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Age-Stage, Two Sex-Life Table of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) reared on four greenhouse cucumber cultivars

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Abstract

The western flower thrips, *Frankliniella occidentalis* (Pergande) is one of the most important pests of a wide range of agricultural crops worldwide. Demographic parameters of this pest on four greenhouse cucumber (*Cucumis sativus* L.) cultivars (Pouya, Negin, Zohal and Sepehr) were evaluated under laboratory conditions at 25±5ºC, 60±5% RH and a photoperiod of 16: 8 (L: D) hours using age-stage, two-sex life table. The value of the net reproductive rate (R0) varied from 27.06 on Sepehr to 39.35 offspring per individual on Pouya. The mean generation time (T) on different cultivars varied from 23.29 to 24.74 days. The insects reared on Pouya and Negin had the longest total preoviposition period (14.2 ± 0.11 days) and those reared on Zohal and Sepehr had the shortest period (13.9 ± 0.12 days). The results revealed that Negin was the most suitable while Sepehr was the least cultivar to this pest.

K e y w o r d s : Cucumber, Demography, *Frankliniella occidentalis*, Greenhouse, Two-sex life table.

Zusammenfassung

Die Kalifornische Blütenthripse *Frankliniella occidentalis* (Pergande) gehört zu den weltweit wichtigsten Schädlingen der Ordnung Thysanoptera. An vier Gurkenarten wurden Vertreter dieser Ordnung unter Gewächshausbedingungen gezüchtet und untersucht. Heimisch im Südwesten der USA, erfuhr die Art mit ihrer aggressiven Verhaltensweise seit etwa 1980 eine weltweite Verbreitung.

Introduction

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), is an invasive species and is one of the most economically important pest within the insect order Thysanoptera (Morse & Hoddle 2006). This species is native to the southwestern United States but has been distributed worldwide from 1980s (Kirk &Terry 2003).

In Iran, WFT was first reported on ornamental plants in Tehran and Mahalt (Markazi province, Iran) (Jalili Moghadam & AzmayeshFard 2004). This thrips has a broad host range of more than 250 species in 60 plant families and are associated with several cultivated crops as well as ornamentals (Tommasini & Maini 1995, Kirk & Terry 2003, Reitz 2009). WFT causes agricultural damage not only by feeding on crops/plants, but also indirectly vectoring Tospoviruses (Medeiros et al. 2004). Cucumber (*Cucumis sativus* L.) is one of the most popular and nutritious vegetable crops in many parts of the world that has been damaged by this pest (Gaum et al. 1994). Life histories of thrips, especially WFT, were reported in several crop hosts, such as chrysanthemum, cotton, cucumber, peanut, pepper and tomato (Boissot et al.1998). Additionally, life table parameters were reported in a few selected crops, including chrysanthemum (De Kogel et al. 1998), peanut (Lowry et al.1992), cucumber (Guam et al. 1994, Soria & Mollema 1995, Van Rijn et al. 1995, De Kogel et al.1997) and bean (Brodsgaard 1994, Gerin *et al*. 1994). However, most of these studies are dealing only with the female population. Chi and Liu (1985) and Chi (1988) developed an age-stage, two-sex life table to take into account the male population and the variable development rate occurring among individual. Determining the life table parameters of *F. occidentalis* would be very useful to assess more resistant varieties for further pest management control. The aim of this study was to compare the age-stage, two-sex life table parameters of *F. occidentalis* on four cucumber cultivars.

Material and methods

Plant cultivation

Seeds of four cucumber cultivars (Pouya, Negin, Zohal and Sepehr) were planted in plastic containers (8×8×10 cm) filled with soil in a greenhouse at 27±5°C, 70 ± 5% relative humidity and a photoperiod of 16:8 (L: D) hours. As soon as the seedlings reached to the stage of blossom, they were used for the experiments. All plants were irrigated at the same time as required. Pesticides or additional fertilizers were not used.

Insect rearing

The laboratory population was initiated from adults collected on flowering Rosa (*Rosa* spp.) in a greenhouse around Shiraz (Fars province, Iran). The culture was maintained at 26 ± 5°C and 60 ± 5% relative humidity.WFT was reared for several generations on each cucumber cultivar before the initiation of the experiments. In order to obtain the same first-aged larva, several pairs of both sexes of the thrips that reared on the related cultivars were maintained in the oviposition plastic containers (8 cm in diameter by 4 cm in height). First larval instars were used in further experiments.

Data analysis

The life history raw data of all individuals were analyzed according to the age-stage, two-sex life table theory (CHI 1988) using the TWOSEX-MS Chart program (CHI 2013). The age-stage specific survival rate (s_{xj}) (where x= age in days and j= stage), the age-stage specific fecundity (f_{xj}) (daily number of eggs produced per female of age x), the age-specific survival rate (l_x), the age-specific fecundity (m_x) (daily number of eggs produced per individual i.e., this number is divided by all individuals (males and females of age x), and the population growth parameters, the intrinsic rate of increase (r), finite rate of increase ($\lambda= e^r$), net reproductive rate (R_0) and the mean generation time (T), are calculated accordingly. The age-specific survival rate includes both male and female was calculated as bellow:

$$l_x = \sum_{j=1}^{m} s_{xj} \tag{1}$$

and

$$m_x = \frac{\sum_{j=1}^{m} s_{xj} f_{xj}}{\sum_{j=1}^{m} s_{xj}} \tag{2}$$

Where m is the number of stages.

The intrinsic rate of increase was estimated by using the iterative bisection method for from:

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

with age indexed from 0 to ω (maximum age).

The relationship between the net reproductive rate (R_0) and the mean female fecundity (F) is given as:

$$R_0 = F \times \left(\frac{N_f}{N} \right) \tag{4}$$

Where N is the total number of individuals used for life table study and N_f is the number of female adults (CHI & SU 2006). The mean generation time is the time length that a population needs to increase to R_0-times of its size as the stable age distribution and the stable increase rate are reached, *i.e.*, $e^{rT} = R_0$ or $\lambda^T = R_0$. Thus, the mean generation time is calculated as $T = \ln R_0 / r$.

The means and standard errors of the population parameters were estimated using the Bootstrap procedure (Meyer et al. 1986, Huang & Chi 2013). In the bootstrap procedure, we randomly take a sample of *an* individuals from the cohort with replacement and calculate the $re_{\text{-boot}}$ for this bootstrap sample as:

$$\sum_{x}^{w} = 0^{e^{-ri-boot(x+1)}} l_x m_x = 1 \qquad [5]$$

where the subscript *i-boot* represents the *i*th bootstrap and l_x and m_x are calculated from the *n* individuals selected randomly with replacement. Generally, the data on the same individual are repeatedly selected. We repeated this procedure *m* times (*m*=10000) and computed the mean of these *m* bootstraps as

$$r_B = \frac{\sum_{i=1}^{m} r_{i-boot}}{m} \qquad [6]$$

The variance (VAR r_B) and standard errors (SE r_B) of these *m* bootstraps were calculated as:

$$\text{VAR } r_B = \frac{\sum_{i=1}^{m} (r_i{-boot}-r_B)^2}{m-1} \qquad [7]$$

$$\text{SE}r_B = \sqrt{\text{VAR}r_B} \qquad [8]$$

The same methods are used for the corresponding estimates of the finite rate of increase (λ), net reproductive rate (R_0) and mean generation time (T).

To compare the means of the life table parameters, the Tukey-Kramer procedure of multiple comparison section of TWOSEX-MSChart program was used (Chi 2013). The obtained fecundity and durations of different life stages of the pest on different cucumber cultivars data were analyzed using one-way ANOVA procedure through Proc GLM in SAS (SAS Institute 2003). Drawings were done using SigmaPlot software (SigmaPlot 2011).

Results

The adult male and female longevity (mean number of days from eclosion to the death) were significantly different among the cultivars (Tab. 1). The longest female and males longevity were observed on Negin. The total fecundity of *F. occidentalis* was affected significantly by different cucumber cultivars ($P < 0.05$). The highest total fecundity of *F.*

occidentalis (83.00 ± 2.58 eggs) was found on 'Pouya' and the lowest (63.61 ± 2.68 eggs) was found on 'Sepehr' (Tab. 1). The population parameters of WFT are presented in Tab. 2. The net reproductive rate (*R*0) was significantly different depending on the cucumber cultivars on which individuals were reared. The highest value of the net reproductive rate (39.35±5.26 offspring per individual) was observed on Pouya and the lowest (27.06±3.95 offspring per individual) was found on Sepehr. The intrinsic rate of increase (*r*) and finite rate of increase (λ) showed no significant difference among the cucumber cultivars. In addition, the mean generation time (*T*) varied from 23.29±0.20 on Zohal to 24.74±0.18 days on Pouya.

Age-stage survival rates of WFT at different cucumber cultivars are plotted (Fig. 1). The age-stage survival curve depict the survival probability of an individual to get to age *x* and stage *j*. where the survival rate to age *x* is approximately 98%. These curves also show the survivorship and stage differentiation, as well as the variable developmental rates. For example, the probability that a newborn nymph survives to the adult female and male stage at Pouyais 0.5 and 0.25 days, respectively. Variation in developmental rates among individuals cause some overlap between different stages (Fig.1). The age-specific survival rate (l_x), the age-specific fecundity (m_x) have been illustrated in Fig. 2. The probability that a newborn will survive to age *x* is shown with age-specific survival rate curve. Variable developmental rates among individuals of *F. occidentalis* stages resulted in curves with significant overlaps between stages, which suggest that all individuals do not complete their development at the same day, simultaneously.

Fig. 3 shows the age-stage life expectancy (e_{xj}) curve. This curve reports the life span that an individual (age *x* and stage *j*) is expected to live after age *x* at different cucumber cultivars. The life expectancy of the first nymphal instar on Pouya, Negin, Zohal and Sepehrwas 29, 32, 29.50 and 29 days, respectively. The maximum life expectancy of *F. occidentalis* was 32 days on Negin (Fig. 3). The life expectancy based on age-stage, two-sex life table distinguishes the difference among individuals of the same age but of different stages. The contribution of an individual of age *x* and stage *j* to the future population is described with the age-stage reproductive value (v_{xj}) (Fig. 4). If the prereproduction period is counted as time from the birth to the first reproduction in females (TPOP), the mean TPOP for *F. occidentalis* females on various cultivars has not any significantly different (Tab. 1). These values are close to the age of peak reproductive value (Fig. 4). The finite rate of increase equals to the reproductive value of a newborn (v_{01}) (Huang & Chi 2012). Once adult female emergence starts, the reproductive value increases dramatically (Fig. 4). The major peaks in reproductive values of females were at the age of 28 days ($v_{28,6}$ = 25) 19 days ($v_{19,6}$ = 20), 18 days ($v_{18,6}$ = 18) and 18 days ($v_{18,6}$ = 19) at Pouya, Negin, Zohal and Sepehr, respectively.

Discussion

In the present study it has been shown that various life table parameters of *F. occidentalis* on four cucumber cultivars are generally different. Demographic parameters of this pest have previously been determined on various host plants including cucumber (Guam et al. 1994, Soria & Mollema 1995, Van Rijn et al. 1995, De Kogel et al.1997, Hulshof et al. 2003). The quality of food had shown that has a great influence on thrips performance

(BRODSGAARD 1987, BRODBECK et al. 2002). Performance criteria include longevity, feeding and oviposition levels, growth, and development on different plant species (BROWN et al. 2002). The faster developmental rates and the higher fecundity of insects on host plants indicate the suitability of a host plant (VAN LENTEREN & NOLDUS 1990). As demonstrate in Tab. 1, the time for completing all life stages of WFT (except the male) are different in Pouya and Negin cultivars in one hand and Zohal and Sepehr in another hand. BROWN (2002) found that different plant species varied in their suitability to support *F. occidentalis*. The population growth of western flower thrips was severely reduced on unsuitable host plants, especially on resistant genotypes (SORIA & MOLLEMA 1995). In this study, WFT was able to complete its life cycle on the four different cucumber cultivars, although life history trait values were significantly different. In general, WFT had the shortest developmental time on Zohal cultivar, the highest R_0 on Pouya cultivar and highest r on Negin. In contrast, the corresponding lowest values were on Sepehr cultivar. The longevity significantly varies with the experimental condition. The shortest longevity was 13 days on Sepehr, whereas the longest longevity was found on Zohal with 16 days. However, the latter period is still much shorter than reported by ZHI et al. (2005) for bean pods (27.88 days) or GERIN et al. (1994) for bean plants (24.45 days), but still longer than those reported by Brodsgaard (1994) for bean plants (10.8 days). In addition to the influence of different host plants, ISHIDA et al. (2003) suggested temperature and photoperiod as important factors for the longevity of thrips. The longer the daylength and the lower the temperature, the longer the longevity of the western flower thrips. The net reproductive rate (R_0) and the intrinsic rate of increase (r) are of the important indicators of insect population dynamics (RICHARD 1961, MORRIS & FULTON 1970, VARLEY & GRADWELL 1970, TSAI & WANG 2001). Comparisons of R_0 and r often provide considerable insight beyond that available from the independent analysis of individual life-history parameters. The R_0 values on four cucumber cultivars in this Study were higher than those reported by van Rijn et al. (1995) on cucumber (22.1). However, the r value was lower than 0.166 (offspring per individual) which was reported by VAN RIJN et al. (1995) (0.166 offspring per individual).

Host plants have remarkable effects on the life table studies and setting up a successful and environmental friendly pest management strategy is impossible without the basic knowledge of life table and therefore, construction of life tables on different target pests, especially economically important ones, and their application in control programs are undoubtedly worth trail. Despite these there are no significant difference among four tested cultivars for intrinsic rate of increase (r) and finite rate of increase (λ) (Tab. 2).

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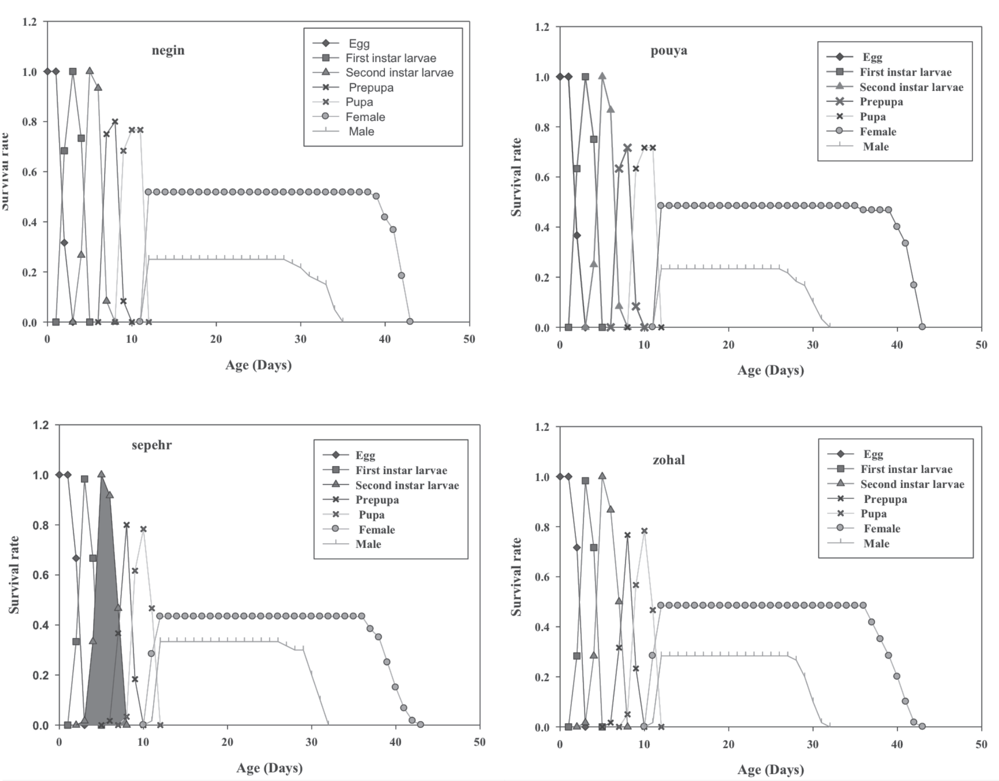

Fig. 1: Age-stage survival rate (*sxj*) of *Frankliniella occidentalis* at different greenhouse cucumber cultivars.

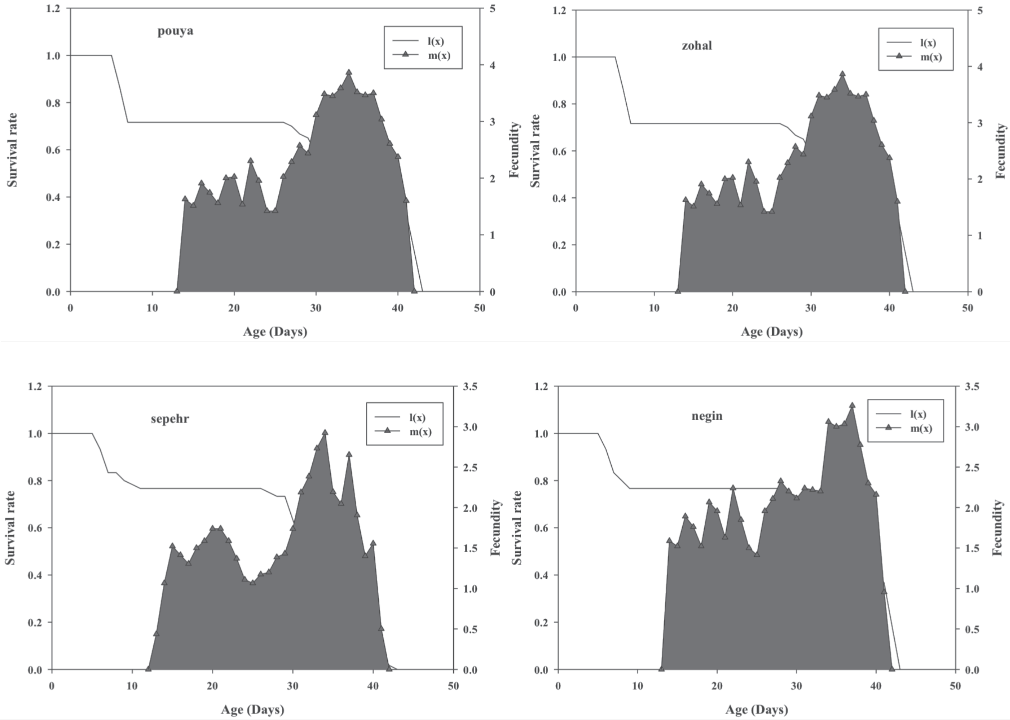

Fig. 2: Age-specific survival rate (*lx*), age-specific fecundity (*mx*) *Frankliniella occidentalis* at different greenhouse cucumber cultivars.

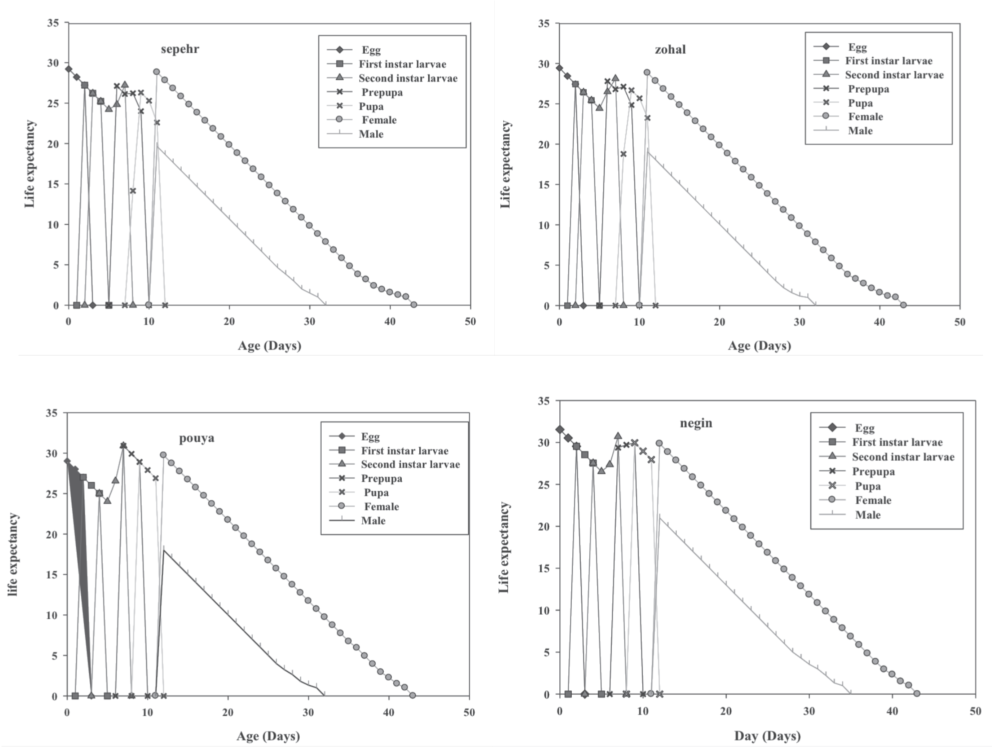

Fig. 3: Age-stage life expectancy (*exj*) of *Frankliniella occidentalis* at different greenhouse cucumber cultivars.

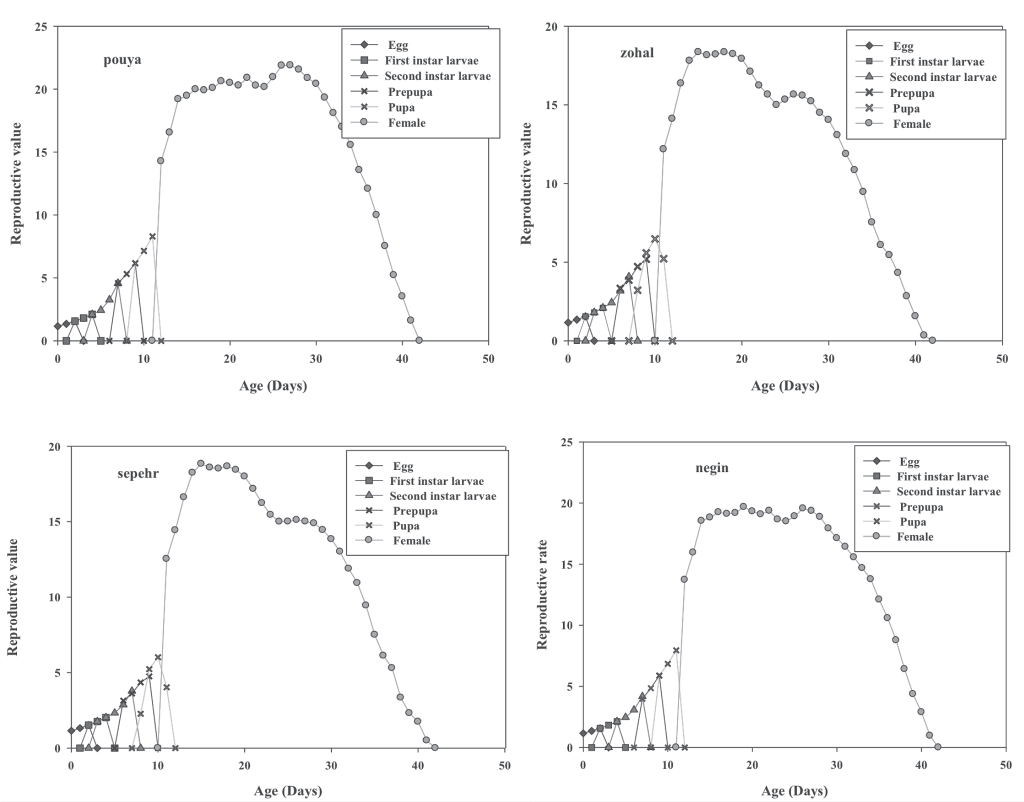

Fig. 4: Age-stage reproductive value (*vxj*) of *Frankliniella occidentalis* at different greenhouse cucumber cultivars.

Tab. 1: The mean ±SE pre-adult duration, adult longevity, preoviposition periods (days) and fecundity (

Cultivars	Preadult duration (day)				
	Egg	Larva1	Larva2	Prepupa	Pupa
Pouya	2.36±0.06b	2.38±0.04a	2.46±0.05b	2.88±0a	2.63±0.06a
Negin	2.31±0.06b	2.41±0.04a	2.42±0.05b	2.0± 0.05b	2.89±0.06a
Zohal	2.71±0.06a	1.98±0.04b	2.95±0.05a	1.62± 0.5c	2.66±0.06b
Sepehr	2.66±0.06a	1.98±0.04b	2.96±0.05a	1.62± 0.5c	2.43±0.06b

Means in each column followed by different letters are significantly different (*P*< 0.05; Tukey test).

Tab. 2: The mean ±SEAge-stage, two-sex life table parameters of *Frankliniella occidentalis* on different greenhouse cucumber cultivars

Cultivars	R_0 (offspring)	r (day $^{-1}$)	λ (day $^{-1}$)	T (day)
Pouya	39.35± 5.26a	0.148± 0.006a	1.159± 0.007a	24.74± 0.18a
Negin	39.03± 4.96a	0.150± 0.006a	1.162± 0.007a	24.34± 0.18a
Zohal	31.15± 4.17ab	0.147± 0.006a	1.159± 0.007a	23.29± 0.20b
Sepehr	27.06± 3.95b	0.140± 0.007a	1.150± 0.008a	23.42± 0.24b

Means in each column followed by different letters are significantly different (*P*< 0.05; Tukey-Kramer test).

(eggs) of *Frankliniella occidentalis* on different greenhouse cucumber cultivars

Adult longevity (day)		APOP (day)	TPOP (day)	Fecundity (eggs/female)
Female	Male			
29.7±0.30a	18.0±0.38b	2.24±0.08b	14.2±0.11a	83.0±2.58a
29.8±0.28a	21.0±0.38a	2.25±0.08b	14.2±0.11a	75.3±2.41b
28.4±0.29b	18.11±0.35b	2.55±0.08a	13.9±0.11a	65.5±2.58c
28.4±0.30b	18.70±0.33b	2.57±0.09a	13.9±0.12a	63.61±2.68c