *A. gossypii* indicated slower development of the field populations than those in the laboratory (Table 2). There was no significant difference in the T (days) between the two conditions. The r and λ were significantly higher under laboratory conditions than under field conditions, respectively. Significantly higher under laboratory conditions than in the field was R_0. The s_{xj} depicts the probability of a newborn surviving to age x and stage j. The parameters l_x, m_x, and age-specific maternity ($l_x m_x$) are also plotted in figure 1. Significant variability can be observed between the field and laboratory conditions. The survival rates in the laboratory were higher than those in the field (Fig. 1).

According to the age-stage, two-sex life table, the age-stage specific life expectancy (e_{xj}) is the lifespan remaining for an individual of age x and stage j (Fig. 2).

The reproductive value v_{xj} is the contribution of individuals of age x and stage j to the future population (Fig. 3). Peaks of reproductive value occurred at the ages

Table 1. Developmental times (days; mean ±SE) of *Aphis gossypii* reared on *Hibiscus syriacus* under laboratory and field conditions

Stages	Laboratory	Field	t value	Pr > |t|
First instar	2±0.111 a	1.5±0.088 b	3.41	0.0010
Second instar	1.56±0.076 b	2.15±0.084 a	5.17	< 0.0001
Third instar	1.6±0.095 b	2.55±0.094 a	7.01	< 0.0001
Fourth instar	1.16±0.072 b	1.875±0.089 a	6.31	< 0.0001
Pre-adult	6.32±0.155 b	8.075±0.18 a	7.41	< 0.0001
Adult	10.44±0.546 a	5±0.322 b	8.05	< 0.0001
Total longevity	16.76±0.473 a	13.075±0.278 b	6.30	< 0.0001
Mean fecundity (*F*)	17.87±1.47 a	4.49±0.57 b	56.62	< 0.0001

Means in the same row followed by the same letter are not significantly different (p = 0.05) using the t-test
There was a significant difference between the statistics of the laboratory and field conditions using the t-test (p = 0.05)

Table 2. Population growth parameters (days; mean ±SE) of *Aphis gossypii* calculated using the age-stage, two-sex life table on *Hibiscus syriacus* under field and laboratory conditions

Parameters	Laboratory	Field	t value	Pr > |t|
The intrinsic rate of increase *r* (per days)	0.271358±0.00092 a	0.140328±0.01279 b	52.79	< 0.0001
Finite rate of increase λ (per days)	1.311791±0.01204 a	1.150736±0.01496 b	46.03	< 0.0001
Net reproductive rate R_0 (offspring)	17.8732±1.4684 a	4.4888±0.5648 b	59.07	< 0.0001
Mean generation time *T* (days)	10.61634±0.177 a	10.6644±0.253 a	1.02	0.2293
Gross reproductive rate (*GRR*) (offspring)	22.8105±1.396 a	6.2373±0.845 b	69.59	< 0.0001

Means in the same row followed by the same letter are not significantly different (p = 0.05) using the t-test

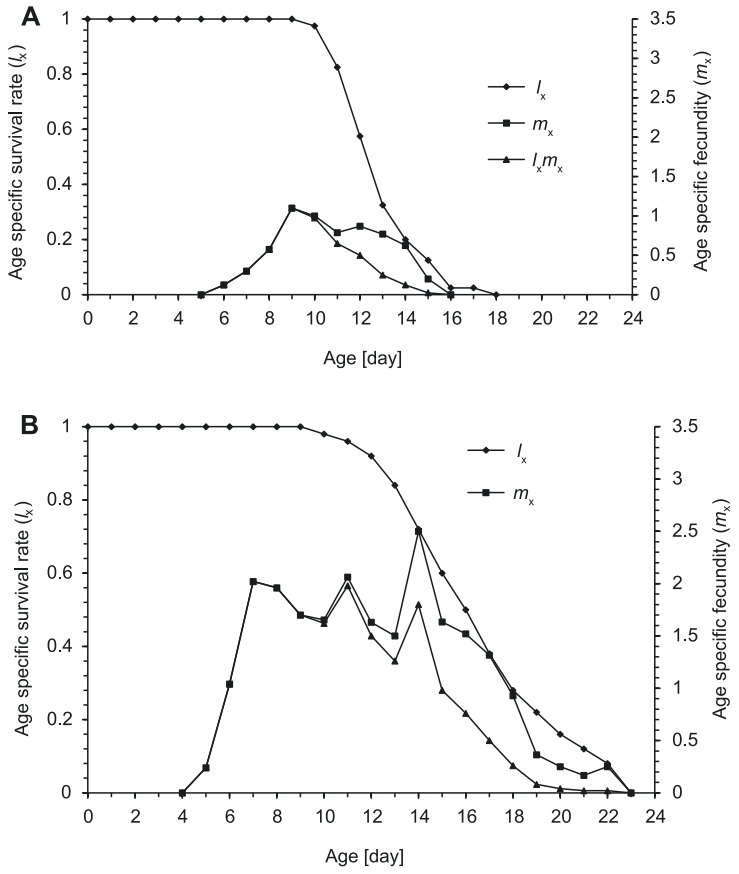

Fig. 1. Age-specific survival rate (l_x), age-specific fecundity (m_x) and age-specific maternity (l_xm_x) of *Aphis gossypii* under field (A) and laboratory (B) conditions

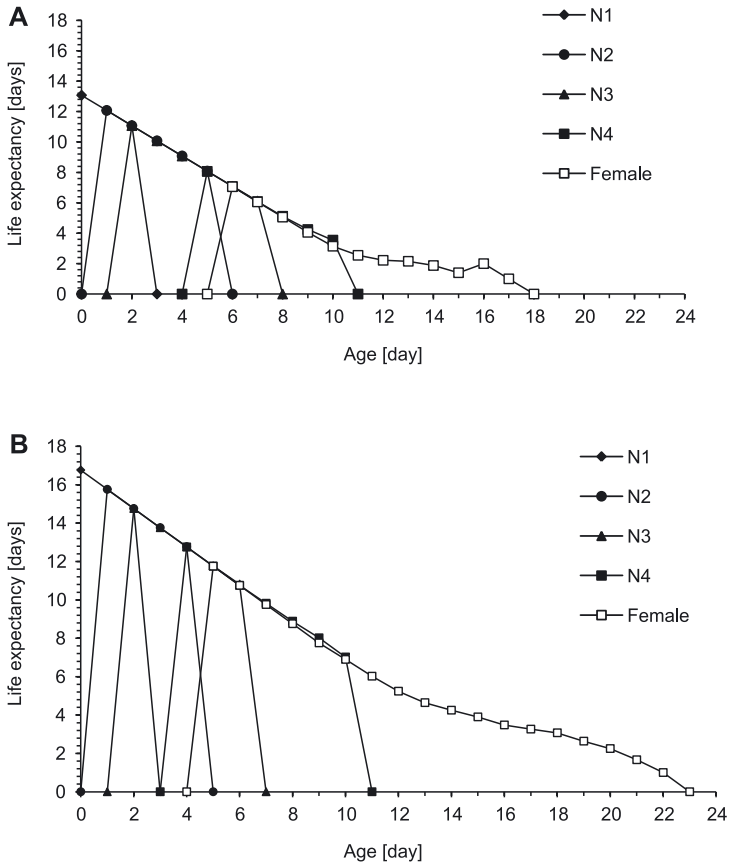

Fig. 2. Age-stage specific life expectancy of *Aphis gossypii* under field (A) and laboratory (B) conditions

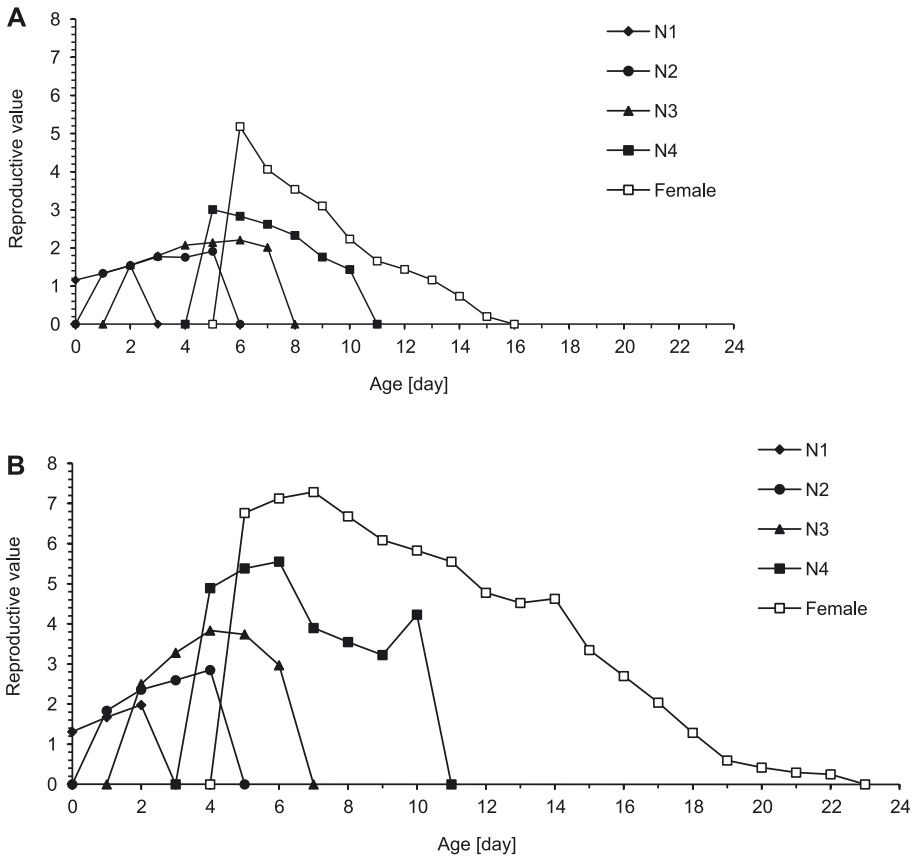

Fig. 3. Age-stage specific reproductive value of *Aphis gossypii* under field (A) and laboratory (B) conditions

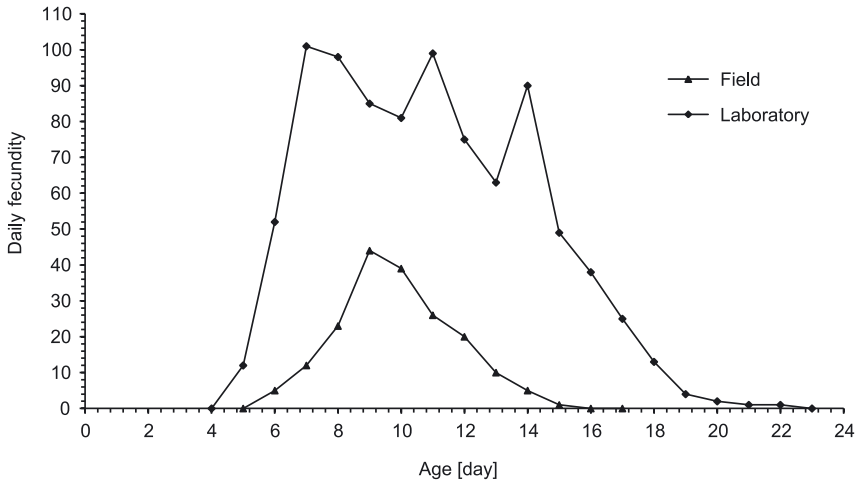

Fig. 4. Age-stage specific total fecundity $F_{t\,(x,j)}$ of all individuals of *Aphis gossypii* under field and laboratory conditions

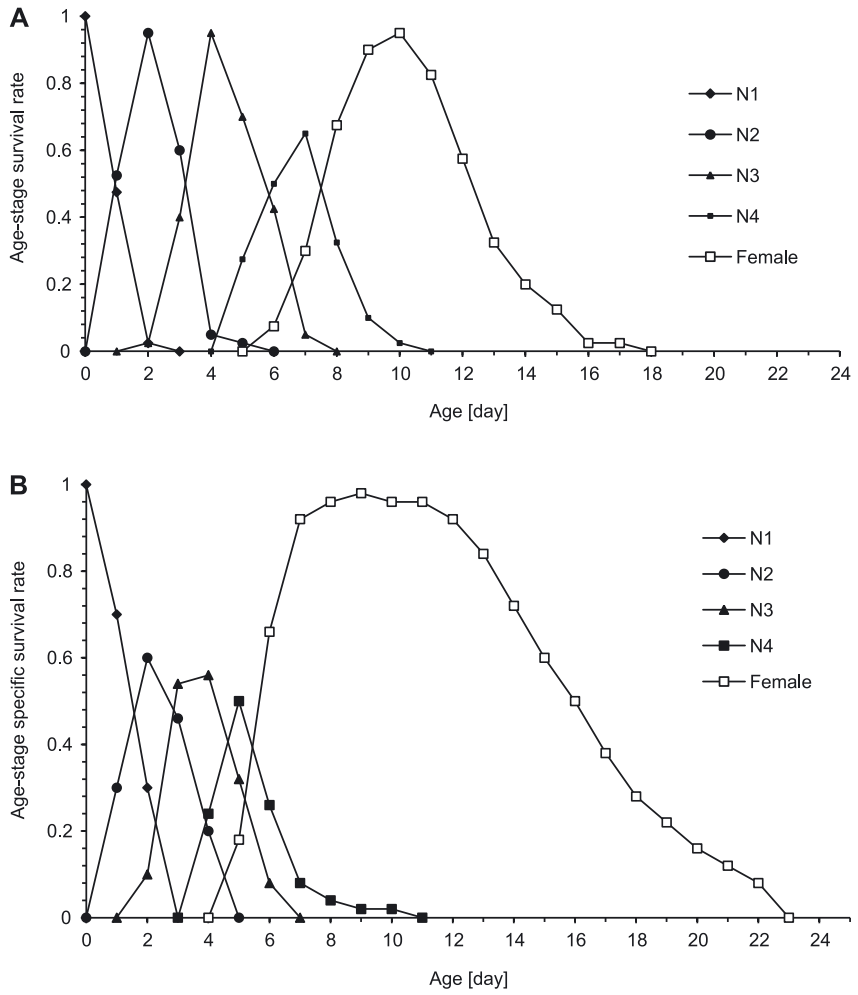

Fig. 5. Age-stage specific survival rate of *Aphis gossypii* under field (A) and laboratory (B) conditions

of seven and six days under laboratory and field conditions, respectively.

The daily mean number of offspring produced by individual *A. gossypii* of age *x* and stage *j* per day is shown with the f_{xj} in figure 4. Age-stage specific survival rates (s_{xj}) of *A. gossypii* under field and laboratory conditions are shown in figure 5.

Discussion

Our study showed that immature development times of *A. gossypii* were longer under field conditions than in the laboratory, except for the first instars nymphs. The lifetime fecundity was lower under field conditions than in the laboratory conditions. Similar results were found for nymphal developmental times of *Bactericera cockerelli* (Sulc) on tomato as they were longer under field condi-

tions than in the laboratory, except for the fifth instars (Yang *et al*. 2013). In the fluctuating climatic and natural conditions of cotton fields, immature development time of *A. gossypii* also increased and adult development times and reproduction decreased (Afshari *et al*. 2007). Longevity of the predatory pentatomid, *Brontocoris tabidus* (Signoret) under field conditions, was also longer than under laboratory conditions. This finding was important because it indicates a longer period of predation was exerted by this predator in the field than was expected from laboratory studies (Zanuncio *et al*. 2006).

It was shown that the adult longevity of *A. gossypii* in field conditions was lower than in laboratory conditions. The shorter adult longevity under field conditions might be due to the high temperature and the higher humidity. Zamani *et al*. (2006) reported that developmental time of *A. gossypii* reared on *Cucumis sativus* L. under laboratory conditions, was inversely related to temperature. Satar *et al*. (2005) reported that developmental periods of immature stages of *A. gossypii* under laboratory conditions, ranged from 10.8 days at 15°C to 4.1 days at 30°C and 32.5°C. Adult longevity of *Hyalopterus pruni* (Geoffroy) decreased when the temperature increased (Latham and Mills 2011). Yang and Chi (2006) reported that mean developmental times of *Bemisia argentifolii* Bellows and Perring decreased with an increase in temperature.

Developmental times of *Brachycaudus schwartzi* (Börner) (Satar and Yokomi 2002) and *Aphis spiraecola* Patch (Wang and Tsai 2000) decreased when the temperature increased. Yang *et al*. (2013) reported that female longevities of *B. cockerelli* reared on tomato were shorter under field conditions than under laboratory conditions and were 16.2±0.9 and 60.5±8.4 days, respectively.

In this study, the population growth parameters showed that *A. gossypii* development was much faster under field conditions than under laboratory conditions. The *r* under field conditions was significantly lower under laboratory conditions. The *r* of *B. cockerelli* fed on potato was significantly higher in the laboratory 0.1966 d^{-1} than in field conditions 0.1015 d^{-1} (Yang *et al*. 2010).

The R_0 was also significantly higher under laboratory conditions. A similar result was found for melon flies reared in the laboratory at 25°C, as the net reproductive rate was higher under field conditions (Huang and Chi 2013).

It can generally be concluded that life table parameters of *A. gossypii* were significantly different under field and laboratory conditions. Understanding the insect pests life tables in field conditions is a useful tool for making accurate management decisions for economically important crops. The differences reported here between the laboratory and field studies, together with the life table analysis, are important for preventing the unsuitable extrapolation of laboratory results to field applications.

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