LIFE HISTORY TRAITS OF *TETRANYCHUS URTICAE* KOCH ON THREE LEGUMES (ACARI: TETRANYCHIDAE)

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ABSTRACT: The two-spotted spider mite, *Tetranychus urticae* Koch, is very polyphagous and considered a serious pest world-wide. The divers host plant species may have been the different effects of this pest; we therefore compared population growth parameters of *T. urticae* reared on three commonly grown and important legumes in Iran (soybean, cowpea and bean). The life table parameters were estimated at 25 ± 1°C, 60 ± 10% RH, and a photoperiod of 18:6 h (L: D). Egg hatchability, development time and survival to adult stage were similar among cultivars, but we detected significant variation in fecundity and longevity, resulting in large differences for population growth parameters such as the intrinsic rate of natural increase (r_m), net reproductive rate (R_o), finite rate of increase (λ) and doubling time (DT). Soybean was the most favorable host for two-spotted spider mites with r_m = 0.296 (offsprings/female/day), followed by cowpea (0.242) and bean (0.230). The slowest population growth was observed on the bean species with r_m = 0.214. These findings indicate that the choice of host plant species will affect how fast spider mite populations reach damaging levels in a culture.

KEY WORDS: host plant, legumes, life table, *Tetranychus urticae*

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari, Tetranychidae) is one of the most serious agricultural pests in the world. This mite is polyphagous and attacks the broad range of crops, including soybean, cowpea, and common bean and etc. (van de Vrie et al., 1972; Khanjani, 2005). These latter three plants are economic important crops, commercially produced in some regions of Iran. Based on reports by the Iranian Ministry of Agriculture in 2005, overall, these crops are grown on more than 180000 ha annually in Iran. Therefore, outbreaks of several pests especially *T. urticae* limits yield of these high cash leguminous plants. The importance of this mite pest is not only due to direct damage to plants including defoliation, leaf burning, and even in excessive outbreaks plant death but also indirect damage to plants which decreases in photosynthesis and transpiration (Brandenburg and Kennedy, 1987).

Host plants of spider mites differ in the degree of food quality, which either depend on the level of primary plant metabolites, or on the quantity and nature of secondary metabolites (Rosenthal and Berenbaum, 1991). Many secondary metabolites found in plants have a responsibility in defense against herbivores, pests and pathogens. These compounds can perform as toxins, deterrents, digestibility reducers or act as precursors to physical defense systems (Bennett and Wallsgrove, 1994; Balkema-Boomstra, 2003).

The rapid developmental rate and high reproductive potential of *T. urticae* allows 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 in response to changes in temperature, host plant species, host plant nutrition, cultivar kind, phenological stage, exposure to pesticides, relative humidity, etc. (Sabelis, 1981; Brandenburg and Kennedy, 1987; Wermelinger et al., 1991; Wilson, 1994; Dicke, 2000; James, 2002; Marcic, 2003; Skorupska, 2004).

Biological knowledge, in particular life table attributes is a significant step to an improved reorganization of the population dynamics of pests. This information may be used as an important means in planning pest management program. On the other hand, host plants have main effects on development, mortality and fecundity rates in spider mite population dynamics; therefore, in order to expand a successful integrated pest management (IPM) program for this spider mite, it is vital to comprehend its life-history parameters on diverse host plans. However, despite its economic importance and word-wide distribution, relatively little is known about its population growth parameters especially on some host plants and the relevance of these results in different conditions of Iran is unknown. Hence, the goal of this study was to evaluate the population growth characteristics of two-spotted spider mite and the suitability of three economically important legumes: common bean, *Phaseolus vulgaris* L., cowpea, *vigna unguiculata*, and soybean, *Glycine max* Merrill, as host plants of *T. urticae*.

MATERIALS AND METHODS

This study was conducted in a laboratory of the plant protection department at the faculty of agriculture, Mohaghegh Ardabili University, Iran in 2007. All experiments were carried out at 25 ± 1 °C, 60 ± 10 humidity and a photoperiod of 16:8 (L: D) in a growth chamber.

Mite colony

Samples of two-spotted spider mites were collected from soybean fields of the Moghan region, Iran in June 2007. These mites were then cultured on potted related plants in a growth chamber for at least three months before conducting the experiments.

Plant material

The development and fecundity of *T. urticae* was estimated on three leguminous host plant including common bean, *Phaseolus vulgaris* L., cowpea, *Vigna unguiculata*, and soybean. Seeds of these bean plants were supplied by the seeds institute of Karaj, and agricultural and resources research center of Moghan, Iran. Plants were grown from seeds in plastic pots of 12 cm in diameter filled with suitable field soil and maintained in a greenhouse. Two or four weeks after planting, clean leaves were collected and used to cut the leaf discs used in the experiments.

Experiment 1. To evaluate the hatchability of eggs, the sex ratio of the offspring and survivorship of immature mites, one female and one adult male from the stock culture were transferred to a fresh leaf disc (30 mm in diameter) placed on a water-saturated cotton in a Petri dish (90 mm in diameter). The females were allowed to deposit eggs for five days after the preoviposition period. All eggs laid by each female were reared through all stages to adulthood. 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). Non-mated females, i.e. producing only males, were not taken into account.

Experiment 2. To assess development and life table parameters of *T. urticae* on each host plant, one female and one male (for mating) were randomly selected from the stock culture and transferred to a fresh leaf disc. Female mites were allowed to lay eggs for 24 hours, after which the mites and all but two eggs were removed from the Petri dish. Development times and survivorship of these eggs and other immature stages (larva and nymphs) were monitored and recorded daily until reaching adulthood. These assays were replicated twenty times for each host plant.

To evaluate mite fecundity, one newly emerged female from the development experiment and one male collected from the stock culture (for mating) were introduced to a 90 mm Petri dish with a fresh leaf disc on water-saturated cotton. Eggs were counted and removed daily until all experimental females died. In this way, we evaluated the fecundity of 20 two-spotted mite females per host plant (see Table 2 and 3) (Gotoh and Gomi, 2003).

Data analysis. Developmental time, the proportion of immature mites surviving, longevity and fecundity of *T. urticae* were analysed with analyses of variance (ANOVA) using the MINITAB-13.1 statistical software (Minitab lnc. 1994 Philadelphia, PA). When the overall variation among cultivars was significant, post-hoc comparisons among means were carried out using Tukey tests at $\alpha < 0.05$.

Life table parameters including intrinsic rate of natural increase (r_m), net reproductive rate (R_o), doubling time (DT), finite rate of increase (λ) and the generation time (T) as well as their standard errors were estimated by the jackknife method (Southwood, 1978; Meyer et al., 1986; Carey, 1993) using the SAS System Software V6.12 (SAS Institute, 1989). Significance of differences between mean values of life table parameters was determined using Student's t test (Maia et al 2000). The r_m for two-spotted spider mites on different cultivars was estimated using the following equation (Birch, 1948):

$$\sum e^{-rx} l_x m_x = 1 \quad [1]$$

Where x is the age in days, r is the intrinsic rate of natural increase, l_x is the age-specific survival, and m_x is the age-specific number of female offspring. After r was computed for the original data (r_{all}), the jackknife technique was applied to appraise the differences in r_m values by estimating the variances (Meyer et al., 1986). The jackknife pseudo-value r_j was calculated for the n samples by using the following formula:

$$r_j = n \times r_{all} - (n - 1) \times r_i \quad [2]$$

The jackknife pseudo-values for each treatment were subjected to an analysis of variance (ANOVA). Also, Jackknife techniques were used to calculate the other parameters of life tables (Maia et al., 2000).

RESULTS

Hatchability, Sex ratio and survivorship. Percentage of egg hatchability ranged from 89 to 92.5 and sex ratio (proportion of females) from 77.7 to 86 percent on different host plants. The survivorship of immature stages (from egg to adult) was from 72.5 to 87.5 percent as well (see Table 1).

Developmental time of immature stages. No significant variation among three host plant was observed for the development period of two-spotted spider mite eggs (F =2.77; df= 2, 68; P = 0.070), of mite nymphs (F = 0.26; df = 2, 68; P = 0.769). While the development period of mite larvae showed significantly differences among host species (F = 8.21; df = 2, 68; P = 0.001). Also, when the total development time, i.e. the sum of the three periods above, is compared among host plants, the variation is not significant (F = 1.93; df = 2, 68; P = 0.153). The means of these periods are listed in Table 2.

Female longevity and lifespan. The adult longevity of two-spotted spider mite as well as the total lifespan (from egg to death) varied significantly among three host plants (adult longevity: F = 10.08; df = 2, 53; P = 0.000; total lifespan: F = 10.68; df = 2, 53; P = 0.000). The mites survived and oviposited clearly longer on the soybean plants than on all other host plants (Table 2).

Fecundity. The number of eggs laid by each female mite (F = 7.77; df = 2, 53; P = 0.001) exhibited significant differences among three host plants. While no significant variation among host plants was observed for the number of eggs laid by each female per day (F = 2.75; df = 2, 53; P = 0.073). Due to much longer adult survival, mites laid about more than twice as many eggs on soybean compared to the bean plants (Table 1).

Life table parameters. The analysis of the net reproductive rate (R_o) of the two spotted spider mite indicated significant differences among three host plants (P < 0.05). The cohorts reared on Soybean had the largest R_o value, followed by cowpea, those on bean had the smallest R_o value (Table 3).

The intrinsic rate of natural increase (r_m) of *T. urticae* was also found to be significantly different among the three host plant species (P < 0.05), ranging from 0.296 on Soybean to 0.230 on bean (Table 3). The finite rate of increase (λ) and the doubling time (DT) varied in a similar fashion and exhibited the same hierarchy of performance: best on soybean, followed by cowpea, worst on bean. Only the generation time (T) followed a different pattern, being shortest on bean and highest on cowpea (Table 3).

DISCUSSION

Plant species vary seriously on the basis of their suitability as hosts for specific insects and mites when measured in terms of insect survival, reproductive rates and acceptance by the pest population (van den Boom et al., 2003; Musa and Ren, 2005; Greco et al., 2006). Host plant species often differ in chemical profiles, thereby affecting host (i.e., herbivore) quality (Ode, 2006). So, host plant quality is a key determinant of the fecundity of herbivorous insects (Awmack and Leather, 2002). Our results showed that there are seriously differences in the spider mite performance among on three leguminous plants tested in this study. Therefore, obtained results from these experiments showed a better performance of *T. urticae* on soybean leaf discs than on any other two plants. This was shown not only in the fecundity (mean number of eggs laid on leaf discs), adult longevity but in the lifetime of the two-spotted spider mite, as well (Table 2). So, the mean number of eggs laid by *T. urticae* on soybean plant (83.16, eggs/female) was more than two times higher than those on bean (34.50 eggs/female). In addition, the means for the lifetime of *T. urticae* were 21.63 days on soybean whereas this value was 21.53 and 14.10 days on cowpea and bean plants, respectively (Table 2). Therefore, the better r_m of mite female found on soybean and by followed cowpea compared with mites on bean was mainly the result of the greater overall fecundity and longer adult oviposition period and lifetime of this pest. The poor performance of mites on bean was the result of poor fecundity, lower survivorship immature stages and shorter life time and adult oviposition period (Tables 1, 2 and 3). The r_m value of *T. urticae* estimated in the current study ranged from 0.230 to 0.296 individuals per female per day (Table 2). 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).

Musa and Ren (2005) demonstrated that life history traits of *Bemisia tabaci* differ greatly between three leguminous species including soybean, garden bean (*P. vulgaris*) and cowpea. Based on their results, the r_m value of *B. tabaci* was 0.1097 (d^{-1}) on garden bean and 0.1857 (d^{-1}) on soybean. In particular, some studies have documented that amount of performance and acceptance of the spider mite differs between plant species. For instance, van den Boom et al (2003) found that the plant species vary in their degree of acceptance by the *T. urticae* population. Their results indicated that the plants including soybean, hop, golden chain and tobacco are highly acceptable to the spider mite, because almost 100% of the spider mites stayed on the plant while eggplant, cowpea and thorn apple had a lower percentage of spider mite acceptance where this value was 65% for cowpea. Besides the findings of Greco et al (2006) showed a high preference and a better performance of *T. urticae* on strawberry leaves than on onion, leek and parsley leaves. This was shown not only in the fecundity but in the maximum number of offspring settled, as well. Several potential mechanisms could be responsible for this phenomenon including plant nutritional quality of the host plant and morphological or allelochemical features (Sabelis, 1985; Krips et al., 1998; Dike et al., 1999; Agrawal, 2000; Pietrosiuk et al., 2003; Balkema-Boomstra et al., 2003). Our findings show that soybean plant is a more suitable host plant than cowpea and bean plants for two-spotted spider mite. Therefore, this pest may be able to create quickly a large and damaging population on soybean plants, and this feature must be considered by growers in order to implement IPM programs for this spider mite.

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Table 1. Number of eggs per female, egg hatchability, immature survivorship and sex ratio of *T. urticae* reared on three legumes at 25°C.

	Parameter (mean ± SE)				
Host	Number of Eggs/female[a]	Number of Eggs/ female/day	Egg hatchability (%)	Immature survivorship (%)	**Sex ratio (% female)**
Soybean	83.16 ± 10.71a (19)	6.59 ± 0.43a (19)	92.5 (153)	87.5 (153)	**81.2 (125)**
Cowpea	65.53 ± 10.26ab(17)	5.05 ± 0.38a (17)	90.0 (129)	72.5 (129)	**86.0 (68)**
Bean	**34.50 ± 5.60bc (20)**	**6.17 ± 0.54a (20)**	**89.0 (54)**	**72.5 (54)**	**81.0 (24)**

[a]For this parameter, differences among species host plant were determined by Tukey tests. Within columns, means followed by different letters are significantly different ($P<0.05$). Sample size of all parameters is in the parenthesis.

Table 2. Development period of immature stages and adult female of *T. urticae* reared on three legumes at 25°C.

	Development period in days (Mean ± SE)					
Host	Eggs	Larva	Nymphs	Total (Immature stage)	Oviposition	Female lifespan
Soybean	4.50 ± 0.14a (22)	1.05 ± 0.05a (22)	3.68 ± 0.14a (22)	9.23 ± 0.11a (22)	12.47 ± 1.51a (19)	21.63 ± 1.53a (19)
Cowpea	4.17 ± 0.99a (24)	1.50 ± 0.12b (24)	3.71± 0.14a (24)	9.38 ± 0.10a (24)	12.06 ± 1.82a (17)	21.53 ± 1.78a (17)
Bean	*4.20 ± 0.08a (25)*	*1.12 ± 0.07a (25)*	*3.80± 0.08a (25)*	*9.12 ± 0.07a (25)*	*5.00 ± 0.53b (20)*	*14.10 ± 0.56b (20)*

For each parameter, differences among bean cultivars were determined by Tukey tests. Within columns, means followed by different letters are significantly different ($P<0.05$).
The *n* value in the parentheses shows the number of the tested individuals.

Table 3. Life table parameters of *T. urticae* reared on three legumes at 25°C.

	Parameter (Mean ± SD)				
Host	R_o	r_m	DT (d)	λ (d)	**T (d)**
Soybean	53.84 ± 6.64a	0.296 ± 0.012a	2.34 ± 0.09a	1.345 ± 0.016a	**13.45 ± 0.67a**
Cowpea	29.13 ± 4.66b	0.242 ± 0.013b	2.86 ± 0.15b	1.274 ± 0.016b	**13.96 ± 0.89a**
Bean	**11.25 ± 1.85c**	**0.230 ± 0.013b**	**3.00 ± 0.15b**	**1.259 ± 0.016b**	**10.59 ± 0.31a**

[a] Differences among bean cultivars were determined by t-test pairwise comparison, based on jackknife estimates of variance for each parameter (Maia et al 2000). Within columns, means followed by different letters are significantly different ($P<0.05$).
[b] Each parameter value is mean of 20 replications.