

Comparative life table of *Aphis pomi* (Hemiptera: Aphididae) on two host plants *Malus pumila* L. and *Chaenomeles japonica* under laboratory conditions

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Abstract: Life table parameters of *Aphis pomi* DeGeer (Hemiptera: Aphididae) were determined on two host plants: apple (*Malus pumila* L.) and flowering quince (*Chaenomeles japonica* Lindl.). This study was carried out under laboratory conditions (25 ± 1 °C and RH of 70 ± 5 % and a photoperiod of 16: 8 h (L: D)). The survivorship from first instar nymphs to adult was very close in *M. pumila* and *C. japonica*. The longevity of *A. pomi* was 8.1 ± 0.458 and 9.65 ± 0.412 days and the fecundity of female was 37.25 ± 2.198 and 32.9 ± 1.802 nymphs on *M. pumila* and *C. japonica*, respectively. Peaks of reproductive value occurred at ages of 8 and 9 days when reared on *M. pumila* and *C. japonica*, respectively. The intrinsic rate of increase (r) on *M. pumila* was higher than that on *C. japonica*, as it was 0.396 ± 0.015 on *M. pumila* and 0.329 ± 0.006 day⁻¹ on *C. japonica*. The mean generation time (T) was 9.13 ± 0.35 and 10.62 ± 0.18 days, on *M. pumila* and *C. japonica*, respectively. The results showed that the two closely related host plants had significant influence on life table parameters of *A. pomi* and the aphid showed a better performance on *M. pumila* than on *C. japonica*. These results indicated that *M. pumila* is more suitable for *A. pomi*, resulting in a higher reproductive performance.

Keywords: Green apple aphid, generation time, intrinsic rate of increase, life table parameters

Introduction

Green apple aphid, *Aphis pomi* DeGeer (Hemiptera: Aphididae), is a holocyclic and autoecious species that feed on apple (*Malus*) and other woody Rosaceae like Asian flowering quince (Japanese flowering quince). Asian flowering quinces, *Chaenomeles*, are closely related to *Cydonia*, *Pyrus*, and *Malus*. The Japanese quince (*C. japonica*) is a shrubby plant with attractive red flowers and aromatic hard fruit that resemble loquat in appearance. It is a

popular landscape ornamental (Hummer and Janick, 2009). *Aphis pomi* can be found in most areas where apple is cultivated. In many areas of Iran, this species is more abundant during June and July on young trees, water buds, and growing terminals and causes damage by sucking the sap, curling the leaves, and inhibiting shoot growth (Radjabi, 1989). If the infestation is severe, the shoots shrivel, and the fruit is deformed. Finally, excreted honeydew causes sooty mold infestation (Rakauskas and Rupais, 1983, Howitt, 1993). High population may cause abnormal growth of terminal shoots, reduce the percentages of non-structural carbohydrates in shoots, roots and leaves of apple trees and reduce the crop (Kaakeh *et al.*, 1993).

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Plant species differ greatly in terms of their suitability as host plants. The plant's nutritional value, secondary metabolites, and architectural characteristics can all affect the insect development, survival, fecundity, population growth and life table of herbivorous insects (Slansky and Feeny, 1977; Norris and Kogan, 1980; Montllor, 1991; Morgan *et al.*, 2001; Tsai and Wang, 2001; Kim and Lee, 2002; Liu *et al.*, 2004; Rutledge and O'Neil, 2005; Yaşar and Güngör, 2005; Kumar *et al.*, 2009). Some plant species protect themselves from herbivorous insects by producing secondary metabolites (Nielsen, 1978; Isman & Duffey, 1982). In some herbivore species, host plant quality during larval growth and development can affect both fecundity and fertility of adults (Awmack and Leather, 2002). Having a low nutritional value and lower suitability of a host plant can also act as a defense against insect attack and increase the herbivore's developmental time or decrease its total reproduction (van Lenteren and Noldus, 1990; Michaud, 1999). Developmental rate and reproduction provide important clues concerning the ability of the host to support a complete insect life cycle, these data should be linked to other parameters (e. g. mortality) before a final conclusion about host suitability (Liu *et al.*, 2004).

For a successful theoretical and applied population ecology and pest management program, it is important to understand the ecology of a pest and estimating the growth parameters and reproduction potential of insect population (Sorouhmehr *et al.*, 2008). The life table provide an integrated and comprehensive description in details of development times, survival rates of each growth stage, fecundity and life expectancy of a population, and is often used by scientists as a method of projecting the growth of populations and predicting the size of a population (Chi, 1990; Carey, 1993; Medeiros *et al.*, 2000; Southwood and Henderson, 2000). Also, collection of life table data for related species of different trophic levels in a food chain is a basic and important task for conservation (Bevill and Louda, 1999; Gabre *et*

al., 2005) and pest management (Naranjo, 2001). The theory and methodology of the life table are discussed in most ecology textbooks (e. g., Price, 1997, Ricklefs and Miller, 1999).

Population growth rate is a basic ecological characteristic that is usually described as the intrinsic rate of increase (r), an estimate of population growth potential introduced by Birch (1948). Southwood (1966) stated that the intrinsic rate of increase is the most practical life table parameter to compare the population growth potential of different species under specific climatic and food conditions and may help predict the outcomes of pest–natural enemy interactions (Roy *et al.*, 2003). The intrinsic rate of increase (r) summarizes the physiological qualities of an animal relative to its capacity to increase (Andrewartha and Birch, 1954). Besides being a measure of population growth, r has been widely used as a bioclimatic index (Hulting *et al.*, 1990), in estimation of insect response to resistant plants (Ruggle & Gutierrez, 1995), and in comparison of different food types that predators consumed (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 (Guldmond *et al.*, 1998).

Since *M. pumila* as a commercial fruit tree and *C. japonica* as a popular landscape ornamental shrub are very important plants, the main purpose of this study was to determine the impact of two host plants on the biology and life table parameters of *A. pomi* population under laboratory conditions. We analyzed the data using the age-stage, two-sex life table to find out the effect of these two host plants on life table parameters and understanding interactions between *A. pomi*, apple tree (*M. pumila*) and flowering quince (*C. japonica*).

Material and methods

Insect culture

Leaves bearing apterous adult and different instars of *A. pomi* were collected from *Chaenomeles* bushes at the College of Agriculture at the University of Guilan

(Northern Iran) and kept in a growth chamber at 25 ± 1 °C, 70 ± 5 % relative humidity (RH) and a photoperiod of 16:8h (L: D).

Life table study

In order to conduct life table experiments, some adult *A. pomi* were placed on Golden delicious apple seedling leaves for 24 h. Then, newly born nymphs of *A. pomi* were placed separately on an apple apical leaf in plastic Petri dishes (10 cm in diameter) with a hole in the center of the lid, which was covered with muslin for aeration and lined with 0.5 cm-thick layer of wetted cotton pad around the leaf in the bottom of the Petri dish. They were reared individually on *M. pumila* L. and *C. japonica* Lindl leaves. Each experiment was replicated 20 times for each host plant. Whenever leaves appeared discolored, they were replaced with fresh ones (usually everyday). The aphid nymphs were placed in their natural position on the undersurface of the leaf (Liu and Meng, 1999). Nymphal development was recorded every 24 h until the adult stage. After adults appearance, survival, mortality and number of nymph produced by females were recorded daily.

Data 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).

The age-stage specific survival rate (s_{xj}) (where x = 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, $\lambda = e^r$; R_0 , the net reproductive rate; T , the mean generation time) were calculated accordingly. In the age stage, two-sex life table, the l_x and m_x were calculated according to Chi and Liu (1985) as:

$$l_x = \sum_{j=1}^k s_{xj} \quad (1)$$

and

$$m_x = \frac{\sum_{j=1}^k s_{xj} f_{xj}}{\sum_{j=1}^k s_{xj}} \quad (2)$$

where k is the number of stages. The intrinsic rate of increase was calculated using the iterative bisection method from

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1 \quad (3)$$

with age indexed from 0 (Goodman, 1982). Data analysis were done using the TWSEX-MSChart program designed in visual BASIC for the Windows operation system (Chi, 2005). The TWSEX-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).

We used the Tukey procedure to compare the differences among treatments following the description of Sokal & Rohlf (1995).

Results

Age-stage, two-sex life table

There was no significant differences in the development periods of immature stages of *A. pomi* feeding on two host plants, although, these periods were slightly higher on *C. japonica* (Table 1).

The adult longevity, total longevity and fecundity are given in Table 2. The adult longevity and total longevity of *A. pomi* was significantly shorter on *M. pumila* than on *C. japonica*. Fecundity of *A. pomi* feeding on *M. pumila* was higher than *C. japonica*, with no significant difference (Table 2). The trend of age-specific fecundity (m_x) showed that reproduction began at the age of 4 days on both host plants. The highest fecundity on both host plants was also observed at the age of 10 days (Fig. 1).

In immature stages, the survival rate of first, second, third instars and adult aphids on *M. pumila* and *C. japonica* were very close to each other (Table 4).

Table 1 Mean developmental times (days; mean \pm SE) of *Aphis pomi* feeding on *Malus pumila* and *Chaenomeles japonica* at 25 ± 1 °C, 70 % \pm 5 % relative humidity, photoperiod 16:8h (L: D).

Stages	<i>Malus pumila</i>	<i>Chaenomeles japonica</i>	df	F	P
First instar nymph	1.45 \pm 0.114 a	1.65 \pm 0.109 a	1,38	1.60	0.214
Second instar nymph	1.2 \pm 0.092 a	1.35 \pm 0.109 a	1,38	1.10	0.300
Third instar nymph	1.3 \pm 0.105 a	1.40 \pm 0.112 a	1,38	0.42	0.519
Fourth instar nymph	1.55 \pm 0.114 a	1.60 \pm 0.112 a	1,38	0.10	0.757
Pre-adult	5.5 \pm 0.295 a	6 \pm 0.178 a	1,38	2.11	0.154

Means in the same row followed by the same letter are not significantly different ($P > 0.05$) using Tukey procedure.

Table 2 Longevity (days) and fecundity (mean \pm SE) of *Aphis pomi* feeding on *Malus pumila* and *Chaenomeles japonica* at 25 ± 1 °C, 70 % \pm 5 % relative humidity, photoperiod 16: 8h (L: D).

Biological parameters	<i>Malus pumila</i>	<i>Chaenomeles japonica</i>	df	F	P
Adult longevity (days)	8.1 \pm 0.458 b	9.65 \pm 0.412 a	1,38	6.32	0.0163
Total longevity (days)	13.6 \pm 0.505 b	15.65 \pm 0.35 a	1,38	11.4	0.0019
Fecundity (F) (eggs/female)	37.25 \pm 2.198 a	32.9 \pm 1.802 a	1,38	2.34	0.1342

Means in the same row followed by the same letter are not significantly different ($P > 0.05$) using Tukey procedure.

Table 3 Associated life table estimates for population parameters (Means \pm SE) of *Aphis pomi* calculated using the age-stage, two-sex life table on *Malus pumila* and *Chaenomeles japonica* at 25 ± 1 °C, 70 % \pm 5 % relative humidity, photoperiod 16: 8h (L: D).

Population parameters	<i>Malus pumila</i>	<i>Chaenomeles japonica</i>	df	F	P
Intrinsic rate of increase (r) (day^{-1})	0.3961 \pm 0.0154 b	0.3291 \pm 0.0062 a	1,38	16.26	0.0003
Finite rate of increase (λ) (day^{-1})	1.4858 \pm 0.0229 b	1.3897 \pm 0.0086 a	1,38	15.46	0.0003
Net reproductive rate (R_0) (offspring)	37.25 \pm 2.2 b	32.9 \pm 1.8 a	1,38	2.34	0.1342
Mean generation time (T) (day^{-1})	9.13 \pm 0.35 b	10.62 \pm 0.18 a	1,38	14.77	0.0004
Gross reproductive rate (GRR) (offspring)	55.99 \pm 5.01 b	39.66 \pm 2.25 a	1,38	8.84	0.0051

Means in the same row followed by the same letter are not significantly different ($P > 0.05$) using Tukey procedure.

Table 4 The survival rates of different stages of *Aphis pomi* feeding on *Malus pumila* and *Chaenomeles japonica* at 25 ± 1 °C, 70 % \pm 5 % relative humidity, photoperiod 16: 8h (L: D).

Host plants	First instar nymph	Second instar nymph	Third instar nymph	Fourth instar nymph	Adult
<i>Malus pumila</i>	42.8882	21.3962	13.9895	9.5636	12.1625
<i>Chaenomeles japonica</i>	41.4269	21.111	13.5067	10.1856	13.7698

The trend of survival rates of adults were very similar on two host plants with slight variation (Fig. 1). Based on the age-stage, two-sex life table, the age-stage-specific life expectancy (e_{xj}) gives the expected life span of an individual of age x and stage j can live after age x (Fig. 2). The trends of life expectancy on two host plants were very close to each other. 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 ages of 9 and 8 days when reared on *M. pumila* and *C. japonica*, respectively. This implies that, in comparison to other ages, female individuals of ages 9 and 8 days make the highest contribution to the population when reared on *M. pumila* and *C. japonica*, respectively.

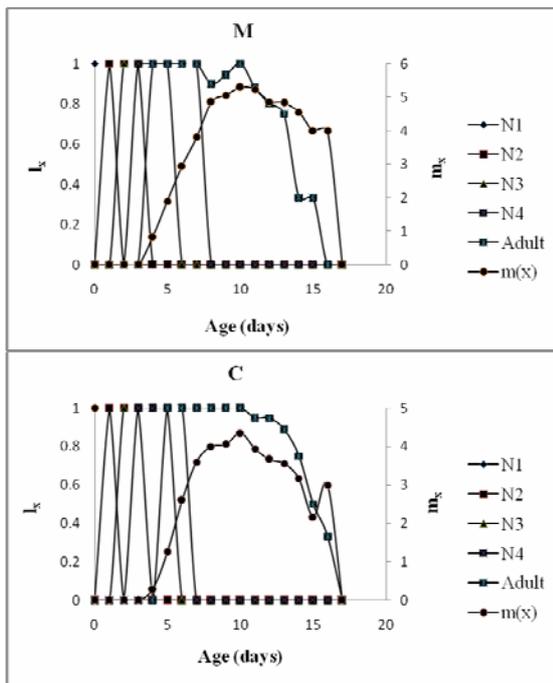


Figure 1 Age-stage specific survivorship (l_x) for adult stage, and age-specific fecundity (m_x) of *Aphis pomi* feeding on *Malus pumila* and *Chaenomeles japonica* (M = *Malus pumila*, C = *Chaenomeles japonica*).

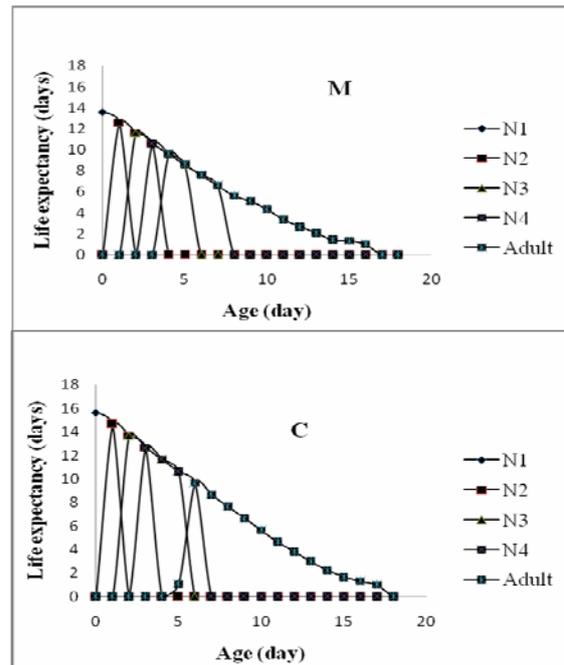


Figure 2 Age-stage-specific life expectancy of *Aphis pomi* feeding on *Malus pumila* and *Chaenomeles japonica* (M = *Malus pumila*, C = *Chaenomeles japonica*).

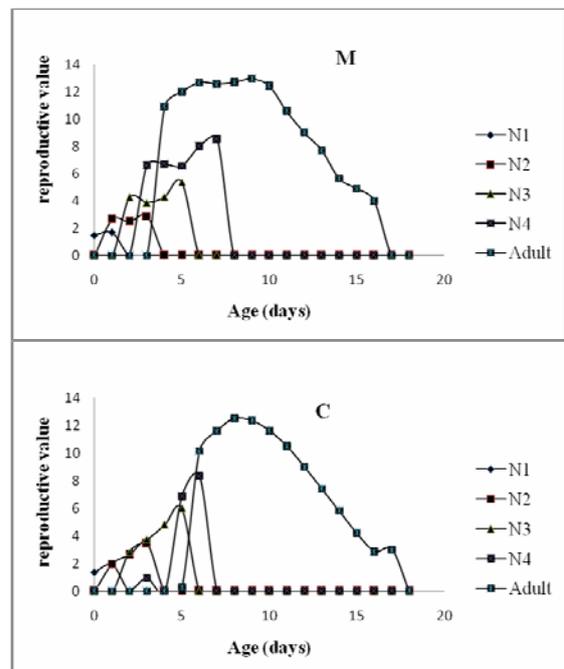


Figure 3 Age-stage-specific reproductive value of *Aphis pomi* feeding on *Malus pumila* and *Chaenomeles japonica* (M = *Malus pumila*, C = *Chaenomeles japonica*).

Population growth parameters

The population parameters such as the intrinsic rate of increase (r), the finite rate of increase (λ), net reproductive rate (R_0), mean generation time (T) and gross reproductive rate (GRR) and their standard errors are shown in Table 3. The intrinsic rate of increase (r), finite rate of increase (λ), net reproductive rate (R_0) and gross reproductive rate (GRR) on *M. pumila* were significantly higher than on *C. japonica*. Mean generation time (T) on *C. japonica* was significantly higher than on *M. pumila*.

Discussion

Host plant availability and quality may play a role in pest population dynamics by affecting immature as well as adult performance (Golizadeh *et al.*, 2009). Few studies have examined the effect of host plants on the developmental stages or on the overall performance of *A. pomi*. In the present study, there was no significant difference in pre-adult developmental times. These results were in agreement with developmental times of this aphid on Red delicious apple and Golden delicious apple at 28 °C (Arbab, 2006). The mean total fecundity of *A. pomi* on *M. pumila* was relatively lower than the fecundity on *C. japonica* but there was also no significant difference between two host plants. According to Arbab (2006), fecundity of *A. pomi* was found to be 55.07 and 50.93 nymphs on Golden delicious apple and Red delicious apple, respectively at 28 °C that was higher than the results obtained here. These differences may be due to differences in host plants and temperature levels. Peaks of reproductive values on two host plants were very close to each other, but it occurred one day later on *M. pumila*. Differences between the results of studies could be attributed to differences among nutritional content of host plant cultivars. Moreover, plant quality varies considerably depending upon external environmental factors (such as predictable changes between seasons and less predictable changes initiated from environmental stresses) and these could be cited

as other reasons for the difference (Awmack and Leather, 2002). Adult insects need carbohydrate-rich food as their main source of energy for longevity, fecundity and mobility. The low number of eggs laid on a plant could have been affected by the more indirect route of reduced fecundity arising from larva feeding on nutritionally poor plants (Verkerk and Wright, 1996; Hamilton *et al.*, 2005).

Since intrinsic rate of increase (r) is a reflective of many factors such as fecundity, survival and generation time and adequately summarizes the physiological qualities of an animal in relation to its capacity to increase, it would be a most appropriate index to evaluate the performance of an insect on different host plants as well as the host plant's resistance (Kocourek *et al.*, 1994; Southwood and Henderson, 2000). The intrinsic rate of increase (r) is a more useful statistic to compare the population growth potential of different species than is R_0 (Price, 1997). According to Southwood (1981) and Huffaker *et al.*, (1984), r-strategists are characterized by a high r , a large fecundity (large R_0) and short generation time (T). A significant difference was observed in the intrinsic rates of increase (r) with respect to host plants in this study. In this research, r value obtained on *M. pumila* (0.396 ± 0.015) was significantly higher than on *C. japonica* (Table 3). However, Arbab (2006) obtained the highest r value (0.48 ± 0.19) for *A. pomi* feeding on Red delicious apple at 28°C and a lower r value (0.45 ± 0.12) on Golden delicious apple. This difference may also be due to temperature and host plants, as Arbab *et al.*, (2006) stated that temperature would affect reproductive potential and especially intrinsic rate of increase (r). In conclusion, the high r value on *M. pumila* indicated that *A. pomi* had a greater reproductive potential and it was presumably more suitable host than the one compared with.

The mean generation time for *A. pomi* on *M. pumila* was significantly lower than on *C. japonica*, suggesting that *M. pumila* is more suitable for an increase in the aphid's population. This was higher than those reported

for *A. pomi* on Golden delicious apple (9.73 ± 2.2 , 8.37 ± 2.2 and 5.2 ± 1.9 days) at 20 °C, 28 °C and 34 °C, respectively (Arbab, 2006). The finite rate of increase (λ) was greater than 1 on both host plants, so these results may suggest that *A. pomi* would be considered as a r-strategist.

The two closely related host plants had significant influence on life table parameters of *A. pomi*, the aphid showed a slightly better performance on *M. pumila* than on *C. japonica*. However, it can be concluded that information on the life table parameters of *A. pomi* on two different host plants provide useful information that would promote better control of this pest. The knowledge of how Rosaceae host plants quality influences the life table parameters of *A. pomi* can help one to understand the population dynamics and select for the proper measures in management of this insect.

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جدول زندگی مقایسه‌ای *Aphis pomi* (Hemiptera: Aphididae) روی دو میزبان سیب (*Malus pumila*) و به ژاپنی (*Chaenomeles japonica*) در شرایط آزمایشگاه

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چکیده: پارامترهای جدول زندگی شته سبز سیب *Aphis pomi* DeGeer روی دو میزبان سیب (*Malus pumila* L. و به ژاپنی (*Chaenomeles japonica* Lindl.)) بررسی شد. این مطالعه در شرایط آزمایشگاه (دمای 1 ± 25 درجه سلسیوس و رطوبت نسبی 5 ± 70 درصد، با دوره نوری ۱۶: ۸ (روشنایی به تاریکی) ساعت) انجام شد. نرخ بقا از پوره سن اول تا بالغ روی سیب و به ژاپنی به نسبت یکسان است. طول عمر شته سبز سیب روی سیب و به ژاپنی به ترتیب $0.458 \pm 8/1$ و $0.412 \pm 9/65$ روز و میزان باروری ماده $2/198 \pm 37/25$ و $1/802 \pm 32/9$ بود. اوج مقدار تولید مثل هنگامی که روی سیب و به ژاپنی پرورش داده شد، به ترتیب در روزهای ۸ و ۹ عمر ماده اتفاق افتاد. نرخ ذاتی افزایش جمعیت (r) روی سیب ($0.15 \pm 0/396$) بیشتر از به ژاپنی ($0.06 \pm 0/329$) بود. میانگین مدت زمان یک نسل (T) روی سیب و به ژاپنی به ترتیب $0.35 \pm 9/13$ و $0.18 \pm 10/62$ روز به دست آمد. نتایج نشان داد که دو میزبان گیاهی خیلی وابسته، تأثیر معنی‌داری بر پارامترهای جدول زندگی شته سبز سیب داشتند و شته روی میزبان سیب نسبت به میزبان به ژاپنی عملکرد بهتری نشان داد. این نتایج نشان داد سیب به دلیل عملکرد بالاتر، میزبان مناسب‌تری برای شته سبز سیب است.

واژگان کلیدی: شته سبز سیب، مدت زمان یک نسل، نرخ ذاتی افزایش جمعیت، پارامترهای جدول زندگی