

Article

Life table parameters of fig mite, *Eotetranychus hirsti* (Acari: Tetranychidae) under laboratory conditions

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Abstract

Fig mite, *Eotetranychus hirsti* Pritchard & Baker, 1955, is one of the major pests of fig trees in Estahban (Fars province, Iran). Life table parameters of *E. hirsti* were studied at 30 ± 1 °C, $60\pm 10\%$ R.H. and 12:12 h (dark: light) photoperiod in 50 replications. The newly laid eggs were placed on the upward surface of fig leaves that were surrounded with a thinned strip of cotton to inhibit mites escaping from Petri dishes. Daily fertility, preimaginal developmental time and mortality rate were analyzed with age-stage, two sex life table analysis software. The result indicated that the developmental times of egg, larva, protochrysalis, protonymph, deutochrysalis, deutonymph and teliochrysalis were 4.32 ± 0.097 , 1.38 ± 0.069 , 1 ± 0 , 1.4 ± 0.07 , 1.06 ± 0.034 , 1.4 ± 0.07 , and 1 ± 0 days, respectively. Maximum adult longevity was 8 and 16 days for male and female mites, respectively. Pre-oviposition period, total pre-oviposition period (counted from birth to adult) were 1.5 ± 0.076 and 13.16 ± 0.133 days, respectively. The mean generation time, net reproduction rate, the intrinsic rate of natural increase and the finite rate of increase were 18.47 ± 0.15 days, 40.5 ± 2.17 offspring, $0.2004\pm 0.003(d^{-1})$, and 1.221 ± 0.004 (d^{-1}), respectively. The two-sex life table analysis gives a comprehensive description of the stage differentiation of, *Eotetranychus hirsti*.

Key words: *Eotetranychus hirsti*, life table parameters, intrinsic rates of increase, reproductive rate

Introduction

Fig spider mite, *Eotetranychus hirsti* (Acari: Tetranychidae) is a serious pest of figs (*Ficus carica* L.) in Iran and other fig growing areas in the world (Baradaran *et al.* 2002). This species with about 0.3 to 0.5 mm lengths is found on the densely hairs of downward surface of the leaf. Under low mite infestation level, the leaves show small transparent patches while under high infestation the leaves with yellowish-green appearance drop down prematurely (Kanta *et al.* 1963). Fig mite has been named as *Tetranychus fici* by Hirst using material that he received from Coimbatore (India) in 1926. He recorded the fig mite on fig trees from Coimbatore, Hyderabad and Pusa, India, indicating that it caused severe damage and prevented ripping of fruits (Cherian, 1938). Rahman and Sapra (1940) redescribed the fig mite as the same name and emphasized that the mite was active from May to October at Lyallpur (Pakistan) while

in November, when the leaves started shedding, the gravid females migrated to the branches and lodged themselves on terminal buds for overwintering. Thereafter when the buds opened at the end of February or early March, the mite infestation increased. Pritchard and Baker (1955) transferred this species into the genus *Eotetranychus*. This new combination was also used by Puttarudriah and Channabasavanna (1959) who introduced it as a serious pest of fig around Bangalor.

To manage a successful biological control program, it is necessary to identify the growth, stage structure and fecundity of the pests. Analysis of the life history has an essential role in this regard. One of the components of this knowledge is life table. Life table information can provide a comprehensive description of the development, survival and fecundity of the pest populations (Farhadi *et al.* 2011). In a study conducted by Southwood (1966), it has been emphasized that the intrinsic rate of increase is the most useful parameter for comparing the growth potential of different species under different climate and food conditions. There are many experiments conducted on life table parameters of tetranychid mites (Shih *et al.* 1976; Silva *et al.* 2009; Sakunwarin *et al.* 2003). Life tables of *Tetranychus* mites have been studied using traditional female age-specific life table methods by a number of researchers (Shih *et al.* 1976; Wermelinger *et al.* 1991; Krips *et al.* 1998). Problems encountered when using the female-based age-specific life table have been discussed by Chi (1988). An age-stage, two-sex life table theory was developed to resolve these problems by including the stage differentiation and male population (Chi, 1988). The age-stage, two-sex life table theory is useful for pest control (Chi, 1990). There was no previous study on the life table parameters of the *E. hirsti*. Therefore, the aim of the present study was to investigate the biological life table parameters and intrinsic rate of natural increase of *E. hirsti* under the laboratory conditions. The current study is the first report of life table of *E. hirsti* and the results can be useful in pest control programs as well as in the efforts to understand the population biology of the mite.

Materials and methods

Fig spider mite culture

Mites were collected from fig orchards (Green cultivar) in Estahban (Fars province, (29° 07' 36" N, 54° 02' 32" E) during summer 2011. The mites were reared on potted figs at 30±1 °C, 60±10% R.H. and 12:12 h (dark: light) photoperiod in the laboratory of Acarology at Shiraz University, Iran. Before using mites in the experiments, they had been reared for several generations in the laboratory.

Life table study

A pure culture of *E. hirsti* was maintained on fig leaves under laboratory conditions of 30±1 °C, 60±10% RH and 12:12 h (dark: light) in 50 replications. The adult mites were placed on fig leaf discs and surrounded with a thinned strip of cotton to inhibit mites escaping from Petri dishes (90 mm in diameter and 15 mm in height). After 24 hours, the adult mites were collected from the leaf surface and only one egg was left in each Petri dishes. Developmental time and mortality rates were measured for each replicate until the adults were emerged. At the next stage, a male mite was selected from the colony and placed in Petri dishes having a female mite, then the daily fecundity and longevity were recorded. Premature duration stage, mortality, total number deposited egg/females of *E. hirsti* were daily counted in order to be used for estimation of life table parameters.

Life table parameters and data analyses

Raw data of individuals were analyzed according to the age-stage, two-sex life table theory

(Chi & Liu 1985; Chi 1988). The age-stage specific survival rate (s_{xj}) (where x = age in days and j = stage; the first stage is the egg-larva stage, the second stage is the pupal stage, the third and fourth stages are the female and male, respectively), 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) are calculated accordingly. The intrinsic rate of increase is estimated by using iterative bisection method from:

$$(1) \quad \sum e^{-r(x+1)} l_x m_x = 1$$

In the age-stage, two-sex life table, the l_x and m_x are calculated as:

$$(2) \quad l_x = \sum s_{xj}$$

and

$$(3) \quad m_x = \sum s_{xj} f_{xj} / \sum s_{xj}$$

(Chi & Liu 1985). Because life table study is extremely time-consuming and replication is impractical, we used the jackknife method (Sokal & Rohlf 1995) to estimate the means and standard errors of the life table parameters. The mean generation time was defined as the length of time that a population needs to increase to R_0 fold of its size at the stable age-stage distribution and was calculated as $T = (\ln R_0)/r$. The age-stage life expectancy (e_{xj}) for individuals of age x and stage j was calculated according to the method described in Chi (1988). To ease the raw data analysis, a computer program, TWOSEX-MSChart for the age stage, two-sex life table analysis (Chi 2008a), was designed in Visual BASIC (version 6, service pack 6) for Windows operating system and the graphs drew using Sigma Plot V. 11.0 software.

Results and Discussion

Development and longevity

Stage developmental time, adult longevity and fecundity of *E. hirsti* are presented in Table 1. The mean of female adult longevity of fig mites was 16 days that was similar to Shishehbor and Kamali (1991) results, indicating the female adult longevity at 25° C and 65% RH was 16 days. Said-Pour Valaei (1992) also showed that the maximum adult longevity was 20 days for females at 35±1 °C. Variation in *E. hirsti* longevity in different studies may be due to differences in temperature and laboratory conditions.

Table 1. Life history statistics mean \pm SE of *E. hirsti* at 30 \pm 1 $^{\circ}$ C, 60 \pm 10% RH.

Parameters	Stage	N	Mean \pm SE
Developmental time (days)	Egg	50	4.32 \pm 0.097
	Larva	50	1.38 \pm 0.096
	Protochrysalis	50	1 \pm 0.0
	Protonymph	50	1.4 \pm 0.07
	Deutochrysalis	50	1.06 \pm 0.034
	Deutonymph	50	1.4 \pm 0.07
	Teliochrysalis	50	1 \pm 0.0
	Adult	50	13.94 \pm 0.387
	Female	44	14.91 \pm 0.1
	Male	6	6.83 \pm 0.4
longevity (days)	Pre-adult	50	11.56 \pm 0.082
Adult pre-oviposition period (APOP) of female (days)	Female	46	1.5 \pm 0.076
Total pre-oviposition period (TPOP) of female (days)	Female	46	13.16 \pm 0.133
Fecundity (F)	Female	46	46.02 \pm 0.449

The results demonstrated the advantages of using the age-stage, two-sex life table theory in describing demography over the female based age-specific life table. For example, the over lapping in the curve of s_{xj} (Fig. 1) showed the potential of the age-stage, two-sex life table in revealing the stage differentiation of *E. hirsti* due to variable developmental rates among individuals. The age-stage specific survival rate (s_{xj}) of *E. hirsti* (Fig. 1) gives the probability that laid eggs will survive in age i and stage j . This curve also showed the survivorship and stage differentiation as well as the variable developmental rate. For instance, the probability that a new born egg survives to the adult stage is 0.12 in males and 0.88 in females.

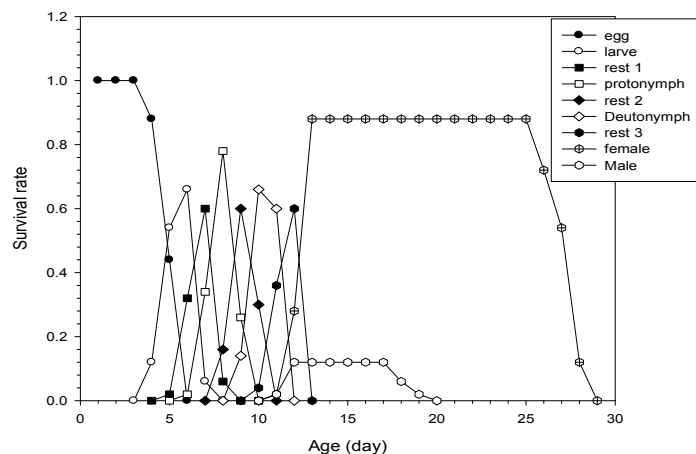


Figure 1. The age-stage specific survival rate (s_{xj}) of *E. hirsti* at 30 \pm 1 $^{\circ}$ C, 60 \pm 10% RH.

Fecundity

The average female fecundity of *E. hirsti* was 46.02 eggs. Similar results were reported by Baradaran *et al.* (2002) and Said-pour Valaei (1992). They reported that

maximum daily oviposition of *E. hirsti* was 10 eggs. The mean fecundity was 39 at 40°C and 70% RH. The age-specific survival rate (l_x), the age-specific fecundity (m_x) and the age-specific maternity ($l_x m_x$) were shown in Figure 2. The age of first reproduction by females has an important effect on population growth, and many researchers plot the fecundity curve on female age thus defining the pre-oviposition period as the time between emergence and first oviposition (APOP). Ignoring the length and variation of preadult stages, APOP for *E. hirsti* is 1.5 ± 0.07 days (mean \pm SE). Comparing Table 1 and Figure 2 showed that the preoviposition period ranged from 1 to 2 days and the total pre-oviposition period (TPOP) which was defined as the time interval from the birth of a female individual (from the egg stage) to its first oviposition day ranged from 11 to 14 days.

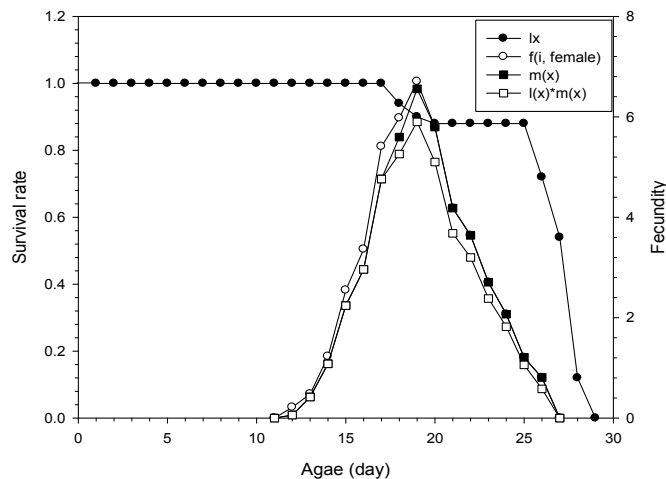


Figure 2. The age-specific survival rate (l_x), age-stage fecundity of female (f_i), age-specific fecundity of total population (m_x) and the age-specific maternity ($l_x m_x$) of *E. hirsti* at $30 \pm 1^\circ\text{C}$ and $60 \pm 10\%$ RH .

Life expectancy

Based on the age-stage survival rate, the life expectancy for each age-stage is plotted in Figure 3 in order to predict the future life of the population. The e_{ij} estimated the individuals of age i and stage j that are expected to be alive. Life expectancy of a newly laid egg was 27 days and decreased by increasing age. Life expectancy of the female adult was much higher than that of the male adult and overlapping occurred between stages. This result was in accordance with that of obtained from Figure 1 where the adult longevity for males was much shorter than the females. Shishehbor and Kamali (1991) reported that the mean life expectancy of female adults of *E. hirsti* collected in natural condition was 21 days that was lower than life expectancy in males.

The result showed that the e_{ij} decreased during the life stages and it was higher for the female compared to the males (Fig. 3).

Reproductive values

According to Fisher (1930) the life table analysis indicates also the contribution of an individual to the growth of future population. Figure 4 illustrates the age-stage reproductive values of *E. hirsti*. If an individual becomes a female adult, its reproductive value increases dramatically. The female at the age of 17th day (counted from birth) gave a peak reproductive value of 23. From the life table data of *E. hirsti*, it

could be concluded that the repeated oviposition is an innate behaviour initiated by the female to overlap or to compensate the mortality rates recorded during its life span (Krips *et al.* 1998). Moreover, such information will be useful for the application of stage-specific control strategies.

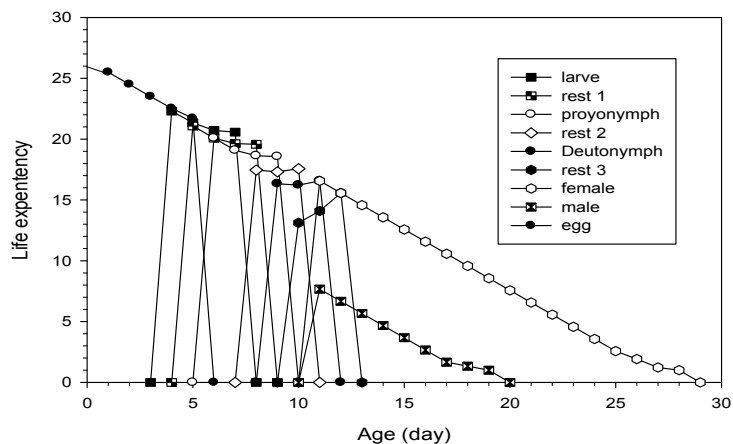


Figure 3. The age-stage specific life expectancy (e_{ij}) of *E. hirsti* at $30\pm 1^\circ\text{C}$, $60+10\%$ RH.

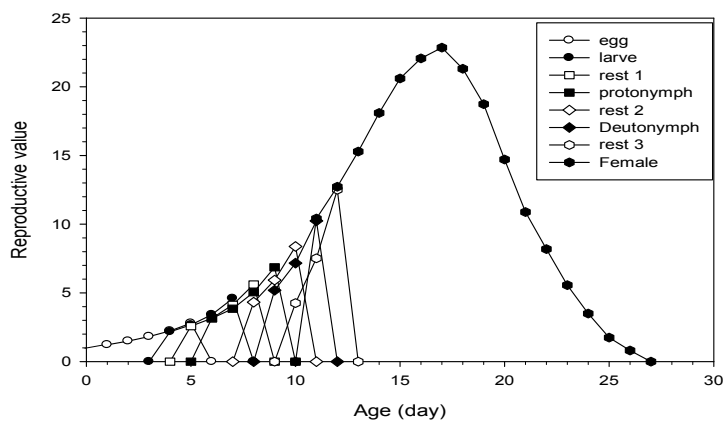


Figure 4. The age-stage reproductive value (v_{xj}) of *E. hirsti* at $30\pm 2^\circ\text{C}$, $60+10\%$ RH.

Life table analysis

Life table parameters of *E. hirsti* are presented in Table 2. T , R_0 , r_m and λ were 18.5 days, 36.97 offspring/female, 0.1955 d^{-1} and 1.2159 d^{-1} , respectively.

Table 2. Life table parameters of *E. hirsti* at $30\pm 1^\circ\text{C}$, $60\pm 10\%$ RH.

Parameters	Mean±SE
Intrinsic rate of increase (r) (day^{-1})	0.2004 ± 0.0034
Net reproduction rate (R_0) (offspring)	40.5 ± 2.17
Gross reproduction rate (GRR)(offspring)	44.07 ± 0.97
The finite rate of increase (λ) (day^{-1})	1.2219 ± 0.0042
The mean generation time (day)	18.47 ± 0.15

Conclusion

During the last three successive years, Iran and specifically Fars region has experienced severe drought conditions. As a result, the region is prone to be infested by fig mite and damage of *E. hirsti* as a harmful species on fig orchards was increased significantly. Our study was the first report to evaluate the *E. hirsti* life table. Life tables are important tools in the study of population ecology and introduced species (Sakai *et al.* 2001), conservation (Wilcox and Murphy 1985), demographic ecotoxicology (Stark & Banks 2003), harvesting theory (Chi 1994) and pest control timing (Chi 1990). Life table information of this mite would be useful for the application of stage-specific strategies for *E. hirsti* to be controlled in lower economical injury levels.

As Cherian (1938) emphasized life table studies are time-consuming and pest studies under laboratory conditions may be of dubious value in evaluating their potential in the field because many biotic and abiotic factors influence their survival, developmental rates, and fecundity. However, life history studies under laboratory conditions allow researchers to collect the data needed for life table analysis to estimate their biotic potential under specific conditions that can be used as basis for simulation models for field use that include other factors (Sakai *et al.* 2001).

Nutrients and food preference play important roles on the developmental rate and fecundity of pest. Hence, for a thorough understanding of the population dynamics of *E. hirsti*, data suitable for life table analysis must be collected on different cultivars under both laboratory and field conditions. Due to drought conditions in Iran and the economical damage of this pest in Estahban Township, the ecology of *E. hirsti* deserves more attention than it has received so far.

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پارامترهای جدول زندگی کنه انجیر، *Eotetranychus hirsti* (Acari: Tetranychidae) در شرایط آزمایشگاهی

نگار دانش‌نیا، محمدعلی اکرمی و مریم آل‌عصفور

چکیده

کنه تارتن انجیر *Eotetranychus hirsti* Pritchard and Baker, 1955 یکی از مهم‌ترین آفات درختان انجیر در استهبان (استان فارس) می‌باشد. بررسی‌ها در شرایط آزمایشگاه در دمای 1 ± 30 درجه سلسیوس، رطوبت نسبی 10 ± 60 درصد و دوره روشنایی ۱۲:۱۲ ساعت (تاریکی: روشنایی) و در ۵۰ تکرار انجام شد. تعداد تخم روزانه، دوره پیش از بلوغ و مرگ و میر با استفاده از نرم افزار جدول زندگی دو جنسی تجزیه و تحلیل شدند. نتایج به دست آمده نشان داد که طول دوران مراحل تخم، لارو، استراحت یکم، پوره سن یکم، استراحت دوم، پوره سن دوم، استراحت سوم و کنه کامل به ترتیب $4/32 \pm 0/097$ ، $1/38 \pm 0/096$ ، 1 ± 0 ، $1/4 \pm 0/07$ ، $1/06 \pm 0/034$ ، $1/4 \pm 0/07$ و 1 ± 0 روز است. مجموع طول دوره رشدی (از تخم تا کنه کامل) در شرایط آزمایشگاهی مذکور برای کنه‌های ماده و نر به ترتیب ۸ و ۱۶ روز بود. طول دوران پیش از بلوغ ماده‌ها، کل دوران بلوغ به ترتیب $1/5 \pm 0/1043$ ، $13/17 \pm 0/1871$ روز به دست آمد. همچنین میانگین مدت زمان یک نسل (T_c)، نرخ خالص باروری (R_0)، نرخ خالص افزایش (r_m) و نرخ رشد محدود جمعیت (λ) به ترتیب $0/15 \pm$ ، $18/47$ روز، $2/17 \pm 40/5$ نتاج، $0/003 \pm 0/2004$ (روز^{-۱}) و $1/221 \pm 0/004$ (روز^{-۱}) به دست

آمد. تجزیه و تحلیل جدول زندگی *E. hirsti*، توصیف کاملی از مراحل مختلف رشدی این کنه را
ارایه می‌دهد.

واژگان کلیدی: *Eotetranychus hirsti*، پارامترهای جدول زندگی، نرخ خالص افزایش، نرخ
باروری.

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