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Demographic analysis and population projection of *Frankliniella occidentalis* (PERGRANDE) (Thysanoptera: Thripidae) on different varieties of cucumbers under laboratory conditions

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Abstract

Western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae) is the most serious pest species in this genus in the world. In this research demographic analysis and population projection of *Frankliniella occidentalis* were studied on the six varieties of cucumber i.e. Girtap, Negin, Pouya, Salar, Zohal and Ygreen under laboratory conditions (25±2°C, 65±5% RH and 14:10 h L: D photoperiod). Based on the results, *Frankliniella occidentalis* had the lowest intrinsic rate of increase (r_m) on Girtap variety. The development time of the egg, L1, L2, prepupal, pupal and female stages of *Frankliniella occidentalis* on Girtap variety significantly differed from others. Age-structure population growth rate of L1 on Negin, Zohal and Pouya varieties was similar.

Key words: Demographic analysis, flower thrips, Tomato spotted wilt virus.

Zusammenfassung

Frankliniella occidentalis (Thysanoptera: Thripidae) ist die ernstzunehmendste Schädlingsart dieser Gattung auf der Welt. In der vorliegenden Studie werden die Auswirkungen dieser Art auf sechs Gurkenvarietäten (Girtap, Negin, Pouya, Salar, Zohal und Ygreen) unter Laborbedingungen (25±2°C, 65±5% RH and 14:10 h L: D photoperiod) untersucht, wobei die Art auf Girtap die niedrigste Wachstumsrate (r_m) aufwies. Die Entwicklungszeit vom Ei bis zur Puppe und die Stadien des Weibchens auf Girtap unterscheiden sich signifikant von denen auf anderen Gurkenvarietäten. Ähnlich verhält es sich mit der Altersstruktur der Wachstumsrate von L1 der Art auf Negin, Zohal und Pouya.

Introduction

Western flower thrips, *Frankliniella occidentalis* is the most serious pest species in this genus in the world (Poorkashkooli et al. 2015a). *Frankliniella occidentalis* originated from the western US, but is now widely distributed throughout the world (Kirk & Terry 2003). It is a pest on various agricultural crops, and is an important vector of tospoviruses (Peters et al. 1996). In these years many studies have been made on *Frankliniella occidentalis* because of its importance. Also, *Frankliniella occidentalis* had one third of the publications on all Thysanoptera in the past 30 years (Reitz 2009) and this pest has been included in greenhouse pest control brochures since 1949 (Cloyd 2009). *Frankliniella occidentalis* has come in Iran since 2001 year (Jalili-Moghddam & Azmayeshfard 1999).

One million and four hundred thousand tones of cucumber are produced in Iran every year and have 3.3% of products in the world which it obtains from the surface of 80,000 hectares. According to the latest statistics that has published in 2004 year, cucumber cultivation area was 78,197 ha. One of the most important pests of cucumber is Thysanoptera (Ministry of Agriculture). *Frankliniella occidentalisis* is a polyphagous insect which forms area major pest in greenhouse crops including cucumber (Mantel & van de Vrie 1988).

Demographic studies should be the first priority in ecologically sound pest management program because only life tables can provide the most detailed and correct descriptions of the survival, stage differentiation and reproduction of populations (Huang & Chi 2012). Gaum et al. (1994) biological characteristics of *Frankliniella occidentalis* were investigated on excised leaves of five vegetables: cabbage, cucumber (*Cucumis sativus* L. var. Zhongnong 8), capsicum, kidney bean and tomato; *Frankliniella occidentalis* had the highest intrinsic rate of increase (r_m) on cucumber.

The simulations of population growth rate based on life table data can be used to predict the growth model of pest population on determine condition (CHI 1990). The simulation is the imitation of real condition or process. Simulation can be used for showing the effect of different condition that there are not in reality (Faghih 1999). Few studies are done on the simulation of Thysanoptera growth rate. van Delden (1993) presented an example of utilization of INSIM by a simulation of growth and development of *Frankliniella occidentalis* and *Neoseiulus amblyseius* on cucumber and their interaction on sweet pepper. A mathematical model was utilized to study the population dynamics of the predator *Orius laevigatus* (Fieber) and *Frankliniella occidentalis* (Pergande). The population interactions between *Orius laevigatus* and *Frankliniella occidentalis* were simulated with different ratio of preys and predators. The simulations demonstrated that was released *Orius laevigatus* 10 day after the appearance of *Frankliniella occidentalis*, they can effectively and actively control the pest population (Burgio et al. 2004).The objective of the present study is to survey *Frankliniella occidentalis* demography and population growth simulation on cucumber varieties. They help to predict *Frankliniella occidentalis* growth in different time and to perform the best management method at the best time also to choose a resistant variety which the growth rate of *Frankliniella occidentalis* is low on it.

Material and methods

The first instar larval thrips were collected from alfalfa farms in West Azarbaijan Province. In order to prepare a colony, cucumber fruits were used as the host for rearing flower thrips. After being disinfected (in ethanol 70% for 1 min) and rinsed, the cucumbers were put in plastic containers with the dimensions of 7×11×18 cm (length × width × height). 5 × 8 cm holes were created on the lid and then covered by nets to make desirable ventilation. Several generations of thrips were reared in vitro (Madadi et al. 2005; Poorkashkooli et al. 2015 b) and pollens were used to feed the larvae (Moritz et al. 2004). The rearing containers were kept in the germinator in 25±2ºC, humidity of 60±10% and light period of 14:10 hour's light/dark (Stumpf & Kennedy 2005, 2007). In this study, the first instar larvae (with maximum age of 18 hours) were put onto cut slices of cucumber leaves in petri dishes, using a fine brush (Zhang et al. 2007) and then they were put into the germinator under the conditions described above (Stumpf & Kennedy 2005, 2007). To prevent the thrips from escaping the cut slice was surrounded by cotton, and to prevent them from flying away from the Petri dish, the Petri dishes were covered by Parafilms (Zhang et al. 2007). The experiment was carried out for each variety and with 52 repetitions. Each Petri was checked every day and the biological processes were recorded until the death. Every three days the cut slice was replaced with a new one. When the thrips got mature, the basin was visited regularly for the male thrips until their death and the viability was recorded. Every female thrips was put close to a male thrips and daily survival and fecundity were recorded for each female until death (Zhang et al. 2007).

Demographic Analysis

According to age-stage, two-sex life table theory, data were analyzed. So, raw data on developmental time, survivorship, longevity and female fecundity were analyzed based on the age-stage, two-sex life table theory (Chi & Liu 1985; Chi 1988) using TWOSEX-MSChart computer program (Chi 2012).

The age-stage specific survival rate (sxj) (x = age and j = stage), the age-stage specific fecundity (fxj), the age-specific survival rate (l_x), the age-specific fecundity (m_x), and the life table parameters (the intrinsic rate of increase (r); the finite rate of increase (λ); the net reproductive rate (R_0); the mean generation time (T) were constructed accordingly.

The intrinsic rate of increase (r) was determined by iteratively solving the Euler-Lotka equation with age indexed The intrinsic rate of increase (r) was determined by iteratively solving the Euler-Lotka equation with age indexed from 0 (GOODMAN 1982):

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

The finite rate of increase (λ) and the net reproductive rate (R0) were calculated as follows:

$$\lambda = e^r$$

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

The mean generation time (T) is then calculated using the following equation:

$$T = \frac{\ln(R_0)}{r}$$

Population Projection

Based on the results of life table, was used TIMING-MSCHART software (CHI, 2012) for simulation. This software was calculated the raw data for 52 individuals as follows:

GWR=log[n(t+1)+1]-log[n(t)+1]

Where GWR is the growth population rate and n is the number of population in a time period based on day.

Statistical analysis

The raw data for 52 individuals were analyzed using the age- stage, two-sex life table approach (YU, et al. 2013). To estimate the means, variances and standard errors of the population parameters (SOKAL & ROHLF, 1995) the bootstrap (EFRON & TIBSHIRANI, 1993) techniques were used. In bootstrap technique, even with a small number of replications, Random resampling will produce variable means and standard errors, so, in order to reduce the variability of results, 10.000 replications were used in this study (YU, et al. 2013).

Results and Discussion

Demographic Analysis

The life table parameters, Net Reproductive Rate (Ro) mean generation time (T), values of finite rate of increase (λ), gross reproduction rate (GRR), intrinsic rate of natural increase (r_m) and estimated by using the Bootstrap method are shown on the Table 1. There were significant differences in the life table parameters among treatments at the 5% significance level (Table 2). Different varieties significantly affected the population parameters of western flower thrips. Intrinsic rate of natural increase (r_m) is high on cucumber which represents it is a suitable host (Poorkashkouli et al. 2015) but some varieties have resistance for growing of *Frankliniella occidentalis*. trichomes can affect on plant resistance against pest insect. Short trichomes, long trichomes and glandular trichomes of different cucumber varieties can affect on Liriomyza sativae (Basij et al. 2011). It can be true for *Frankliniella occidentalis* and difference in the life table parameters that showed hosts have various physical characteristics.

The Ages pecific survival rate (lx) represents the probability that a newborn will survive to age x (Huang & Chi 2012). This parameter gives a detailed description not only of survival but also of stage transitions. This parameter decreases with the increasing age eventually gets down to zero. The age- specific survival rate (lx), female age-specific fecundity (mx) is depicted in Fig.1. It showed that the survival rate patterns (lx) of curve of Girtap differs with others and is type 3 in the curve pattern of survival rate because this cultivar is resistance for *Frankliniella occidentalis.* Other the patterns of variety curves are type 1. The first oviposition of Pouya and Zohal varieties occurred simultaneously on day 14.The peak of age specific fecundity (mx) was seen at 29 d after birth for Girtap and Y green varieties. Efforts are made to develop thrips-resistant cucumber varieties (Mollema et al. 1995). Soria & Mollema (1995) showed that reproduction of thrips is lower on some resistant cucumber accessions than on a susceptible control.

The development time of the egg, L1, L2, prepupal, pupal and female stages of *Frankliniella occidentalis* in the first treatment differed significantly than others when the Tukeytest is used at the 5 % significance level but male stages did not show significant difference (Tab. 2). Duration of life cycle onion thrips including egg, L1, L2, prepupa, pupa and adult on cucumber (*Cucumis sativus* L. var. Sultan) was 2.82±1.33, 1.95±1.42, 4.12±0.92, 1.03±1.44, 1.97±0.91 and 14.4±3.13 days (Pourian et al. 2009). Sultan variety has not short trichomes, long trichomes and grandular trichomes (Basij et al. 2011). It is similar to sensitive Pouya variety and this variety is sensitive too because both varieties have not trichome or have a few trichome therefore they are proper host for growing of thrips (Basij et al. 2011; Doryanizadeh et al. 2012).

The age-stage life expectancy (exj), the expectation life span of an individual of age x and stage j to live after age x, is plotted on the age-stage life expectancy (exj) curve (Fig. 3). Life expectancy represents the time that an individual of age x and stage j is expected to live. The life expectancy of an egg was 28, 31, 32, 35, 35 and 31 d for Girtap, Negin, Pouya, Salar, Ygreen and zohal varieties, respectively.

Population Projection

Influences of the six cucumber varieties, Girtap, Negin, Pouya, Salar, Zohal and Ygreen on the Total population growth rate of *Frankliniella occidentalis* were compared. Total population growth rate represents changing the population growth rate to age x based on day. Age-structure population growth rate showed in the table 3. For example Age-structure population growth rate of 2nd larvae on Pouya variety was significantly higher than that on Girtap, Salar, Zohal and Ygreen varieties but there was no significant difference in it between Negin and Pouya varieties. The Age-structure population growth rate of female was shortest on Pouya variety. Therefore, Pouya variety is considered to be the best of the 6 cucumber varieties for growing western flower thrips. The results confirmed that Pouya variety has the least trichomes among varieties and some varieties have many trichomes such as Girtap that they are resistance to pest. An undamaged plant maintains a baseline level of volatile metabolites that are released from the surface of the leaf and/or from accumulated storage sites in the leaf. These constitutive chemical reserves, which often include monoterpenes, sesquiterpenes, and aromatics, accumulate to high levels in specialized glands or trichomes (PARE & TUMLINSON 1997).

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Table 1. Population parameters (with r as the intrinsic rate of increase, λ, the finite rate of increase,R0, the net reproductive rate, T, the mean generation time and GRR, Gross reproductive rate) + the standard errors of Frankliniella occidentalis, estimated by using all individuals and the bootstrap techniques.

Population parameters / Varieties	Girtap	Zohal	Negin	Salar	Ygreen	Pouya	F	df	sig
Intrinsic Rate of Increase (rm)	-0.0169±0.0103 (a)	0.1326±0.0002 (d)	0.0780±0.0002 (c)	0.0592±0.0001 (b)	0.0601±0.0001 (b)	0.1356±0.0001 (e)	14146.764	5	0.000
values of finite rate of increase (λ)	0.9832±0.0101 (a)	1.1418±0.0002 (d)	1.0811±0.0002 (c)	1.0610±0.0001 (b)	1.0620±0.0001 (b)	1.1452±0.0001 (e)	16169.072	5	0.000
gross reproduction rate (GRR)	1.3990±0.4398 (a)	21.8788±0.0802 (d)	13.5410±0.0556 (c)	9.7380±0.0385 (b)	10.1382±0.0449 (b)	23.2592±0.0764 (e)	9220.959	5	0.000
mean generation time (T)	36.9127±0.8394 (a)	21.2907±0.0236 (e)	27.2756±0.02072 (c)	30.9179±0.0244 (b)	31.0153±0.0240 (b)	21.9204±0.0172 (d)	21968.270	5	0.000
Net Reproductive Rate (Ro)	0.5000±0.1811 (a)	16.8925±0.0646 (d)	8.5136±0.0460 (c)	6.3142±0.0327 (b)	6.5440±0.0352 (b)	19.6405±0.0673 (e)	12370.335	5	0.000

Table 2. Life history statistics (mean ± SE) of Frankliniella occidentalis on cucumber varieties

Stage /Varieties	Girtap	zohal	Negin	Salar	Ygreen	Pouya	F	df	sig
Egg	4.634±0.125 (a)	1.576±0.079 (bc)	2.000±0.106 (cd)	2.3685±0.116 (de)	2.480±0.118 (e)	1.403±0.067 (b)	124.705	5	0.000
First instar	4.333±0.134 (a)	1.686±0.098 (bc)	1.965±0.102 (c)	2.456±0.115 (e)	2.413±0.096 (e)	1.449±0.071 (b)	91.415	5	0.000
Second instar	5.533±0.184 (a)	2.333±0.167 (b)	3.454±0.110 (c)	4.022±0.132 (cd)	4.386±0.130 (d)	3.454±0.110 (b)	74.997	5	0.000
Pre pupae	3.208±0.134 (a)	1.313±0.071 (bc)	1.522±0.082 (c)	2.409±0.081 (d)	2.500±0.089 (d)	1.173±0.052 (b)	85.193	5	0.000
Pupae	4.000±0.187 (ab)	2.428±0.154 (de)	2.947±0.164 (cd)	3.894±0.145 (b)	3.552±0.123 (bc)	2.309±0.104 (e)	23.840	5	0.000
Female longevity	44.900±1.224 (a)	25.974±0.859 (c)	31.357±0.291 (b)	33.357±0.563 (b)	32.928±0.391 (b)	26.073±0.726 (c)	54.500	5	0.000
Male longevity	25.111±2.353 (a)	16.600±1.401 (a)	18.100±2.193 (a)	20.700±2.431 (a)	19.100±2.141 (a)	`16.600±1.600 (a)	2.293	5	0.000
Adult Preo-vipisition period	12.250±1.278 (a)	9.948±0.274 (b)	11.115±0.471 (b)	10.576±0.392 (ab)	11.384±0.483 (ab)	9.973±0.288 (ab)	3.322	5	0.000
Total preo-viposition period	12.250±1.278 (a)	17.359±0.436 (b)	23.000±0.502 (c)	26.076±0.531 (d)	26.653±0.543 (d)	18.891±0.570 (b)	66.875	5	0.000

Table 3. Simulation population growth rate (mean ± SE) of Frankliniella occidentalis on cucumber varieties

Stage /Varieties	Girtap	zohal	Negin	Salar	Ygreen	Pouya	F	df	sig
Egg	-0.039±0.002 (b)	0.1059±0.059 (ab)	0.0907±0.010 (ab)	0.028±0.001 (b)	0.0322±0.002 (b)	0.3208±0.001 (a)	3.169	5	0.008
L1	0.000±0.032 (b)	0.1434±0.05793 (ab)	0.128±0.049 (ab)	0.062±0.008 (b)	0.073±0.009 (b)	0.356±0.010 (a)	4.184	5	0.001
L2	0.000±0.025 (b)	0.146±0.051 (ab)	0.128±0.038 (b)	0.059±0.006 (b)	0.083±0.005 (b)	0.354±0.099 (a)	5.159	5	0.000
Prepupae	0.000±0.017 (b)	0.134±0.041 (b)	0.114±0.030 (b)	0.032±0.029 (b)	0.066±0.002 (b)	0.328±0.091 (a)	6.132	5	0.000
Pupae	0.007±0.006 (a)	0.137±0.040 (a)	0.118±0.030 (a)	0.022±0.008 (a)	0.071±0.006 (a)	0.434±0.025 (a)	2.187	5	0.055
Female	0.020±0.009 (b)	0.147±0.021 (b)	0.130±0.016 (b)	0.059±0.002 (b)	0.074±0.003 (b)	0.408±0.050 (a)	4.872	5	0.000
Male	0.007±0.002 (b)	0.117±0.017 (b)	0.103±0.011 (b)	0.037±0.004 (b)	0.053±0.004 (b)	0.394±0.057 (a)	4.614	5	0.000

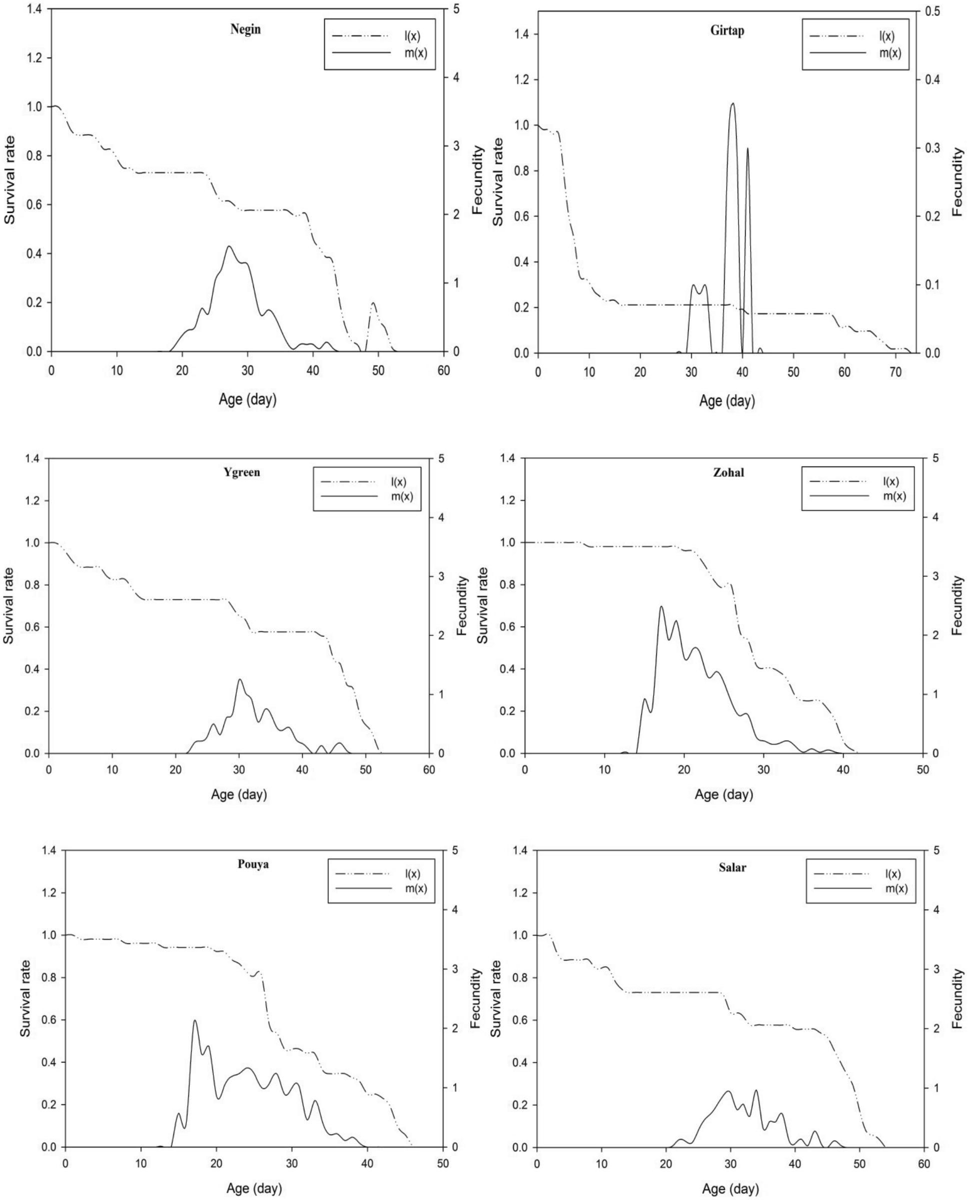

Fig. 1. Age- specific survival rate (l_x) and age-specific fecundity (m_x) of *Frankliniella occidentalis* on cucumber varieties

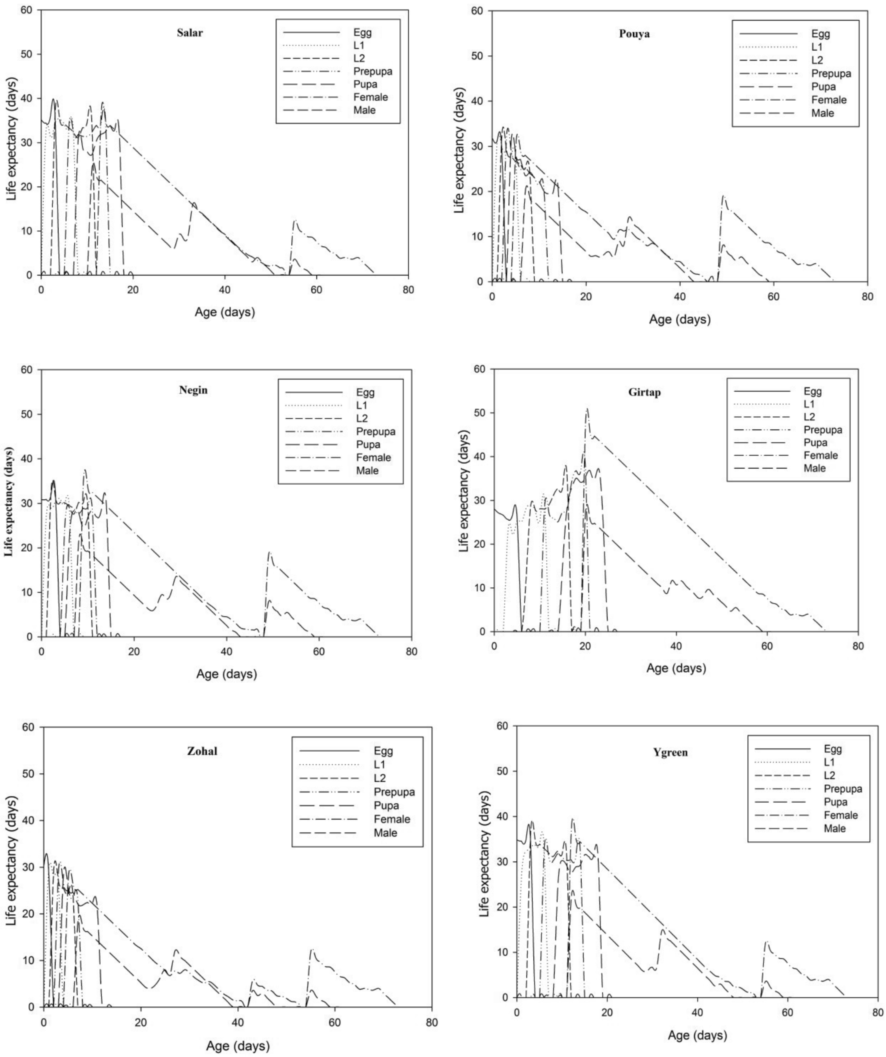

Fig. 2. Age- stage life expectancy (e_{xj}) of *F. occidentalis* on cucumber varieties.

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