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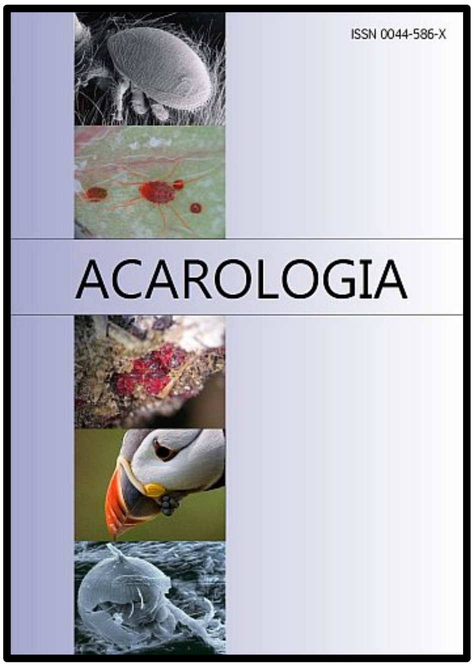
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POPULATION GROWTH PARAMETERS OF THE TWO-SPOTTED SPIDER MITE, *TETRANYCHUS URTICAE*, ON THREE PEACH VARIETIES IN IRAN

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ABSTRACT — The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch is one of the most important pests of peach trees in Iran. The reproduction, survival, and life table parameters of TSSM on three peach cultivars: Redtap, G.H.Hale and Kardi, were studied at 27 ± 1 °C, 50 ± 10 % RH and a photoperiod of 12L:12D. The average developmental time from egg to female adult on the cultivars was 10.3 ± 0.303, 9.431 ± 0.176 and 9.9 ± 0.166, respectively. Intrinsic rates of increase (r_m) were 0.07 ± 0.02, 0.21 ± 0.01 and 0.18 ± 0.008, respectively. Based on some biological and demographic parameters of *T. urticae* on the different peach varieties, along with the significant differences between Redtap and the other 2 varieties, it was concluded that the Redtap variety is not as suitable a host as the other two varieties.

KEYWORDS — *Tetranychus urticae*; peach; fecundity; life table; mortality; development time

INTRODUCTION

The two-spotted spider mite, *T. urticae* Koch, is the most polyphagous species of spider mites and has been reported from over 150 host plant species of some economic value (Zhang 2003). This mite causes heavy damages to peach orchards, Chaharmahal Va Bakhtiari province, Iran. Symptoms of *T. urticae* damage are yellowish foliage, whitish streaks on the stems caused by mite feeding, and very little lower foliage (Snetsinger *et al.* 1965). The rapid developmental rate and high reproductive potential of *T. urticae* allow them to achieve damaging population levels very quickly when growth conditions are good, resulting in an equally rapid decline of host plant quality. The population growth parameters of *T. urticae* such as developmental rate, survival, reproduction and longevity may vary with temperature, host plant species, host plant nutrition, cultivar, phenological stage, exposure to pesticides and relative humidity (Brandenburg and Kenedy 1987; Wermelinger *et al*. 1991; Wilson 1994; Dicke 2000; James and Price 2002; Marcie 2003; Skorupska 2004).

Plants have main effects on demographic parameters of spider mite population dynamics. Therefore, in order to develop a successful integrated pest management (IPM) program, it is important to accurately characterize its life-history parameters on diverse host plants (Watson 1964; Laing 1969; Poe 1971; Carey and Bradley 1982; Cai *et al*. 1992; Wilson 1994; Krips *et al.* 1998; Skirvin and

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Williams 1999; Kasap 2002, 2004; Pietrosiuket *et al*. 2003; Parslika and Huszar 2004; Rajakumar *et al.* 2005; Saeidi 2006; Yong Hao 2008; Razmjou *et al.* 2009; Riahi 2011; Saeidi 2011). During a survey on tetranychid mites in Chaharmahal Va Bakhtiari province, Shahrekord, Iran, high densities of *T. urticae* were observed on peach trees. To address the lack of knowledge on the biology of this mite on fruit trees in Iran and facilitate future control of this mite, the present study aims to assess the main life history parameters of *T. urticae* on three peach tree varieties in this latter province.

Materials and methods

Experimental conditions

The rearings of *T. urticae* and further experiments were carried out in growth chambers at 27 ± 1 °C, 50 ± 10 % humidity and photoperiod of 12:12 (L:D). Population growth parameters of this mite in this region was calculated at different temperatures by several authors. Results showed that the optimal temperature was 27 °C (Riahi 2011; Saeidi 2011). Moreover, the highest population density of the mite is observed during the summer season (July to September) when temperature is high. The maximum and minimum of day length were 14 hours (at 10 July) and 11:30 hours (end of September), respectively. Previous studies (Riahi 2011; Saeidi 2011) reflected no difference in population growth parameters between 12L:12D and 14L:10D photoperiods at 27 °C.

Mite rearing and host plant production

Individuals of *T. urticae* were collected from cucumber (*Cucumis sativus* L.) in a field in shahrekord region, Iran. Collected mites were placed on detached sprouts and leaves of three varieties of peach, namely, Redtap, G.H.Hale and Kardi in wood framed cages (100 x 150 x 200 cm) and reared for several generations about four month before the experiments.

Experiments

Peach leaves were collected from three peach varieties in outdoor orchards, in which neither acaricides nor insecticides had been applied for two years before the initiating of the experiments.

Leaves of each peach variety were carefully checked under a stereomicroscope to remove any mite. Then, leaf discs (3 cm in diameter) were cut and placed upper side down on water saturated cotton in Petri dishes (9 cm diameter) with a mesh-covered ventilation hole (3 cm diameter) on the lid.

To obtain eggs of the same age, four to six females of *T. urticae* were placed on each leaf disc and allowed to lay eggs. After three hours, the females and extra eggs were killed to get one egg per disc. Then, observations were made twice daily at 12 - h intervals. Incubation periods of the egg stage, developmental times and survivorship of the eggs, larvae and nymphs were monitored and recorded daily until adulthood. The number of replicates was 74, 65 and 70 on Redtap, G.H.Hale and Kardi varieties, respectively. Female in their quiescent stage prior to adulthood (teleiochrysalids) were provided with a newly emerged male isolated from the stock culture of the three peach varieties. The male were removed 24 h after the female emerged. Eggs were counted daily until female death, in order to obtain mean female longevity, and the mean duration of pre-oviposition, oviposition and post-oviposition periods. The number of replicates was 15, 35 and 40 on Redtap, G.H.Hale and Kardi varieties, respectively. To estimate the sex ratio, egg samples were collected each day throughout the oviposition period (except for 1 or 2 days before last oviposition day) and maintained at the same conditions as the parental females, until adult emergence.

Statistical analysis

Developmental time was calculated as half the time interval between the two observations: when the mite was developed to the upper stage between two observation times, the half interval time (6 hours) was computed for each stage. Data on duration of the immature stages, the preoviposition, oviposition and post oviposition periods, and the longevity of females were analyzed using one-way ANOVA followed by Fisher's LSD test ($P = 0.05$) to compare the means (SAS 9.0).

Population growth parameters

Population growth parameters were estimated according to Birch (1948) and Southwood and Henderson (2000). The intrinsic rate of increase (r_m) resulted from the following equation:

$$\sum l_x m_x e^{-r_m x} = 1$$

Where x is the age class, l_x is the probability of survival at age x, and m_x is the mean number of female progeny at age x. The net reproductive rate (R_0), the mean generation time (T), the doubling time (DT), and the finite rate of increase (λ) were calculated by the following equations:

$$R_0 = \sum l_x m_x$$
$$T = ln\frac{R_0}{r_m}$$
$$DT = \frac{ln2}{r_m}$$
$$\lambda = e^{rm}$$

The mean and standard error values of demographic parameters were determined using program developed by Maia *et al.* (2000), based on the Jackknife's procedure. After r_m was computed from the original data (r_{a11}), the differences in r_m -values were tested for significance by estimating the variance using the jackknife method which facilitated calculation of the standard errors of r_m estimates. The jackknife Pseudo-Value (r_j) was calculated for the n samples by using the following formula:

The mean values of (n-1) jackknife pseudo-values for each treatment were subjected to a variance analysis (ANOVA). All data were checked for normality prior to analysis. Differences in longevity and total fecundity among the plant varieties were compared by ANOVA (SAS 2003). Log transformation of survival time and log(x+1) of total fecundity were used to minimize variances and means were compared using Student-Newman-Keuls sequential test. This procedure was used to compare of

TABLE 1: Development time in days (mean ± SE) of female and male of *T. urticae* reared on three varieties of peach trees.

Sex	Stages	Peach varieties			
		Redtap	G.H.Hale	Kardi	*P* -value
Female	Egg	4.13 ± 0.16	3.90 ± 0.10	4.04 ± 0.06	0.314
	Larva	1.40 ± 0.15 a	0.88 ± 0.06 b	1.01 ± 0.06 b	0.0005
	Protochrysalid	0.91 ± 0.04 a	0.66 ± 0.05 b	1.03 ± 0.07 a	0.0001
	Protonymph	0.84 ± 0.08	0.76 ± 0.05	0.89 ± 0.05	0.235
	Deutochrysalid	0.95 ± 0.06	0.89 ± 0.07	0.77 ± 0.08	0.289
	Deutonymph	1.03 ± 0.12	1.11 ± 0.05	1.00 ± 0.05	0.370
	Teliochrysalid	1.00 ± 0.07	1.22 ± 0.09	1.12 ± 0.07	0.289
	Immature	10.26 ± 0.30 a	9.43 ± 0.18 b	9.88 ± 0.17 ab	0.034
Male	Egg	4.93 ± 0.14 a	3.84 ± 0.17 b	3.64 ± 0.31 b	0.006
	Larva	1.22 ± 0.18	0.98 ± 0.15	1.14 ± 0.14	0.55
	Protochrysalid	0.82 ± 0.11 a	0.75 ± 0.08 a	1.27 ± 0.13 b	0.005
	Protonymph	0.91 ± 0.07	1.08 ± 0.20	0.98 ± 0.11	0.74
	Deutochrysalid	0.87 ± 0.09	0.93 ± 0.12	1.23 ± 0.20	0.265
	Deutonymph	0.89 ± 0.11	0.96 ± 0.16	0.99 ± 0.12	0.884
	Teliochrysalid	0.88 ± 0.14	1.21 ± 0.12	0.87 ± 0.14	0.143
	Immature	10.54 ± 0.26	9.75 ± 0.34	10.18 ± 0.61	0.491

Different letters indicate significant differences between peach varieties, (within rows; $P < 0.05$).

the different r_m (Sokal and Rohlf 1995). Differences between the means were evaluated using the least significant differences (LSD) test at $P < 0.05$. Homogeneity of variances was also tested with Bartlett's test in SAS.

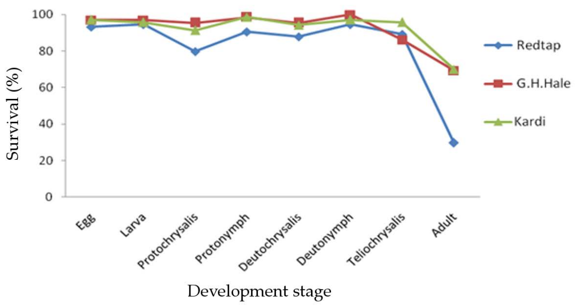

FIGURE 1: Survival rate for life stages of *T. urticae*, from egg to adult emergence, on three peach varieties, Redtap, G.H.Hale and Kardi, under 27 ± 1 °C, 50 ± 10 % humidity and photoperiod of 12:12 (L:D) conditions.

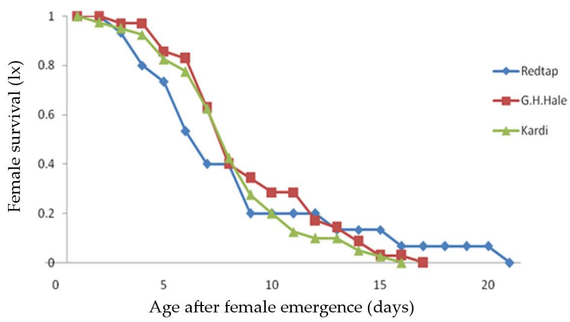

FIGURE 2: Age-specific survival (l_x) curves of female of *T. urticae* in adulthood on three peach varieties.

RESULTS

Immature developmental time

The female and male immature developmental time (from laid egg to adult emergence), are shown in Table 1. The immature developmental time differed significantly between Redtap and G.H.Hale varieties for female (df = 2, F = 3.52 and $P = 0.033$), and did not significantly differ for male (df = 2, F = 0.73 and $P = 0.491$). Within each developmental stage, there were only few significant differences between peach varieties (Table 1). The significantly longer female larval stage of *T. urticae* on Redtap vs other varieties explain in part the overall development time differences between Redtap and G.H.Hale. The male egg stage was longer on Redtap compared to other varieties. There were also significant differences for the protochrysalid stage.

Immature mortality

Survivorship of *T. urticae* stages on the three peach varieties is shown on Figure 1. The mortality of most stages of *T. urticae* was similar for the three peach varieties considered. However, it was higher for the protochrysalids on Redtap (79.73 % survival vs 95.38 and 91.43 for G.H.Hale and Kardi, respectively). The total mortality from egg to adult emergence was 72.55, 32.78 and 31.5 % on Redtap, G.H.Hale and Kardi respectively.

TABLE 2: Mean in days (± S.E.) of female longevity and pre-oviposition, oviposition and post-oviposition periods (days) of *T. urticae* on three peach varieties.

	Redtap	G.H.Hale	Kardi
Pre-oviposition	1.52 ± 0.30	1.46 ± 0.13	1.38 ± 0.09
Oviposition	4.81 ± 1.34	4.93 ± 0.54	5.35 ± 0.55
Post oviposition	0.49 ± 0.07	0.61 ± 0.05	0.56 ± 0.19
Longevity	5.44 ± 1.03	5.92 ± 0.55	6.62 ± 0.55

No significant differences were observed among peach varieties.

TABLE 3: Mean (± SE) total fecundity (eggs/female), daily fecundity (eggs/female/day) and sex ratio of the three peach varieties.

	Redtap	G.H.Hale	Kardi
Total fecundity	11.53 ± 3.73	18.74 ± 2.61	16.60 ± 1.90
Daily fecundity	2.15 ± 0.41	3.10 ± 0.55	2.11 ± 0.39
Sex ratio	0.68 ± 0.14	0.78 ± 0.03	0.82 ± 0.12

No significant differences were observed among peach varieties.

Tetranychus urticae completed its development on all peach varieties, but significant differences in female mortality were observed (Figure 2). A mortality of 50 % occurred after 9, 16 and 16 days on Redtap, G.H.Hale and Kardi varieties respectively. No live mite was observed after 31, 26 and 25 days, respectively. No mortality occurred before the 2th,

2^{th} and first days for Redtap, G.H.Hale and Kardi, respectively (Figure 2).

Female longevity, fecundity and sex ratio

The mean female longevity and the mean duration of pre-oviposition (from adult emergence to egg laying), oviposition (from first to last egg laid) and post-oviposition periods (from last egg laid until death) did not differ significantly among the three peach varieties (Table 2). Overall fecundity (df = 2, F = 1.17 and P = 0.314) and daily fecundity (df = 2, F = 0.46 and P = 0.631) of *T. urticae* females reared on the three peach varieties did not differ either (Table 3). The daily fecundity of cohort, expressed as the total number of eggs laid by the surviving females, is presented in figure 3.

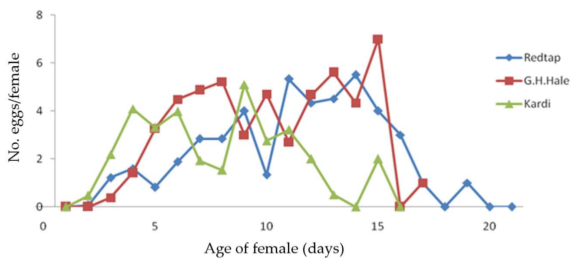

FIGURE 3: Daily fecundity curves (eggs/female/day) of *T. urticae* on three peach varieties.

The sex ratio of *T. urticae* did not differ among the three peach varieties (Table 3). In all varieties, sex ratio of progeny was male biased in the first 2 – 3 days of the oviposition period. However, for the rest of the oviposition period, the sex ratio was greatly female biased (Figure 4).

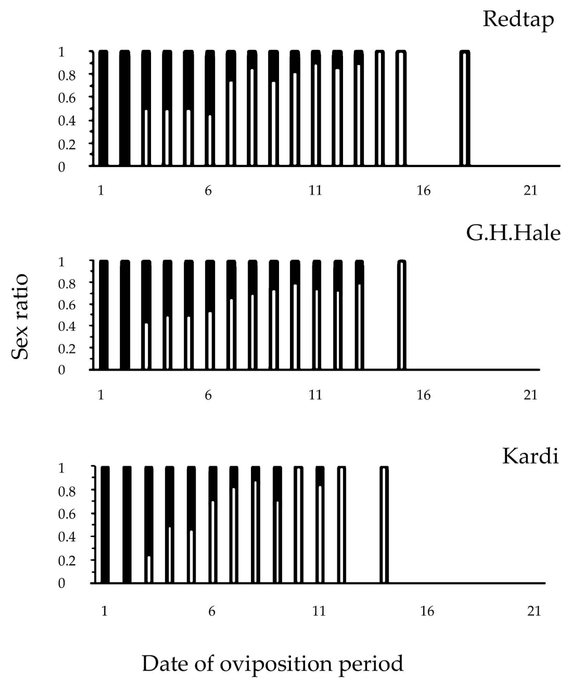

FIGURE 4: Offspring sex ratio of females of *T. urticae* reared on three peach varieties. At each sampling date, black and white bars indicate the percentages of male and female offspring, respectively.

Life table

Demographic parameters of *T. urticae* clearly differed among peach varieties (Table 4). Mites reared on Redtap had a significantly lower intrinsic rate of increase (r_m) than those reared on the two other varieties (df = 2, F = 14.84 and P = 0.0001).

TABLE 4: Life table parameters of *T. urticae* reared on three peach varieties at 27 °C.

Parameter	Varieties		
	Redtap	G.H.Hale	Kardi
r_m	0.07 ± 0.02 b	0.21 ± 0.01 a	0.18 ± 0.02 a
R_o	3.18 ± 1.03 b	12.11 ± 1.69 a	10.11 ± 1.16 a
T	16.09 ± 1.33 b	11.68 ± 0.41 a	12.68 ± 0.23 c
λ	1.07 ± 0.02 b	1.24 ± 0.01 a	1.21 ± 0.02 a
DT	9.65 ± 1.59 b	3.25 ± 0.16 a	3.80 ± 0.16 a

Different letters indicate significant differences between peach varieties, (within rows; $P < 0.05$).

The net reproductive rate (R_0) for mites reared on Redtap variety was about 3 to 4 times lower than for those reared on Kardi and G.H.Hale varieties. Mean generation time (16.09 $\pm$ 1.33 days) and population doubling time (9.65 $\pm$ 1.59 days) was clearly the highest; the finite rate of increase (1.07 $\pm$ 0.02) was lowest for *T. urticae* reared on Redtap variety (Table 4).

Discussion

A great number of studies have been performed on the biology of *T. urticae* on different host plants. However, it would be uphill to compare the present results with others, as rearing conditions (temperature: 27 °C, as well as host plants) were different. We will thus compare the present results first to results obtained at the same temperature and then to results obtained on peach leaves. Shih *et al.* (1976) found that *T. urticae* required in average 7.5 days to develop from egg to adult at 27 °C on lima bean leaves. This duration is shorter than the one presently observed (9.4 – 10.3 days). Saeidi (2011) reported that females of *T. urticae* on almond required an average of around 5.15 – 5.27 days to grow from larva to adult at 27 °C and 12L:12D. The female longevity presently observed (5.44 – 6.62 days) is almost identical to what Saeidi found on almond (5.2 – 10.45 days) but considerably shorter than what Shih *et al*. (1976) reported on lima bean (19.1 days). Furthermore, 27.45 to 68.5 % of eggs developed to maturity in the present study, whereas Saeidi (2011) found that 47 – 88 % could.

The average fecundities reported in other studies at 27 °C are much higher than those presently observed: 143.9 eggs/ female on lima bean (shih *et al*. 1976), 141 on eggplant (Ju *et al*. 2008) and around 15.1 – 57.6 eggs/ female on almond (Saeidi 2011). Our results are considerably lower than those of Ju *et al*. (2008) and Shih *et al*. (1976). The presently observed highest value of r_m and R_0 were 0.21 and 12.1 (on G.H.Hale). These values are much lower than those reported by Shih *et al*. (1976) on lima bean (0.34 and 97.4, respectively).

The differences observed with bibliographic results could be due to plant, especially to peach leaves. Morphology of the leaf surface, such as thick cuticle and glandular or non- glandular hairs, the chemical contents, food quality, plant's nutritional value, the secondary metabolites, leaf texture as well as relative humidity could affect mite development. Furthermore, development could also vary according to the populations considered and their origin.

Only a few studies have been carried out to assess the biology of *T. urticae* on peach. Riahi (2011) found that a female developmental time, female longevity and total fecundity of 13.23, 12.91 days and 40.09 eggs/ female at 25 °C. These latter values were higher than those presently found. Yong Hao (2008) reported that the r_m value of *T. urticae* at 25 °C on peach was 0.193; this is almost identical to our results. The finite rate of increase (λ) of *T. urticae* was 1.44 (Yong Hao, 2008) and 1.16 (Riahi, 2011) at 25 °C, the former is higher than our findings whereas the latter is equal. The net reproduction rate (R_0 = 16.87) and the mean generation time (T = 19.32) in Riahi's study were higher than our findings. Temperature is the overriding environmental influence in life history parameters. Hence, the differences between our study and other workers may stem from different temperature. However, these differences could also be attributed to populations, relative humidity, age plant, or the more complete nutrient supply in the soil which resided in the excised leaves.

In this study, the slowest population growth rate, longest immature developmental time of female and lowest survivorship of immatures was observed on the Redtap variety, indicating that Redtap is a less suitable plant for *T. urticae* than G.H.Hale and Kardi varieties. Thus, this pest could not be able to create quickly and damaging population on Redtap variety so, it can be considered by growers in order to develop a successful integrated pest management (IPM) program for this pest. However, after these laboratory studies, more attention as well as considerations should be devoted to field experiments to obtain more applicable results.

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