

## Life Parameters of *Tetranychus urticae* (Acari: Tetranychidae) on Six Common Bean Cultivars

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**ABSTRACT** It is well recognized that the quality of host plants affects the development and survival of twospotted spider mite *Tetranychus urticae* Koch. The life table parameters of *T. urticae*, on six cultivars of common bean (*Phaseolus vulgaris* L.) (chiti Khomein, chiti Ks21189, red Akhtar, red Ks31169, white Pak, and white G11867) were studied at constant laboratory conditions ( $27 \pm 2^\circ\text{C}$ ,  $70 \pm 5\%$  RH and 16:8 L:D). Total development times of immature males and females were significantly influenced by bean cultivar. *T. urticae* laid significantly more eggs per day on red Akhtar (16.16) than on the other cultivars. The mean generation time ranged from 23.37 to 34.82 d, and a significant varietal effect was seen. Percentage of egg hatchability of twospotted spider mite ranged from 88.25 to 94.20%. The highest intrinsic rate of increase, was recorded on red Akhtar ( $0.269 \pm 0.031$ ) and the lowest value was obtained on white Pak ( $0.129 \pm 0.048$ ). In addition, net reproductive rate and finite rate of increase of the twospotted spider mite had the highest value on red Akhtar:  $62.38 \pm 1.05$  and  $1.30 \pm 1.02$ , respectively. The lowest values of these parameters were recorded on white Pak as  $26.11 \pm 1.40$  and  $1.13 \pm 1.10$ , respectively. Doubling time varied significantly on different cultivars and the lowest and highest values were obtained on red Akhtar and white Pak, respectively. Our findings revealed that white beans (Pak and G11867) were less suitable cultivars, suggesting that they are more resistant to the twospotted spider mite than the other cultivars.

**KEY WORDS** life table parameter, fecundity, resistance, common bean, twospotted spider mite

Common bean (*Phaseolus vulgaris* L.) is one of the most important and widely grown crops in the world, and commercially produced in Markazi, Lorestan, Fars, and Zanjan provinces of Iran. Based on reports by the Iranian Ministry of Agriculture (Statistical Bulletin, Iran, 2005) this crop is grown on >105,000 ha annually in Iran. Various pests affect common bean production in Iran, among which the twospotted spider mite, *Tetranychus urticae* Koch, is considered important in many bean-growing areas of Iran (Rott and Ponsoby 2000, Fikru and Leon 2003, Ragkou et al. 2004, Khanjani 2005, Khanjani and Haddad 2006). Twospotted spider mite infests the underside of leaves, where profuse webbing may be present. *T. urticae* feeds using a piercing-sucking process that damages plant cells and tissues. This behavior leads to the appearance of chlorotic spots on the leaves. Because the chloroplasts in leaves are gradually destroyed as the population of feeding mites increases, photosynthesis declines, sto-

mata close, and transpiration decreases, leading to reduced production (Brandenburg and Kennedy 1987, Martinez-Ferrer et al. 2006). The rapid developmental rate, short generation time, and high net reproductive rate of *T. urticae* allows them to achieve damaging population levels very quickly when growth conditions are suitable, 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 in response to changes in temperature, host plant species, host plant nutrition, cultivar kind, phenological stage, exposure to pesticides, and relative humidity (Sabelis 1981; Carey and Bradley 1982; Brandenburg and Kennedy 1987; Wermelinger et al. 1991; Wilson 1994a, 1994b; Dicke 2000; James and Price 2002; Marcic 2003; Skorupska 2004).

Life tables and fertility tables are powerful tools for analyzing and understanding the impact that an external factor has upon the growth, survival, reproduction, and rate of increase of an insect population (Bellows et al. 1992, van den Boom et al. 2003, Musa and Ren 2005, Greco et al. 2006). In the middle of this factors, host plants have main effects on development, mortality, and fecundity rates of insects and mites. Wittmeyer et al. (2001) showed that the nutritional quality of food consumed during both nymphal and

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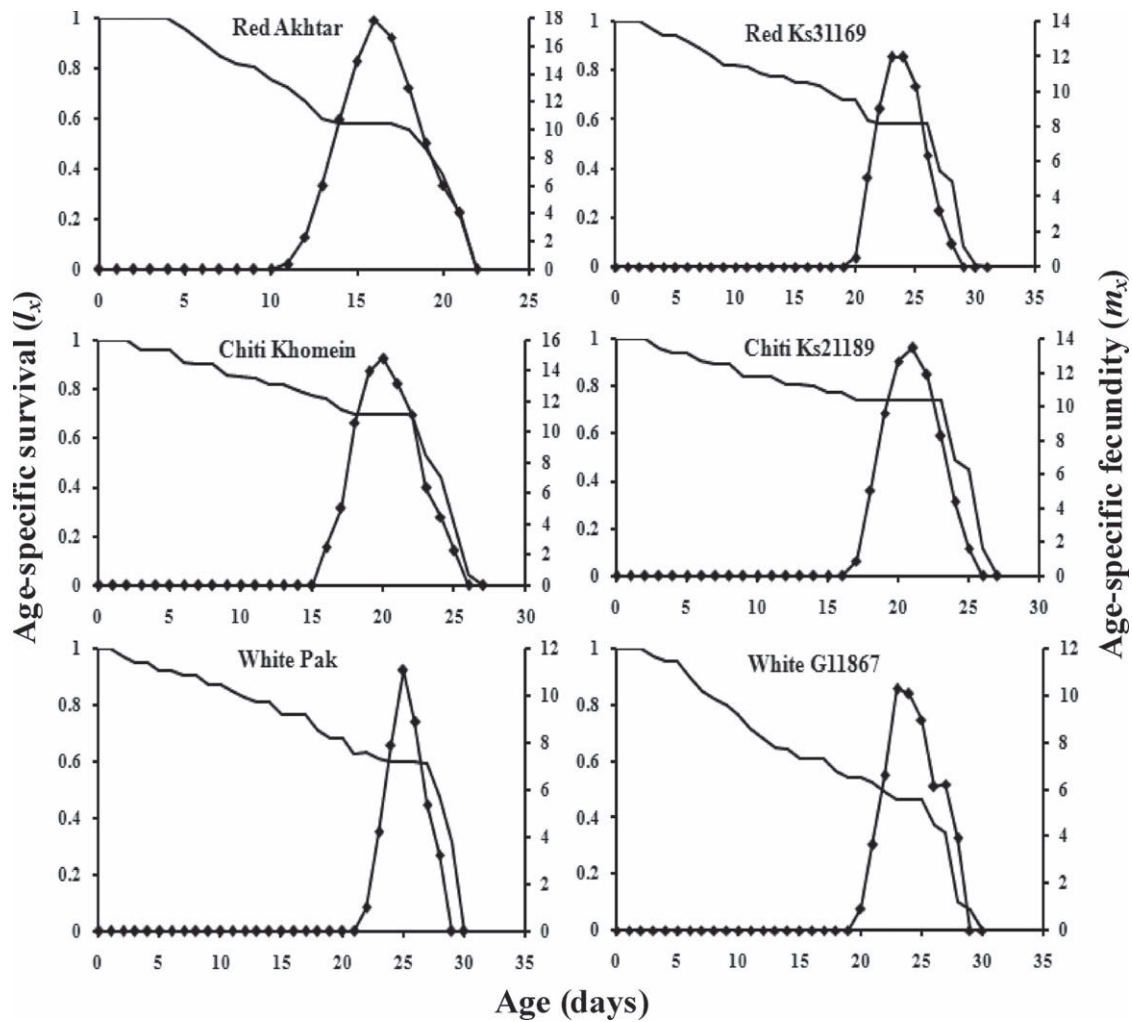


Fig. 1. Age-specific survival ( $l_x$ , simple line) and age-specific fecundity ( $m_x$ , solid diamonds) of *T. urticae* on six bean cultivars.

adult stage of development influenced the fecundity and fertility of adult female *Podisus maculiventris* Say.

Life table parameters, including net reproductive rate ( $R_0$ ), mean generation time ( $T$ ), doubling time ( $DT$ ), finite rate of increase ( $\lambda$ ), and intrinsic rate of natural increase ( $r_m$ ) have been used to evaluate the susceptibility or resistance of several host plants in relation to various pests (Tsai and Wang, 2001, Satar and Yokomi, 2002, Razmjou et al. 2009a). Among these parameters, the intrinsic rate of increase is commonly used to evaluate the level of plant resistance to insects (Razmjou et al. 2006). Therefore, knowledge of cultivar susceptibility or resistance might be a fundamental component of an integrated pest management (IPM) program for any crop. Such information can be used in developing an insect-resistant cultivar (Stoner and Shelton 1988, Jyoti et al. 2001, Yang and Chi 2006,).

Despite the economic importance and worldwide distribution, relatively little is known about the population growth parameters of twospotted spider mite

on different common bean cultivars. Hence, the goal of this study was to evaluate the population growth characteristics of twospotted spider mite on six bean cultivars: chiti beans (Khomein and Ks21189), red beans (Akhtar and Ks31169), and white beans (Pak and G11867).

### Materials and Methods

**Mite Colony.** Adults of twospotted spider mite were originally collected from common bean fields of the Khomein region, Iran in May 2009. These mites were reared on Black eye pea (*Vigna sinensis* L.) grown in plastic pots (20 cm diameter  $\times$  25 cm height) in a growth chamber ( $27 \pm 2^\circ\text{C}$ ,  $70 \pm 5\%$  RH and a photoperiod of 16:8 L:D) for at least 2 mo (several generations) before conducting the experiments. All experiments were performed at the above-mentioned conditions in growth chambers. This study was conducted in laboratory at the Department of Entomol-

ogy, Islamic Azad University, Arak Branch, Iran during 2009–2011.

**Plant Materials.** The fecundity and development time of *T. urticae* were studied on six bean cultivars including: chiti beans (Khomein and Ks21189), red beans (Akhtar and Ks31169), and white beans (Pak and G11867). These bean cultivars are planted in the most bean fields of Iran, especially in Markazi province. Required cultivars were obtained from the Bean Research Institute of Khomein, Iran. The seeds were sown in plastic pots (20 cm diameter  $\times$  25 cm height) filled with fertilized field soil. Each cultivar was planted in 20 replications and maintained in a greenhouse. After 4 wk, bean leaves were detached and used for leaf disc preparation. During the experiments, all plants were irrigated at the same time and no fertilizers or pesticides were used.

**Leaf Discs.** To perform the experiments, the leaf disc method was used (Pedigo and Buntin 1994, Naher et al. 2006). Each leaf disc was 4 cm<sup>2</sup> of area cut from the center of leaves. Each leaf disc was placed on plastic petri dishes (8 cm diameter  $\times$  1.5 cm height with a hole in its center). Thereafter, one fully expanded young leaf (third leaf below the apical meristem of 1-mo-old plants) was randomly collected and used for the leaf disc preparation. The leaves of different common bean cultivars were selected from all replications and cut into a leaf disc (2  $\times$  2 cm) and then placed on a water-saturated cotton in the petri dish with the underside facing upward. During the experiments, all the common bean cultivars were periodically planted in the greenhouse (every 10 d), and to reduce the effects of plant age on mite development and fecundity, the new leaf discs were prepared from their leaves and the mites transferred on them.

**Experiments.** The life table parameters of *T. urticae* were determined on six bean cultivars in laboratory conditions at 27  $\pm$  2°C, 70  $\pm$  5% humidity and a photoperiod of 16:8 L:D h. The study was initiated with 120 eggs of the *T. urticae* as cohort for each cultivar. In this regards, 10 pairs of *T. urticae* (reared on each cultivar), were transferred onto new leaf discs of the same cultivar. Twelve hours later, the laid eggs were collected from these leaf discs and individually transferred with a fine camel hair brush onto new leaf discs. Thereafter, for all experiments, each cohort of mites was used for life table parameters determination of *T. urticae* on each bean cultivar.

To estimate the hatchability of eggs, the sex ratio of the offspring, immature development time to adult, and survivorship of immature mites, one female and one adult male from each cohort of mites were transferred to a fresh leaf disc placed on a water-saturated cotton in a petri dish (20 replications). The females were allowed to deposit eggs for 12 h after the pre-oviposition period (36 h) and then the female mites were eliminated. An individual egg laid was placed on a leaf disc in a petri dish and reared through all stages to adulthood. All the transferred eggs and subsequent stages (larva, nymph, and adult) were carefully checked daily until reaching adulthood and their survival and molting to the next stage were recorded. As soon as adults emerged, the females were differenti-

ated by their round caudal ends and males by their pointed caudal ends. From these data we calculated the hatchability of mite eggs, the immature mite's survivorship and the sex ratio of the appearing mites (Gotoh and Nagata 2001). This assay was performed in 120 replicates for life table and 20 replicates for fertility tables for each cultivar.

To estimate mite fecundity, one newly emerged female from the development experiment and one male collected from the stock culture (for mating) were introduced into a petri dish with a fresh leaf disc on water-saturated cotton. When females began to lay eggs, their eggs were counted and removed daily until all experimental females died. The ovipositing females were transferred to the new leaf discs every 3 d. In this way, we evaluated the fecundity of 20 twospotted mite females per each bean cultivar (Gotoh and Gomi 2003).

**Data Analysis.** The age-specific fecundity ( $m_x$ ) and age-specific survival ( $l_x$ ) of females on six bean cultivars were calculated according to Birch (1948) and the life table parameters estimated based on the suggested formula by Carey (1993). The life table parameters included were net  $R_0$ ,  $r_m$ ,  $\lambda$ ,  $T$ , and  $DT$ .

Data on immature developmental period and adult longevity of twospotted spider mite were analyzed with one-way analyses of variance (analysis of variance [ANOVA]). When the variation among cultivars was significant, means comparisons were done based on Duncan multiple range test ( $P < 0.05$ ). Tests of significance for population level life table parameters among the bean cultivars were conducted using the jackknife procedure (Meyer et al. 1986, Maia et al. 2000). In this procedure, jackknife pseudo values of each life table parameter were calculated for  $n$  females by following equation:

$$A_{(j)} = n \times A_{(all)} - (n - 1) \times A_{(i)}$$

where  $A_{(j)}$  is the jackknife pseudo value,  $n$  is the number of females,  $A_{(all)}$  is the calculated life table parameters for all females and  $A_{(i)}$  is the calculated parameters for  $(n-1)$  females. Various life table parameters including:  $r_m$ ,  $R_0$ ,  $T$ ,  $\lambda$ , and  $DT$  were inserted in this equation instead of  $(A)$ . Subsequently,  $n$  calculated jackknife pseudo values were subjected to one-way ANOVA and if significant differences were detected, a Duncan multiple range test was run ( $P < 0.05$ ). The obtained sex ratios of offspring were compared with expected ratio of 1:1 by a  $\chi^2$  test ( $\chi^2$ ;  $P < 0.05$ ). A  $t$ -test was run for comparison of total immature developmental times of males and females on the same cultivar. All statistical analyses were carried out using the Minitab statistical software (MINITAB 2000) and SPSS statistical packages (SPSS 2004).

## Results

### Generation Time, Egg Hatchability, Sex Ratio and Immature Mortality

The mean longevity of generation time, egg hatchability, immature mortality, and sex ratio of *T. urticae* on six bean cultivars are shown in Table 1. The gen-

**Table 1. Mean longevity of generation time (mean ± SE), egg hatchability, immature mortality, and sex ratio of *T. urticae* on six bean cultivars in laboratory conditions**

Bean cultivars	Generation time (days)		Egg hatchability (%)	Immature mortality (%)	Sex ratio (♂:♀)
	♀	♂			
Chiti Khomein	27.07 ± 1.70b	21.36 ± 1.25b	93.40	12.35	1:4.62 <sup>a</sup>
Chiti Ks21189	29.39 ± 1.91ab	23.99 ± 1.14ab	91.05	15.77	1:4.31 <sup>a</sup>
Red Akhtar	23.37 ± 1.08b	17.94 ± 1.21b	94.20	11.65	1:4.71 <sup>a</sup>
Red Ks31169	31.51 ± 2.05ab	24.81 ± 2.25ab	89.25	14.02	1:4.09 <sup>a</sup>
White Pak	34.82 ± 2.62a	26.56 ± 2.87a	88.25	18.75	1:3.81 <sup>a</sup>
White G11867	32.88 ± 2.32a	25.91 ± 2.56a	90.50	16.55	1:4.00 <sup>a</sup>

Means followed by similar letters in column are not significantly different (one-way ANOVA;  $\alpha = 0.05$ ).  
<sup>a</sup> Significant difference with expected ratio of 1:1 ( $\chi^2$ ;  $P < 0.05$ ).

eration time (male and female combined), differed significantly among cultivar (for males:  $F = 9.52$ ;  $df = 5,96$ ;  $P < 0.05$ ; for females:  $F = 13.36$ ;  $df = 5,428$ ;  $P < 0.05$ ). This period was longest on white Pak and shortest on red Akhtar. The generation time of mite females was significantly longer than the mite males. Egg hatchability ranged from 88.25 to 94.20% and immature mortality (from egg to adult) ranged from 11.65 to 18.75% on different bean cultivars. The greatest mortality during immature stages occurred on white Pak and the least occurred on red Akhtar. Among immature stages, the greatest mortality occurred during the egg stage. The sex ratio (male:female) of offspring on all bean cultivars were significantly female based. The highest (1:4.71) and lowest (1:3.81) sex ratios occurred on red Akhtar and white Pak, respectively.

**Developmental Times of Immature Stages.** The development times of various stages (males and females) of twospotted spider mite on six bean cultivars are given in Table 2. Egg incubation period of male and female mites did not differ among the six cultivars. The development periods of female mites of larvae ( $F = 8.56$ ;  $df = 5,648$ ;  $P < 0.05$ ), protonymphs ( $F = 7.71$ ;  $df = 5,600$ ;  $P < 0.05$ ), and deutonymphs ( $F = 6.89$ ;  $df = 5,566$ ;  $P < 0.05$ ) and of male mites of larvae ( $F = 6.25$ ;

$df = 5,462$ ;  $P < 0.05$ ), protonymphs ( $F = 5.32$ ;  $df = 5,394$ ;  $P < 0.05$ ), and deutonymphs ( $F = 4.51$ ;  $df = 5,342$ ;  $P < 0.05$ ) showed significant differences among various host plants.

Total immature development time for males ( $F = 6.89$ ;  $df = 5,96$ ;  $P < 0.05$ ) and females ( $F = 9.63$ ;  $df = 5,428$ ;  $P < 0.05$ ) was significantly different among the six cultivars and ranged from  $12.00 \pm 0.17$  to  $24.74 \pm 0.24$  d for females and from  $12.19 \pm 0.25$  to  $23.34 \pm 0.31$  d for males on red Akhtar and white Pak, respectively (Table 2). Within cultivar, development times of males and females did not differ ( $t$ -test;  $\alpha = 0.05$ ).

**Female Longevity and Fecundity.** The preoviposition, oviposition, postoviposition periods, and females longevity of twospotted spider mite on six bean cultivars are shown in Table 3. The postoviposition periods ( $F = 6.14$ ;  $df = 5,428$ ;  $P < 0.05$ ) and oviposition periods ( $F = 8.35$ ;  $df = 5,428$ ;  $P < 0.05$ ) of twospotted spider mite were significantly influenced by the bean cultivars. No significant host plant effects were observed on the preoviposition period of twospotted spider mite. Host plant cultivars significantly affected on the total females longevities ( $F = 11.58$ ;  $df = 5,428$ ;  $P < 0.05$ ). The shortest and longest females longevities were observed on white Pak and red Akhtar.

**Table 2. Mean longevity of development times (in days) of immature stages of *T. urticae* on six bean cultivars in laboratory conditions (mean ± SE)**

Stages	Bean cultivars						
	Chiti Khomein	Chiti Ks21189	Red Akhtar	Red Ks31169	White Pak	White G11867	
E	♀	2.00 ± 0.04a	2.15 ± 0.04a	2.00 ± 0.03a	2.00 ± 0.03a	2.00 ± 0.03a	2.23 ± 0.04a
	♂	2.01 ± 0.09b	2.63 ± 0.08a	2.00 ± 0.09b	2.00 ± 0.07b	2.41 ± 0.12a	2.17 ± 0.09b
L	♀	5.21 ± 0.06c	5.63 ± 0.02c	3.39 ± 0.06d	6.21 ± 0.02b	7.96 ± 0.11a	7.58 ± 0.04a
	♂	4.45 ± 0.04bc	5.56 ± 0.05b	3.28 ± 0.03c	6.32 ± 0.08ab	7.21 ± 0.09a	6.96 ± 0.05ab
P	♀	4.35 ± 0.02b	5.45 ± 0.08ab	3.25 ± 0.05c	5.86 ± 0.06ab	6.86 ± 0.06a	5.95 ± 0.03ab
	♂	4.45 ± 0.06b	5.26 ± 0.05ab	3.32 ± 0.09c	5.75 ± 0.02ab	6.62 ± 0.08a	5.92 ± 0.07ab
D	♀	4.40 ± 0.08bc	5.21 ± 0.09b	3.36 ± 0.03c	6.58 ± 0.05ab	7.92 ± 0.04a	6.98 ± 0.06ab
	♂	4.98 ± 0.05bc	5.43 ± 0.06b	3.59 ± 0.04c	6.42 ± 0.03ab	7.10 ± 0.02a	6.89 ± 0.10ab
T	♀	15.96 ± 0.20e	18.44 ± 0.23d	12.00 ± 0.17f	20.65 ± 0.16c	24.74 ± 0.24a	22.74 ± 0.17b
	♂	15.89 ± 0.24d	18.88 ± 0.24c	12.19 ± 0.25e	20.49 ± 0.20b	23.34 ± 0.31a	21.94 ± 0.31b

E, egg; L, larva and quiescent stage; P, protonymph and quiescent stage; D, deutonymph and quiescent stage; T, total development time. Means followed by similar letters in rows are not significantly different (one-way ANOVA;  $\alpha = 0.05$ ).

**Table 3. Preoviposition, oviposition, and postoviposition periods and reproduction rate of *T. urticae* on six bean cultivars in laboratory conditions (mean  $\pm$  SE)**

	Bean cultivars					
	Chiti Khomein	Chiti Ks21189	Red Akhtar	Red Ks31169	White Pak	White G11867
Stages						
Preoviposition	1.28 $\pm$ 0.04b	1.37 $\pm$ 0.07ab	1.00 $\pm$ 0.04b	1.50 $\pm$ 0.08ab	2.10 $\pm$ 0.23a	1.93 $\pm$ 0.16a
Oviposition	8.63 $\pm$ 0.95a	8.58 $\pm$ 1.02a	8.95 $\pm$ 0.80a	8.36 $\pm$ 1.10a	6.98 $\pm$ 1.22b	7.25 $\pm$ 1.19ab
Postoviposition	1.20 $\pm$ 0.51a	1.00 $\pm$ 0.59a	1.40 $\pm$ 0.40a	1.00 $\pm$ 0.71a	1.00 $\pm$ 0.93a	1.00 $\pm$ 0.80a
Total	11.11 $\pm$ 1.50a	10.95 $\pm$ 1.68ab	11.35 $\pm$ 1.24a	10.86 $\pm$ 1.89ab	10.08 $\pm$ 2.38b	10.18 $\pm$ 2.15b
Reproduction rate						
Daily fecundity	13.33 $\pm$ 1.47b	12.09 $\pm$ 1.69bc	16.16 $\pm$ 1.25a	10.98 $\pm$ 1.89c	12.63 $\pm$ 2.12bc	12.39 $\pm$ 1.98bc
Total fecundity	116.54 $\pm$ 6.98b	99.55 $\pm$ 8.23bc	142.05 $\pm$ 6.58a	90.52 $\pm$ 8.54c	82.45 $\pm$ 8.89c	89.05 $\pm$ 8.21c

Means followed by similar letters in each rows are not significantly different (one-way ANOVA;  $\alpha = 0.05$ ).

Mean daily per capita egg production ( $F = 8.21$ ;  $df = 5,54$ ;  $P < 0.05$ ) and total fecundity ( $F = 14.56$ ;  $df = 5,54$ ;  $P < 0.05$ ) of twospotted spider mite (Table 3) differed significantly among cultivars. Daily egg production was highest on red Akhtar, which was significantly greater than on the other cultivars. Total fecundity of twospotted spider mite was significantly different among the tested bean cultivars and was highest on red Akhtar.

**Life Table Parameters.** Life table parameters of the twospotted spider mite on the six bean cultivars are presented in Table 4. There were significant differences among cultivars for all parameters measured ( $R_0$ ,  $r_m$ ,  $\lambda$ ,  $T$ , and  $DT$ ;  $P < 0.05$ ). The  $R_0$  was the highest on red Akhtar and lowest on white Pak. The  $r_m$  and the  $\lambda$  showed a pattern similar to  $R_0$  in which it was highest on red Akhtar and lowest on white Pak cultivars. The  $T$ , is required time for population of twospotted spider mite to multiply as  $R_0$  and varied from  $15.24 \pm 1.12$  to  $25.55 \pm 1.09$  d on red Akhtar and white Pak cultivars, respectively. The lowest and greatest values of  $DT$  were estimated to be  $2.54 \pm 1.14$  and  $5.33 \pm 1.25$  d on red Akhtar and white Pak cultivars, respectively.

The age-specific survival ( $l_x$ ) and age-specific fecundity ( $m_x$ ) curves indicate that twospotted spider mite completed its development on all bean cultivars. The highest and lowest survival rates of immature stages (from egg to adult) were recorded on red Akhtar and white Pak, respectively (Table 1).

### Discussion

In the current study, biological characteristics of twospotted spider mite were investigated on six bean

cultivars. These parameters indicate insect population growth rates in the current and next generations (Frei et al. 2003) and understanding them is essential to develop an IPM strategy.

In this research, the results showed that the development times of twospotted spider mite differed among bean cultivars. In other words, the population growth parameters of *T. urticae* may vary in response to changes in bean cultivars. Total developments of both males and females were significantly different among six bean cultivars. Red Akhtar with  $12.00 \pm 0.17$  and  $12.19 \pm 0.25$  d and white Pak with  $24.74 \pm 0.24$  and  $23.34 \pm 0.31$  d for females and males were the shortest and longest, respectively (Table 2). These results conform Mondal and Ara (2006) on fresh bean (*Lablab purpureus* L.) and Deciyanto et al. (1989) on six cultivars of *Mentha piperita* L. and *M. arvensis* L. Puttaswamy (1980) on cucurbit, Adango et al. (2006) on *Amaranthus cruentus* L. and *Solanum macrocarpon* L., Moros and Aponte (1994) on *P. vulgaris* and da Silva (2002) on cotton, recorded mean duration of developmental stages of the same spider mite species were shorter than our findings on bean cultivars. These variations could be ascribed to differences in host plant quality, environmental factors, either reflected in differences in nutrients required by the mite or differences in the levels of secondary metabolites (van de Vrie et al. 1972, Leszczynski et al. 1988, Fu et al. 2002, Greco et al. 2006). Previous studies on twospotted spider mite attributed population growth variation to be related to plant nutrition, leaf age, leaf surface structure, and secondary compounds (Wermelinger et al. 1991, Krips et al. 1998, Agrawal 2000, Balkema-Boomstra et al. 2003, Pietrosiuk et al. 2003, Skorupska

**Table 4. Life table parameters of *T. urticae* reared on six bean cultivars in laboratory conditions (mean  $\pm$  SE)**

Parameters	Bean cultivars					
	Chiti Khomein	Chiti Ks21189	Red Akhtar	Red Ks31169	White Pak	White G11867
$r_m$ ( $\varphi/\varphi/d$ )	0.203 $\pm$ 0.063b	0.187 $\pm$ 0.055b	0.269 $\pm$ 0.031a	0.152 $\pm$ 0.024c	0.129 $\pm$ 0.048d	0.137 $\pm$ 0.069cd
$R_0$ ( $\varphi/\varphi/generation$ )	60.39 $\pm$ 1.48a	51.84 $\pm$ 1.55b	62.38 $\pm$ 1.65a	38.51 $\pm$ 1.36c	26.11 $\pm$ 1.40d	27.37 $\pm$ 1.39d
$T$ (day)	20.19 $\pm$ 1.18c	21.09 $\pm$ 1.10c	15.24 $\pm$ 1.12d	24.04 $\pm$ 1.21b	25.55 $\pm$ 1.09a	23.68 $\pm$ 1.19b
$\lambda$ ( $\varphi/\varphi/d$ )	1.22 $\pm$ 1.01b	1.20 $\pm$ 1.08b	1.30 $\pm$ 1.02a	1.16 $\pm$ 1.01c	1.13 $\pm$ 1.10d	1.14 $\pm$ 1.12d
$DT$ (day)	3.40 $\pm$ 1.22e	3.70 $\pm$ 1.20d	2.54 $\pm$ 1.14f	4.54 $\pm$ 1.18c	5.33 $\pm$ 1.25a	5.02 $\pm$ 1.23b

Means followed by similar letters in rows are not significantly different (one-way ANOVA;  $\alpha = 0.05$ ).

2004). Spider mite populations grew at a relatively fast and slow rate on small and large plants, respectively (Rotem and Agrawal 2003). Changes in plant quality after herbivory contribute to spider mite reproduction and survival and may explain the differential growth of spider mite populations on small and large plants (Karban 1987). Indeed, differential plant induction based on size and phenology has been previously reported (Stout et al. 1996).

Therefore, other external factors (temperature and relative humidity) have effect upon the population growth parameters of *T. urticae*. This research was studied at constant laboratory conditions ( $27 \pm 2^\circ\text{C}$ ,  $70 \pm 5\%$  RH). Shih (1999) stated the optimum temperature for development of spider mite was between  $23\text{--}30^\circ\text{C}$ . He suggested that the mean longevity of generation time of *T. urticae* declined with increasing temperature. This period 6.5 d at  $30^\circ\text{C}$  (Sabelis 1981), 17.7, 14.3, and 11.6 d at 22.7, 26.6, and  $30.5^\circ\text{C}$  (Northcraft and Watson 1987) and 7.8 and 6.3 d at 31 and  $36^\circ\text{C}$ , respectively (Bonato 1999).

Our findings indicated that the development times of immature stages of twospotted spider mite females were similar to males on each bean cultivar in laboratory conditions. This result is close to the results of Laing (1969), who found similar development times for males and females (16.1 and 16.9 d, respectively) but the results of other researchers (van de Vrie et al. 1972, Rajakumar et al. 2005) are different from what was reported here (Table 2).

van de Vrie et al. (1972) emphasized the occurrence of the differences between males and females as to development rate. Shih et al. (1976) reported lower values for longevity of females (19.1 d) and males (14.6 d), but according to van de Vrie et al. (1972) specimens of different stages can be vary considerably in relation to their exposure to environmental conditions. The increase in the longevity of females may be an important adaptation for the pest to maintain its generation when food quality is low, because only a limited number of females are able to remain (Bengston 1970, Crooker 1985, Uckan and Ergin 2002, Kasap 2004). According to this study, the number of dead twospotted spider mite immature at the end of experiment was very low on the bean cultivars (Table 2). Low mortality of immature stages suggests that the bean cultivars were not harmful to this mite. Therefore, these results conform Shih and Wang (1996), except the development times of deutonymphs. They also demonstrated that these variations could be ascribed to differences in host plant quality. The host plant affected on fecundity and longevity of development times of mite immature stages.

Egg incubation period in this study calculated from  $2.00 \pm 0.03$  to  $2.23 \pm 0.04$  d and no significant variations were observed among six bean cultivars (Table 2). Moros and Aponte (1994) and da Silva (2002) found that the egg incubation period is the longest of all other life stages of *T. ludeni*. Egg hatchability, development time, and survival to adult stage were similar among bean cultivars. Razmjou et al. (2009b) reported total immature stages of *T. urticae* on three legumes

including soybean, cowpea, and bean (9.23, 9.38, and 9.12 d, respectively) that were shorter than our results. Chahine and Michelak (1994) pointed out that no difference was found in longevity when eggplant, tomato, and bean were used as hosts, but fecundity was indeed affected by the host plants. These results indicates that the developmental cycle of *T. urticae* is influenced by several factors.

The  $R_0$  and the  $r_m$  are important indicators of tetranychid population dynamics (Sabelis 1985, Krips et al. 1998). Comparisons of  $R_0$  and  $r_m$  often provide considerable insight beyond that available from the independent analysis of individual life-history parameters (Zhang et al. 2007). In the current study, bean cultivars greatly affected twospotted spider mite fecundity and life-table parameters (Table 4). The  $r_m$  values ranged from  $0.269 \pm 0.031$  to  $0.129 \pm 0.048$  females/female/d. Hence, the population development of twospotted spider mite was the shortest on red Akhtar. This was mainly because of short development time, an early peak in reproduction, high daily egg production, and high total fecundity. Our findings revealed that White bean cultivars (Pak and G11867) were less suitable cultivars for twospotted spider mite. These values are close to those estimated for the spider mites reared on other host plants (Sabelis 1985, Gotoh and Gomi 2003, Kasap 2003, Kafil et al. 2007). Razmjou et al. (2009c) reported Sayyad cultivar was the most favorable host for twospotted spider mites with  $r_m = 0.295$  and Talash cultivar with  $r_m = 0.214$  was unfavorable host. Sabelis (1985, 1991) has reported  $r_m$  values of *T. urticae* from 0.219 to 0.336 and Ahmadi et al. (2007) has estimated  $r_m$  values from 0.038 to 0.142 females/female/d on common bean.

The  $R_0$  found on bean cultivars are similar to those reported by Silva et al. (1985) for *T. urticae* on cotton. Ahmadi et al. (2007) has reported  $R_0$  values of *T. urticae* from 2.043 to 8.822 (females/female/generation) that were shorter than those reported in this study. The same situation may have influenced the  $T$ , where Silva et al. (1985) found values between 22.2 and 24.9 d on cotton and beans, respectively, which was similar to values of this study. The higher values of  $r_m$  and  $R_0$  indicate the susceptibility of a bean cultivar to twospotted spider mite, while the lower ones indicate that the bean cultivar is resistant to twospotted spider mite. Therefore, among examined cultivars, red Akhtar and white Pak are the most susceptible and resistant cultivars for twospotted spider mite, respectively.

Daily fecundity of twospotted spider mite, was estimated from  $10.98 \pm 1.89$  to  $16.16 \pm 1.25$  eggs/female/d and total fecundity was between  $142.05 \pm 6.58$  and  $82.45 \pm 8.89$  eggs/female. These parameters on cucumber (*Cucumis sativus* L.) has been reported as 5.98 and 104.85, respectively (Ullah et al. 2006). The total number of eggs laid per female in her lifetime was averaged as  $108.3 \pm 3.23$  in the laboratory condition on fresh bean (*Lablab purpureus* L.) (Mondal and Ara 2006). The mean number of eggs laid and the lifetime of *T. urticae* was 34.50 eggs/female and 14.10 d, respectively, on bean that lower than results in this study

(Razmjou et al. 2009b). The life table parameters of twospotted spider mite on 14 soybean genotypes were evaluated and the highest  $r_m$  was recorded on L17 (0.392 females/female/d) and the lowest values of this parameter was obtained on Tms (0.233 females/female/d). Therefore,  $R_0$  and  $\lambda$  of the twospotted spider mite had the highest value on L17 as 45.521 females/female/generation and 1.475 females/female/d, respectively. The lowest values of these parameters were recorded on Tms as 12.149 and 1.258, respectively.  $DT$  varied significantly on different genotypes and the shortest and longest values of this period were obtained on L17 and 032 genotypes, respectively (Sedaratian et al. 2009, 2010).

According to Gallo et al. (2002), the twospotted spider mite feeds on a large number of plant species such as cotton, strawberry, rose, tomato, bean, soybean, peach, and so forth, evidence of a potential pest for Brazil. On suitable host plants, spider mites had  $r_m$  values between 0.220 and 0.340 (Sabelis 1985). The reported  $r_m$  values of *T. cinnabarinus* on bean ranged between 0.197 and 0.440, while the same values of *T. urticae* were 0.282 and 0.143 on cucumber (susceptible line), strawberry, bean, and cucumber (resistant line), respectively, at 25°C (Laing 1969, Hazan et al. 1973, Gerson and Aronowitz 1980, Duzgune and Cobano 1983, Sabelis 1985, Pietrosiuk et al. 2003).

These results complemented previous studies, demonstrating variation in mite performance on different cultivars of the same crop. Examples include *T. truncatus* Ehara on corn (Baoping et al. 2005), *Amphitetranychus viennensis* Zacher and *T. urticae* on apple (Kasap 2003, Skorupska 2004), *T. urticae* on strawberry (Wold and Hutchison 2003), and on cucumber (Park and Lee 2007). The use of crop cultivars that support only low pest population growth or even resistant varieties is an important part of IPM (Razmjou et al. 2009c). An important goal of future research will be to compare the varieties susceptibility to twospotted spider mite with other economically relevant traits.

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