

# Susceptibility of *Tetranychus urticae* Koch (Acari: Tetranychidae) on seven strawberry cultivars

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**ABSTRACT:** The two-spotted spider mite, *Tetranychus urticae* Koch is one of the cosmopolitan pests, which attack many agricultural and greenhouse plants. The suitability of seven strawberry cultivars (Marak, Yalova, Aliso, Gaviota, Sequoia, Camarosa and Chandler) for the development, reproduction and preference of *T. urticae* were investigated. To antixenosis mechanisms of resistance, 400 adult mites were released in the center of seven cultivars. Mites were counted 24 and 48 hours after releasing. Sequoia and Marak could be defined as preferred and Gaviota was the least preferred by the spider mite. Antibiosis test was studied on leaflet of the same cultivars. Life table parameters of *T. urticae* was studied in the laboratory conditions ( $27\pm 1^{\circ}\text{C}$ ,  $60\pm 5\%$  RH and 16L: 8D photoperiod). Data were analyzed based on the age-stage, two-sex life table theory. Proportion of mite surviving to adult ranged from 48% to 84%. Duration of protonymph and deutonymph stages reared on different cultivars showed a significant difference. Total longevity of mites reared on Chandler (10.58 days) were significantly longer than those reared on other cultivars, whereas female longevity was the same on the seven strawberry cultivars. The life time fecundities of *T. urticae* on Marak and Sequoia (26.70, 45.43 eggs/female, respectively) were lower than those on other cultivars. Lowest intrinsic rate of increase found in mites reared on Marak and Sequoia. Higher intrinsic rate ( $0.28 \text{ day}^{-1}$ ) and fecundity found in mite reared on Chandler, it may be due to the higher nutritional quality and low density of trichome. Marak and Sequoia were least suitable cultivars for *T. urticae*.

## INTRODUCTION

The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae), is a major pest of strawberry throughout the world. Strawberry plants are susceptible to attack in the preflowering and flowering period (Huffaker *et al.*, 1969; Dabrowski *et al.*, 1971; Sances *et al.*, 1979; Wyman *et al.*, 1979; Oatman *et al.*, 1985; Hamiten *et al.*, 1988; Shanks & Doss, 1989; Stonneveld *et al.*, 1996; Walsh *et al.*, 2002; Sato *et al.*, 2004). Heavy infestation of strawberry leaves by spider mites reduce plant growth and yield (Klamkowski *et al.*, 2006).

Host-plant resistance can be an useful component of an integrated pest management system that is compatible with other methods and identification of mechanism of host-plant resistance to specific pest is the first step in developing resistant cultivars (Lorenzon *et al.*, 2001). Several studies have indicated significant differences in susceptibility, resistance or tolerance level to *T. urticae* on strawberry (Shanks & Barritt, 1975, 1980, 1984; Luczynski *et al.*, 1990; Gimenez-Ferrer *et al.*, 1993, 1994; Shanks & Moore, 1995; Shanks *et al.*, 1995; Lourencao *et al.*, 2000; Petrova *et al.*, 2000; Labanouska, 2007; Afifi *et al.*, 2010)

Nutritional quality, physiological, ecological and chemical condition of the host plant may influence on life history parameters of two-spotted spider mite (van de Vire *et al.*, 1972; Jeppson *et al.*, 1975; Wermelinger *et al.*, 1991)

In this research, resistance or susceptibility in seven strawberry cultivars to TSSM was studied under laboratory and greenhouse conditions, in addition to, two mechanisms of resistance (antixenosis and antibiosis) of these cultivars were investigated.

## MATERIAL AND METHODS

### **Plant material**

Seven strawberry cultivars (Marak, Yalova, Aliso, Gaviota, Sequoia, Camarosa and Chandler) were obtained from horticulture field plot of University of Tehran in Karaj, Iran. Crowns were stored at 1–4 °C for 3 weeks, then plants were plotted in container. Each cultivar was planted in 15 plots in greenhouse. The pots were watered daily and fertigated once every 2 weeks with a 20:20:20 (N-P-K).

### **Mite colony**

Mites were reared on bean for several generations in controlled condition at 27±1°C, 60±5 % RH and 16L: 8D photoperiod. The spider mites used in each experiment were obtained from a culture maintained at each strawberry cultivar (separately for each cultivar) for 3 generation times.

### **Antixenosis tests**

Greenhouse choice tests were conducted to evaluate the preference of *T. urticae* for different strawberry cultivars. The bean plants were infested by *T. urticae* and each plant was counted 100 mites. For a test, seven strawberry were arranged in a circle around 4 these bean (with a distance of about 20 cm) with an insect proof cage (50×40×60 cm<sup>3</sup>). Individual mite moved and colonized different plants by their own free choice. Then, the number of mites on each entire plant after 24 and 48 hours was counted. This test were carried out with 20 replications. The number of eggs that laid by these migrated female was recorded in this test.

### **Antibiosis tests**

To evaluate possible antibiotic effects, the age- specific life table of *T. urticae* on seven strawberry cultivars were investigated. All experiments were carried out at 27±1°C, 60±5% relative humidity RH and a 16 L: 8D photoperiod in a growth chamber. We used leaflets for each test.

The leaves of different strawberry cultivars were selected and cut in to a leaflets in square shape (15×15 mm) and then placed upside down on agar (3%) in a 6 cm diameter Petri dish with a ventilated lid for each of the strawberry cultivars.

Two to five female of *T. urticae*, obtained from stock culture of strawberry cultivars, were transferred into separately upside down of the fresh leaflet, then these female mites were allowed to lay eggs after 8 hours, only one eggs was remained on each leaflet and the mites and additional eggs were removed. Developmental time and survivorship of the immature stage were recorded daily until reaching adulthood. The female were differentiated by their round caudal end than male with pointed caudal end. After emerging of adult, it was paired with an individual of the opposite sex from the cohort. Because of more female than male emerged, additional young male from the mass rearing colony were used for mating when it was necessary. To reduce the effect of plant age on mite developmental and its fecundity, new leaflets were replaced every 4–5 days.

Then fecundity of female was checked and the eggs removed daily from each leaflet of different strawberry cultivars. This experiment was continued until all experimental female and male died. For each cultivar 100–120 replication were considered.

### **Statistical analysis**

Developmental time of all individuals, including male and female and those dying before adult stage and female daily fecundity were analyzed according to the age-stage, two- sex life table (Chi & Liu, 1985) and the method described by Chi (1988). APOP (pre-oviposition period of adult female) and TPOP (total pre-oviposition period of female counted from birth) were also studied. Based on the age-stage, two-sex life table, the number of individual of each stage can be properly simulated. We calculated  $S_{xj}$  (age-stage, specific survival rate),  $l_x$  (age- specific survival rate),  $m_x$  (age-specific fecundity) for each treatments.

The age-stage specific life expectancy ( $e_{xj}$ ) for individual of age  $x$  and stage  $y$  was calculated as  $e_{xy} = \sum^n$

$$i=x \sum_{j=y}^m S_{ij}$$

In the Chi & Liu model (1985) the population parameters were calculated based on data of the entire cohort i.e. both sexes and the variable developmental rate among individuals. Intrinsic rate of increase was estimated by using the iterative bisection method from the Euler- Lotka formula with age indexed from 0 (Goodman, 1982).

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

The population parameters ( $r$  (intrinsic rate of increase),  $\lambda$  (finite rate of increase),  $R_0$  (net reproduction rate) and  $T$  (the mean generation time)) were calculated as well. All parameters were calculated by using TWOSEX-MSChart software. The means and SEs of the population parameters were estimated using the jackknife method (Sokal & Rohlf, 1995), the data were analyzed by SAS ver. 9.1 software.

The mean generation time was defined as the length of time that a population need to increase to  $R_0$ -fold of its size as the stable age distribution and the stable increase rate are reached i.e.  $e^{rt} = R_0$ .

We project the population growth with on initial population of 100–120 eggs for each treatments. For projection of population, we used TIMING- MsChart software (Chi, 2006) based on the life table results.

## RESULTS

### Antixenosis tests

These tests showed that a significant effect of the strawberry cultivars on the number of *T. urticae* colonizing a plant (per leaf) in first and second multiple choice (after 24 and 48 hours releasing mites) (Fig. 1). The result showed that the number of mite on Sequoia, Marak and Yalova were more than other cultivars in first multiple choice ( $F= 2.99$ ,  $df= 133$ ,  $P=0.009$ ). The mites tended to increase on Sequoia from 24 to 48 hours. The number of mites was the most on Sequoia and the least number of mites was observed on Gaviota 48 hours after mite release and there were a significant difference between the strawberry cultivars ( $F= 5.17$ ,  $df= 133$ ,  $P= 0.0001$ ).

The number of mites on strawberry cultivars reflected preferential choice of TSSM for different strawberry cultivars aafter 24 and 48 hours in the first and second multiple-choice tests, respectively. Number of eggs of TSSM (ovipositional preference) on different strawberry cultivars in first and second multiple-choice tests were plotted in Figure 2, ovipositional preference was not influenced and these strawberry cultivars did not have a significant effect on the number of eggs were laid on different strawberry cultivars in first and second multiple-choice tests ( $F=1.86$ ,  $df=133$ ,  $P=0.09$  and  $F=1.78$ ,  $df=133$ ,  $P=0.1$  for first and second multiple-choice tests, respectively).

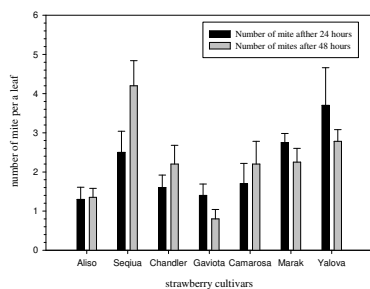


Figure 1. Number of *T. urticae* per leaf of different strawberry cultivars in first and second multiple-choice test for antixenosis test.

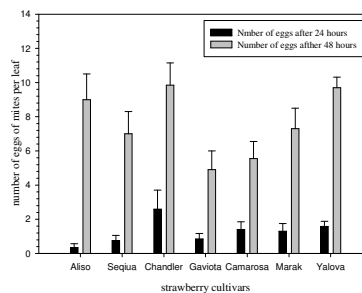


Figure 2. Number eggs of *T. urticae* per leaf of different strawberry cultivars in first and second multiple-choice test for antixenosis test.

### Antibiosis tests

Percentage of egg hatchability on Sequioia, Camarosa, Marak, Chandler, Aliso, Gaviota and Yalova were 58%, 65%, 60%, 72%, 58%, 63% and 60% respectively, the survivorship of immature stage (from egg to adult) on these cultivars were 50%,60%, 48%,84%,59%, 58% and 69%, respectively. The number of emerged male and female showed the sex ratio (proportion of female) were 72%, 77%, 71%, 74%, 83%, 78% and 74% on Sequioia, Camarosa, Marak, Chandler, Aliso, Gaviota and Yalova, respectively.

The means of developmental periods for each developmental stages, longevity for adult male and female, female fecundity of *T. urticae* on seven strawberry cultivars are given in Table 1. The duration of all developmental stages of *T. urticae* except larva and female adult were affected by different strawberry cultivars. Significant difference was observed on egg incubation period on different cultivars. The highest developmental time was observed on Camarosa, Sequioia, Marak for protonymph and on Marak, Aliso, Gaviota, Camarosa for deutonymph. The male of TSSM longevity on Gaviota, Yalova, Aliso, Camarosa and Chandler was higher than other cultivars.

The age of first reproduction by female has an important effect on population growth. The adult pre ovipositional period (APOP) were significantly shorter in TSSM on Aliso, Gaviota and Sequioia. The total pre-ovipositional period (TPOP) did not show any significant difference among seven strawberry cultivars. The fecundity of mites on Marak significantly differ from other cultivars and the highest fecundity observed on

Chandler. The life time longevity of mites on Chandler significantly differ from other cultivars and the longest duration was seen on this cultivar.

Table1. Life history statistics (Means ± SE) of *T. urticae* on leaflets of seven strawberry cultivars

Statistics	Marak	Yalova	Aliso	Gaviota	Sequoia	Camarosa	Chandler	F	df	P
Developmental time										
Egg	3.30±0.0 8 <sup>cb</sup>	3.65±0.0 7 <sup>a</sup>	3.30±0.0 6 <sup>cb</sup>	3.23± 0.07 <sup>c</sup>	3.31± 0.06 <sup>cb</sup>	3.47± 0.07 <sup>ab</sup>	3.52± 0.06 <sup>ab</sup>	4.2 1	471 4	0.00
Larva	1.03±0.0 2	1.03±0.0 2	1.08±0.0 3	1.05± 0.03	1.07± 0.03	1.06± 0.03 0.00	1.00± 0.00	1.1 6	426 9	0.32
Protonymph	1.36± 0.07 <sup>ab</sup>	1.09±0.0 4 <sup>cd</sup>	1.16± 0.05 <sup>cd</sup>	1.24± 0.05 <sup>cb</sup>	1.41± 0.07 <sup>a</sup>	1.25± 0.07 <sup>abc</sup>	1.06± 0.03 <sup>d</sup>	5.8 0	364 1	0.00
Deutonymph	1.28±0.0 8 <sup>ab</sup>	1.07±0.0 4 <sup>b</sup>	1.58±0.2 1 <sup>a</sup>	1.35± 0.17 <sup>ab</sup>	1.19± 0.07 <sup>b</sup>	1.28± 0.08 <sup>ab</sup>	1.14± 0.05 <sup>b</sup>	2.1 5	284	0.04
Adult longevity										
Female	7.0±0.49 8	8.52±0.6 8	8.21±0.7	8.68±0.4 5	7.70±1.0 9	9.37±0.82	9.88±0.8	1.8 7	248	0.08
Male	4.54±0.5 3 <sup>cb</sup>	4.86±0.4 6 <sup>abc</sup>	4.86±0.4 6 <sup>abc</sup>	5.60±0.5 0 <sup>ab</sup>	3.56±0.4 4 <sup>c</sup>	5.12±0.8 <sup>abc</sup>	6.67±0.6 6 <sup>a</sup>	2.6 7	74	0.02
Preoviposition period										
APOP	0.85±0.0 9 <sup>a</sup>	1.03±0.0 7 <sup>a</sup>	0.44±0.1 0 <sup>b</sup>	0.54±0.0 8 <sup>b</sup>	0.73±0.1 1 <sup>bc</sup>	0.96±0.13 <sup>a</sup>	0.86±0.0 8 <sup>a</sup>	4.7 9	213 1	0.00
TPOP	7.74±0.2 2	7.81± 0.3	7.85±0.3 0	7.43±0.3 0	7.74±0.3 1	8.15±0.22	7.52±0.1 4	1.0 0	213	0.43
Lifetime fecundity	26.70±2. 81 <sup>b</sup>	55.35±6. 29 <sup>a</sup>	46.74±5. 52 <sup>a</sup>	56.54±5. 39 <sup>a</sup>	45.43±10 .6 <sup>ab</sup>	55.96±7.31 <sup>a</sup>	64.16±8. 90 <sup>a</sup>	2.6 6	248	0.02
Lifetime longevity	7.40±0.4 2 <sup>b</sup>	8.57±0.5 5 <sup>b</sup>	8.04±0.5 <sup>b</sup>	8.28± 0.51 <sup>b</sup>	7.22± 0.5 <sup>b</sup>	8.81± 0.66 <sup>b</sup>	10.58±0. 63 <sup>a</sup>	4.4 2	764	0.00

The age-stage specific survival rate ( $S_{xj}$ ) (where x is the age j is the stage) gives by the probability that a newly hatched egg will survive to age x and stage j, overlapping occurs between stages. This curve also show the survivorship and stage differentiation rate of TSSM on different cultivars. Relative number alive in each age-stage group of TSSM on strawberry cultivars is shown in Figure 3.

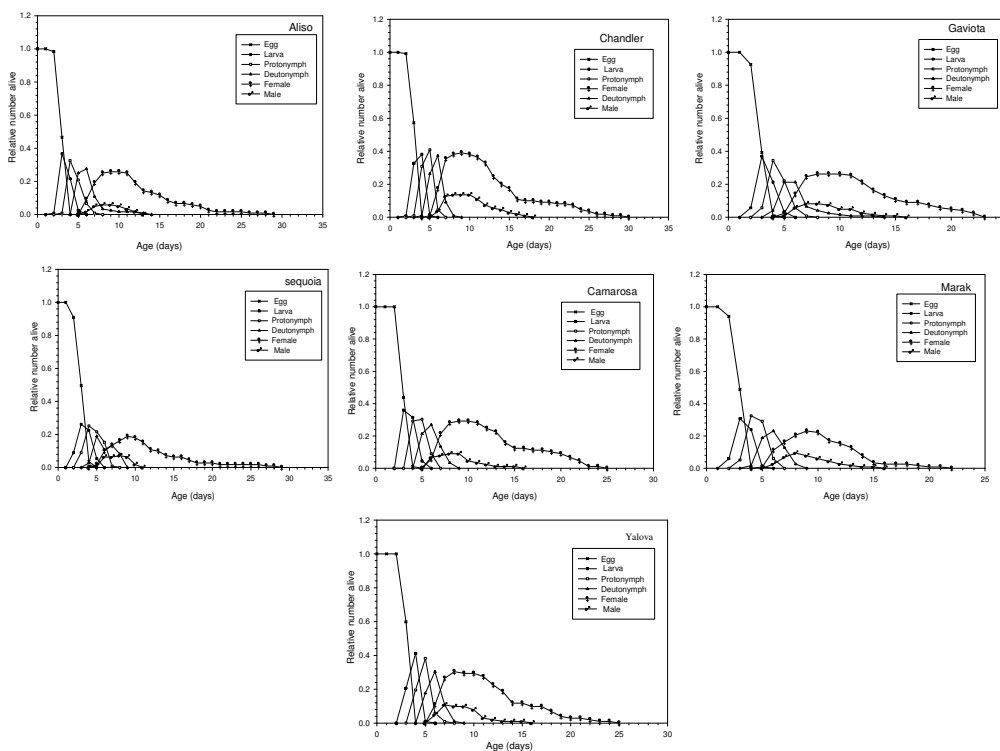


Figure 3. Relative number alive in each age-stage group ( $S_{xj}$ ) of *T. urticae* on leaflets of seven strawberry cultivars

The means and standard error of  $r$ ,  $\lambda$ ,  $R_0$  and  $T$  estimated using the jackknife method are shown in Table 2. Statistical analysis showed that there are significant difference between  $r$ ,  $R_0$ ,  $\lambda$ , however the mean generation time on seven strawberry cultivars did not show any significant difference. The highest  $r$ -value of TSSM was observed on Chandler and the lowest on Marak and Sequoia.

Table2. Mean  $\pm$  SE of intrinsic rate of increase  $r$  ( $\text{day}^{-1}$ ), finite rate of increase ( $\lambda$ )( $\text{day}^{-1}$ ), net reproductive rate ( $R_0$ ) (offspring/individual) and mean generation time ( $T$ ) of *T. urticae* on leaflets on seven strawberry cultivars

parameters	Marak	Yalova	Aliso	Gaviota	Sequoia	Camarosa	Chandler	F	df	P
$r$	0.17 $\pm$ 0.02 <sup>c</sup>	0.24 $\pm$ 0.01 <sup>ab</sup>	0.23 $\pm$ 0.02 <sup>ab</sup>	0.25 $\pm$ 0.02 <sup>ab</sup>	0.19 $\pm$ 0.02 <sup>bd</sup>	0.23 $\pm$ 0.02 <sup>ab</sup>	0.28 $\pm$ 0.01 <sup>a</sup>	4.35	764	0.002
$\lambda$	1.19 $\pm$ 0.02 <sup>c</sup>	1.28 $\pm$ 0.02 <sup>ab</sup>	1.26 $\pm$ 0.02 <sup>ab</sup>	1.28 $\pm$ 0.02 <sup>ab</sup>	1.21 $\pm$ 0.03 <sup>cb</sup>	1.26 $\pm$ 0.02 <sup>ab</sup>	1.33 $\pm$ 0.02 <sup>a</sup>	4.41	764	0.002
$R_0$	6.16 $\pm$ 1.22 <sup>c</sup>	16.82 $\pm$ 3.16 <sup>ab</sup>	13.24 $\pm$ 2.47 <sup>cb</sup>	16.22 $\pm$ 3.19 <sup>ab</sup>	9.41 $\pm$ 2.78 <sup>bd</sup>	16.97 $\pm$ 3.50 <sup>ab</sup>	25.08 $\pm$ 4.57 <sup>a</sup>	3.96	764	0.007
$T$	10.62 $\pm$ 0.27	11.50 $\pm$ 0.36	11.21 $\pm$ 0.41	11.19 $\pm$ 0.34	11.71 $\pm$ 0.87	12.13 $\pm$ 0.46	11.36 $\pm$ 0.26	0.92	764	0.48

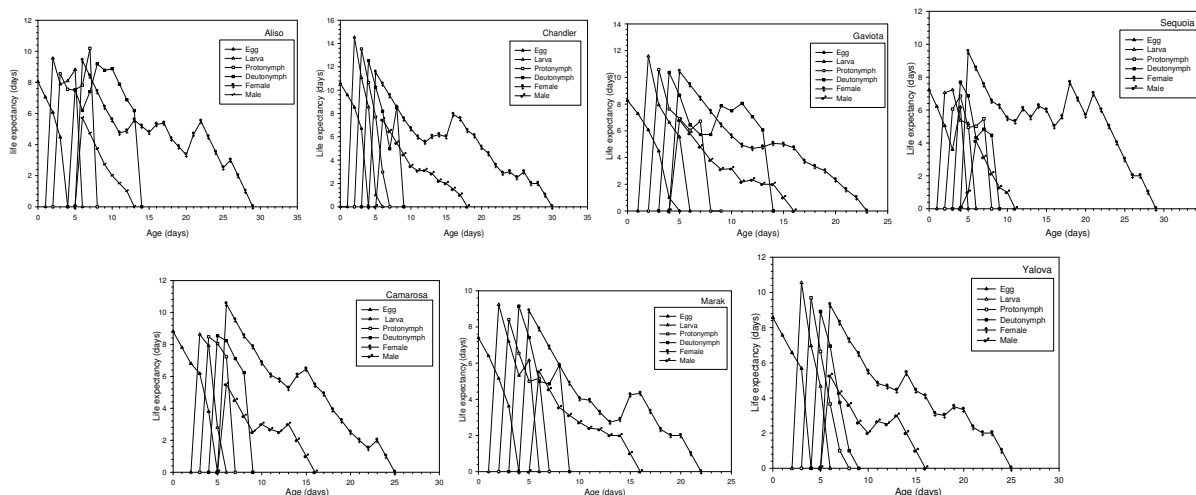


Figure 4. Age-stage life expectancies ( $e_{ij}$ ) of *T. urticae* on leaflets of seven strawberry cultivars

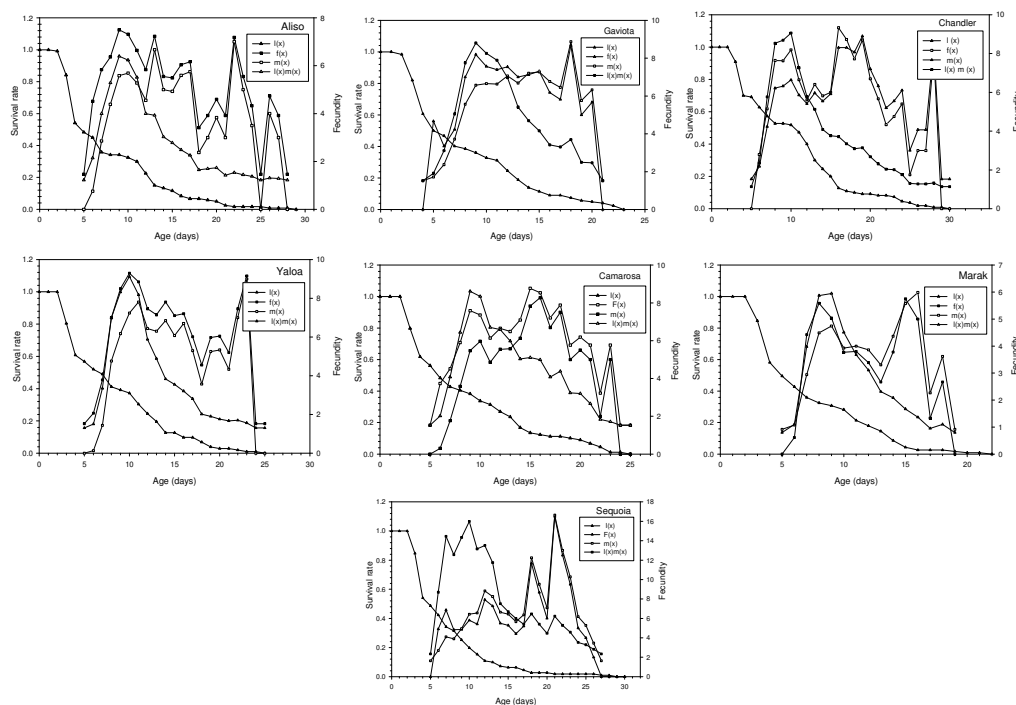


Figure 5. Age- specific survival rate ( $l_x$ ), age- specific fecundity of the total population ( $m_x$ ) age-stage specific fecundity ( $f_{xj}$ ) and age-specific maternity ( $l_x m_x$ ) of *T. urticae* on seven strawberry cultivars

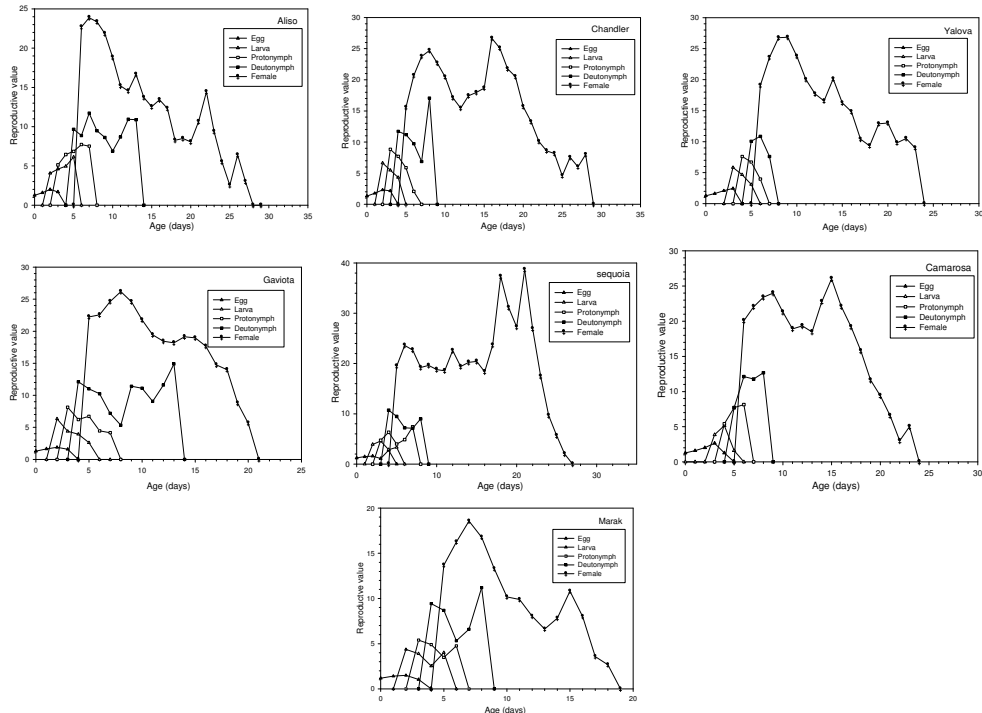


Figure 6. Age-stage specific reproductive values ( $v_{xj}$ ) of *T. urticae* on seven strawberry cultivars

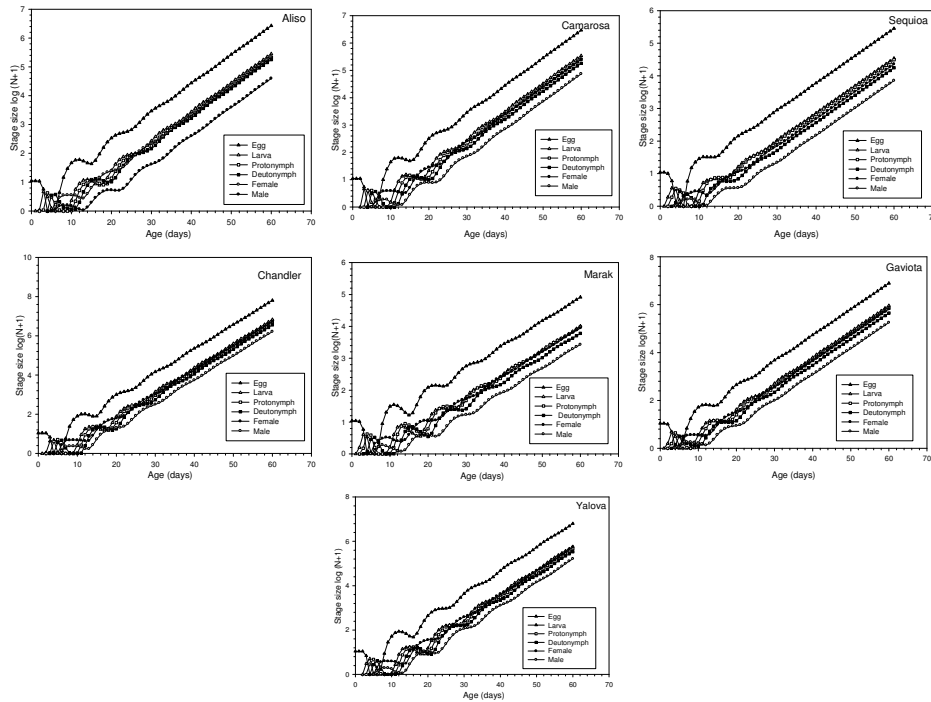


Figure 7. Population projection of *T. urticae* on seven strawberry cultivars

The age-stage specific life expectancy ( $e_{xj}$ ) was calculated according to Chi & Su (2006). The age-stage life expectancies of TSSM on strawberry cultivars are shown in Fig. 4. The life expectancy of a new egg for Aliso, Sequoia, Chandler, Gaviota, Camarosa, Marak and Yalova are 8.0, 7.2, 10.6, 8.3, 8.8, 7.4 and 8.6 days, with life expectancy decreasing with increasing age. The age-specific survival rate ( $l_x$ ), the age-specific fecundity ( $m_x$ ) and age-stage specific fecundity ( $f_{xj}$ ) are shown in Fig. 5. Fecundity curves of TSSM on Gaviota begin one day earlier than others.

The reproductive value ( $v_{xj}$ ) gives the expectation of future offspring of individuals of age  $x$  and stage  $j$ . The major peak in reproductive values of female occurred much earlier on Aliso (Fig. 6). We project the population growth with an initial population of eggs to reveal the growth. The population project of TSSM on strawberry cultivars is plotted in Fig. 7.

The number of trichome of different strawberry cultivars vary between  $120 \pm 8$  to  $192 \pm 12$  and the least number was found on Chandler.

## DISCUSSION

In the present study, resistance mechanisms to *T. urticae* were investigated on strawberry cultivars. Yano *et al.* (1998) have shown that the host plant range of spider mite was determined by the oviposition preference. Oviposition preference of TSSM on seven strawberry cultivars did not show any significant difference in antixenosis tests. The host plant range of *T. urticae* may also be determined by the selection pressure imposed by the low host plant suitability on potential hosts. Among strawberry cultivars studied, Sequioa is the most preferred and Gaviota is the least preferred for TSSM, however Marak and Yalova are preferable host plant in first multiple-choice tests. Wilson (1994) showed two-spotted spider mite strongly preferred to feed and oviposit on younger leaf tissue compared with other leaf tissues, because of the higher nitrogen content. Yano and colleagues suggested that host plant acceptance is influenced by the previous feeding behaviour of the spider mite. In this study, the number of spider mite on different strawberry cultivars may be affected by the previous feeding on these cultivars.

We conducted our study to examine the host plant relationship between the TSSM and seven strawberry cultivars based on a leaflet bioassay screen, life table of *T. urticae* mite maintained on leaflets have been studied using traditional female age-specific life table methods by a number of researchers (Shih *et al.*, 1976; Wermelinger *et al.*, 1991; Wilson, 1994; Krips *et al.*, 1998, 1999; Bounfour & Tanigoshi, 2001; Kasap, 2004; Martinez-villar *et al.*, 2005; Sedaratian *et al.*, 2009; Razmjou *et al.*, 2009).

The population growth parameters of *T. urticae* varied in response to changing in strawberry cultivars. Development time of TSSM was varied on different cultivars, these variation in the TSSM development time could be the result of differences in plant nutritional quality, morphological condition or secondary compounds (Dicke, 2000; Agrawal, 2000).

Several researchers have demonstrated that plant cultivars affect on life parameters of TSSM i.e. bean (Fathipour *et al.*, 2006; Moddarress, 2012); cotton (Wilson, 1994); cucumber (Parak & Lees, 2007), Gerbera (Krips *et al.*, 1999); ivy geranium (Opit *et al.*, 2001), soybean (Razmjou *et al.*, 2009, Sedaratian *et al.*, 2009; Wheatley & Boethel, 1992).

Developmental period of protonymph and deutonymph of *T. urticae* on different strawberry cultivars in this study ranged between 1.06 to 1.41 days and 1.07 to 1.58 days, respectively. Life span of male was shorter than life span of female. The longest life time longevity of TSSM was on Chandler.

Chahine & Michelak (1994) pointed out that no difference was found in two-spotted spider mite longevity when eggplant, tomato and bean were used as host plant. *Tetranychus urticae* developed faster on bean plant (9.42 days), followed by cucumber (10.26 days) and sweet pepper (10.92 days) (Praslicka & Huszar, 2004). Cedola & Sanchez (2003) investigated the survival and fecundity of TSSM on tomato hybrids and suggested that these hybrids affected the fecundity of TSSM. Sadaratian *et al.* (2009) showed the developmental time of immature stage varied from 9.69 to 9.82 days on soybean cultivars. Skirvin & William (1999) showed that development time of TSSM on three species of aromatic plants varied 10.5 to 11.7 days. Reproduction period ranged from 8.5 to 19.1 days. Proportion of mite surviving to adulthood ranged from 65% to 69%. It is possible that the observed difference could be due to the different morphology of the plant species, although this is confounded possibility of different chemical composition. It has been shown that the chemical composition of the host plant affected mite longevity.

The highest average fecundity of mite observed on Chandler and the lowest on Marak. The fecundity of TSSM on different strawberry cultivars ranged between 26.70 to 64.16 eggs/female in this study.

The average fecundity on bean plant was 79.28 eggs, 71.48 eggs on sweet pepper and 71.22 eggs on cucumber (Praslicka & Huszar, 2004). Two-spotted spider mite fecundity was positively correlated with nitrogen and carbohydrate content of the strawberry leaves and negatively with phenolic content (Wermelinger *et al.*, 1991). Total fecundity was reported between 82.45 and 142.05 eggs/female on bean (Moddarress, 2012) and between 5.98 and 104.85 on cucumber (Ullah *et al.*, 2006). Sadaratian *et al.*, 2009 demonstrated that soybean genotype had a significant effect on TSSM fecundity. It is possible that observed differences could be due the morphological difference of the genotype, although this is confounded with the possibility of different chemical composition in these genotypes.

The intrinsic rate of population increase has been used an indicators of *T. urticae* population performance (Sabelis, 1985). The intrinsic rate of natural increase is one measure used to evaluate the level of plant resistance to insects or mites (Cary, 1993; Yang & Chi, 2006; Razmjou *et al.*, 2006; Moddarress, 2012).

Sabelis (1985) has reported  $r_m$ -value of *T. urticae* from 0.21 to 0.34 female/female/day on different host plants. The life-table analysis showed a gradual decline in the intrinsic rate of natural increase with nitrogen deficiency (Wermelinger *et al.*, 1991). Razmjou *et al.* (2009) reported Sayyed cultivar was the most favourable host for TSSM with  $r_m = 0.29$  female/female/day and Talash cultivar with  $r_m = 0.21$  female/female/day was unfavorable host.

The higher value of  $r_m$  and  $R_0$  indicate the susceptibility of strawberry cultivars to TSSM. The highest value of intrinsic rate of natural increase of TSSM was shown on Chandler. There were not any significant difference between five cultivars (Chandler, Camarosa, Gaviota, Aliso and Yalovaa). The least value was shown on Sequoia and Marak. The results showed that Sequoia and Marak were not suitable host plant for TSSM, but other cultivars were more suitable than Sequoia and Marak. The highest value of  $R_0$  was observed on Chandler. Fathipour *et al.* (2006) showed the most suitable host plants (bean cultivars) of spider mite had  $r_m$  value between 0.22 and 0.34 female/female/day. Sadaratian *et al.* (2009) showed intrinsic rate of natural increase for TSSM ranged from 0.21 to 0.29 female/female/day. In this study,  $r$ -value ranged between 0.17- 0.28 day<sup>-1</sup> on different strawberry cultivars.

Afifi *et al.* (2010) showed that Camarosa is more susceptible to infestation by *T. urticae* than Sweet charlie. Leaf trichomes of Sweet charlie have a higher density and are longer and sharper pointed than those of Camarosa. Gimenez-Ferrer *et al.* (1994) showed that Chandler among other strawberry cultivars (Totem, Canoga, Profumata, Selva and Rainier) is resistance cultivar that this resistance pattern were intermediate. Twenty strawberry cultivars were evaluated by Labanowska (2007), all of these were susceptible for infestation but degree of susceptibility varied from cultivar to cultivar. Shanks *et al.* (1995) studied eleven clones which most clones were moderately to highly susceptible to spider mite.

Some morphological difference among varieties might be related to spider mite resistance in strawberry (Kishaba *et al.*, 1971). Leaves of two species of solanaceous plants *Lycopersicon hirsutum* Humb. & Bonpl and *Solanum sarachoides* Sendtner have a dense covering of glandular hairs were founded to be unsuitable for TSSM development because spider mites were entrapped in their exudates and the leaves of these plant species (Rasmy, 1985). Skorupska (2004) showed a negative correlation between increasing number of hairs on abaxial surface of apple leaves and fecundity of TSSM. Strawberry leaves had two types of trichomes. The first were simple trichomes were located mainly on leaf veins and leaf margins, mostly on the underside of the leaf, the second were smaller glandular trichomes, these trichomes consisted of one basal epidermic cell, several stalk cell and single rounded head cell. The nonglandular trichomes were not the resistance factor for strawberry cultivars against spider mite (Steinite & Levinsh, 2003). It was concluded that glandular trichomes localized inducible response are among the potential resistance mechanisms against spider mite in strawberry. Removing trichomes increased oviposition of mites (Luczynski *et al.*, 1990). Cotton cultivar with high trichomes was resistance against TSSM (Kamal & Elkassaby, 1965), however, More susceptible cultivars in general had a higher of trichomes on the underside of leaves than resistant cultivar. Strawberry cultivars more resistant to TSSM are characterized by a higher inducible activity of oxidative enzymes (Steinite & Levinsh, 2002)..

Marak and Sequoia were more resistant to TSSM than other cultivars in antibiosis test, higher mortality of immature stage of TSSM on these cultivars also showed a resistant pattern in these cultivars. However, in antixenosis test Aliso is more resistant than others. Resistance to TSSM appears to be qualitative because it is conditioned by different among cultivars. The poor performance of mites on Marak and Sequoia was the result of poor fecundity, lower survivorship immature stage and longer developmental time. In the present study, Chandler has leaves with lower number of trichomes and it may be related to susceptibility of this cultivar or the low chemical defense of this cultivar against TSSM.

Knowledge of susceptibility or resistance of strawberry cultivars and biology of TSSM on these cultivars in greenhouse are fundamental component of integrated pest management. Among the resistance mechanisms, antibiosis is the most important, which has a direct effect on the life history and developmental and use of resistant cultivars in greenhouse would improve other methods of *T. urticae* control.

## REFERENCES

- Afifi AM, El-Laithy AYM, Shehata SA, El-Saiedy MA. 2010. Resistance of strawberry plants against the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). In: Sabelis, M.V., Bruin, J. Trends in Acarology. Proceedings of the 12<sup>th</sup> International Congress. Amsterdam. The Netherlands. pp: 505-507.
- Agrawal AA. 2000. Host-range evolution: adaptation and trade-offs in fitness of mites on alternative hosts. *Ecology*. 81: 500-508.
- Bounfour M, Tanigoshi LK. 2001. Effect of temperature on development and demographic parameters of *Tetranychus urticae* and *Eotetranychus carpini borealis* (Acari: Tetranychidae). *Ann. Entomol. Soc. Am.* 94: 400-404.
- Cary JA. 1993. *Applied Demography for Biologists with Special Emphasis on Insect*. Oxford University Press. New York.
- Cedola CV, Sanchez NE. 2003. Effect of tomato pubescence on development, survival and fecundity of *Tetranychus urticae* Koch and *Neoseiulus californicus* (McGregor) (Acari: Tetranychidae: Phytoseiidae). *Acarologia*. 43: 255-260.
- Chahine H, Michellakis S. 1994. Bioecological control studies of *Tetranychus urticae* Koch (Acari: Tetranychidae). *Bull. IOBC/WPRS*. 17: 121-124.
- Chi H, Liu H. 1985. Two new methods for the study of insect population ecology. *Bull. Inst. Zool. Acad. Sin.* 24: 225-240.



- Chi H, Su HY. 2006. Age-stage, two-sex life tables of *Aphidius gifuensis* (Ashmead) (Hymenoptera: Braconidae) and its host *Myzus persicae* (Sulzer) (Homoptera: Aphididae) with mathematical proof of the relationship between female fecundity and the net reproductive rate. *Environ. Entomol.* 35: 10-21.
- Chi H. 1988. Life-table analysis incorporating both sexes and variable development rates among individuals. *Environ. Entomol.* 17: 26-34.
- Chi H. 2006. TIMING-MSChart: a computer program for the population projection based on age-stage, two-sex life table. (<http://140.120.197.173/Ecology/Download/Timing-MSChart.zip>).
- Dabrowski ZT, Rodrigez JG, Chapin CE. 1971. Studies in the resistance of strawberries to mite. IV. Effect of season on preference or nonpreference of strawberries to *Tetranychus urticae*. *J. Eco. Entomol.* 64: 806- 809.
- Dicke M. 2000. Chemical ecology of host-plant selection by herbivorous arthropods: a multitrophic perspective. *Biochem. Syst. Ecol.* 28:601–617.
- Fathipour Y, Ahmadi M, Kamali K. 2006. Life table and survival rate of *Tetranychus urticae* (Acari: Tetranychidae) on different bean varieties. *Iranian J. Agric. Sci.* 37: 65- 71 (in Persian with English abstract).
- Gimenez-Ferrer R M, Erb W A, Bishop B L, Scheerens J C, 1994. Host-pest relationships between the twospotted spider mite (Acari: Tetranychidae) and strawberry cultivars with differing level of resistance. *J. Econ. Entomol.* 87: 168-175.
- Gimenez-Ferrer RM, Scheerens JC, Erb WA. 1993. In vitro screening of 76 strawberry cultivars for twospotted spider mite resistance. *HortScience* 28: 841–844.
- Goodman D. 1982. Optimal life histories, optimal notation, and the value of reproductive value. *Am. Nat.* 119: 803- 823.
- Hamilton TR, Andersen RA, Rodriguaz JG, Loughrin JH, Patterson CG. 1988. Strawberry foliage headspace vapor components at periods of susceptibility and resistance to *Tetranychus urticae* Koch. *J. Chem. Ecol.* 14: 789-796.
- Huffaker CB, van de Vrie M, McMurtry JA. 1969. The ecology of tetranychid mites and their natural control. *Annu. Rev. Entomol.* 14:125-174.
- Jeppson LR, Keifer HH, Baker EW. 1975. Mite injurious to economic plants. University of California. Berkley. CA. USA.
- Kamel SA, Elkassably EY. 1965. Relative resistance of cotton varieties to spider mite, leafhopper and aphids. *J. Econ. Entomol.* 58: 117-119.
- Kasap I. 2004. Effect of apple cultivar and of temperature on the biology and life table parameters of the twospotted spider mite *Tetranychus urticae*. *Phytoparasitica* 32: 73-82.
- Kishaba AN, Voth V, Fowland AF, Bringham RS, Toba HH. 1971. Twospotted spider mite resistance in California strawberries. *J. Econ. Entomol.* 65: 117–119.
- Klamkowski K, Sekrecka M, Fonyodi H, Treder W. 2006. Changes in the rate of gas exchange, water consumption and growth in strawberry plants infested with the two-spotted spider mite. *J. Fruit Ornament. Plant Res.* 14: 155-162.
- Krips OE, Willems PEL, Dicke M. 1999. Compatibility of host plant resistance and biological control of the two-spotted spider mite *Tetranychus urticae* in the ornamental crop gerbera. *Biological Control.* 16: 156-163.
- Krips OE, Witul A, Willems PEL, Dicke M. 1998. Intrinsic rate of population increase of the spider mite *Tetranychus urticae* on the ornamental crop gerbera: intraspecific variation in host plant and herbivore. *Entomol. Exp. Appl.* 89: 159-168.
- Labanowska BH, 2007. Susceptibility of strawberry cultivars to the two-spotted spider mite. *J. Fruit Ornament. Plant Res.* 15: 133-146.
- Lorenzen JH, Balbyshev NF, Lafta AM, Casper H, Tian X, Sagredo B. 2001. Resistant potato selections contain leptine and inhibit development of the Colorado potato beetle (Coleoptera: Chrysomelidae). *J. Econ. Entomol.* 94:1260-1267.
- Lourencao AL, de Moraes GJ, Passos FA. 2000. Resistance of strawberries to *Tetranychus urticae* Koch (Acari: Tetranychidae). *An. Soc. Entomol. Bras.* 29: 339-346.
- Luczynski A, Isman MB, Raworth DA, Chan CK. 1990. Chemical and morphological factors of resistance against the twospotted spider mite in beach strawberry. *J. Econ. Entomol.* 83: 564-569.
- Martinez-Villar E, Saenz-de-Cabezón FJ, Moreno-Grijalba F, Marco V, Perez-Moreno I. 2005. Effects of Azadirachtin on the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). *Exp. Appl. Acarol.* 35:215-222.
- Modaress SS. 2012. Resistance to *Tetranychus urticae* Koch (Acari: Tetranychidae) in *Phaseolus vulgaris* L. *Middle- East J. Sci. Res.* 11: 690-701.
- Oatman ER, Badgley ME, Platner GR. 1985. Predators of the two-spotted spider mite on strawberry. *Calif. Agri.* 39: 9–12.
- Opit GP, Jonas VM, Williams KA, Margolles DC, Nechols JR. 2001. Effect of cultivar and irrigation management on population growth of the twospotted spider mite *Tetranychus urticae* on greenhouse ivy geranium. *Exp. Appl. Acarol.* 25: 849-857.
- Park YL, Lee JH. 2007. Seasonal dynamics of economic injury levels for *Tetranychus urticae* Koch (Acari, Tetranychidae) on *Cucumis sativus* L. *J. Appl. Entomol.* 131:588–592
- Petrova V, Cudare Z, Steinite I, Laugale V. 2000. Preliminary studies on resistance of some strawberry cultivars to spider mite *Tetranychus urticae*. *IOBC/WPRS Bull.* 23: 119–122.
- Praslicka J, Huszar J. 2004. Influence of temperature and host plants on the development and fecundity of the spider mite *Tetranychus urticae* (Acari: Tetranychidae). *Plant. Prot. Sci.* 4: 141- 144.
- Rasmy AH. 1985. The biology of the two-spotted spider mite *Tetranychus urticae* as affected by resistant solanaceous plants. *Agri. Ecos. Environ.* 13: 325-328.
- Razmjou J, Tavakkoli H, Fallahi A. 2009. Effect of soybean cultivar on life history parameters of *Tetranychus urticae* Koch (Acari: Tetranychidae). *J. Pest Sci.* 82: 89-94.
- Sabelis MW. 1985. Reproductive strategies. In: Hell, W., Sabelis, M.W. Spider mite, Their Biology, Natural Enemies and Control. *World Crop Pests. Vol:1A.* Elsevier. Amsterdam. pp: 265-278.
- Sances FV, Wyman JA, Ting IP. 1979. Morphological responses of strawberry leaves to infestations of twospotted spider mite. *J. Econ. Entomol.* 72:710–713.
- Sato ME, Miyata T, Da Silva M, Raga A, De Souza Filho MF. 2004. Selections for Fenpyroximate resistance and susceptibility, and inheritance, cross-resistance and stability of Fenpyroximate resistance in *Tetranychus urticae* Koch (Acari: Tetranychidae). *Appl. Entomol. zoo* 39:293–302
- Sedaratian A, Fathipour Y, Moharrampour S. 2009. Evaluation of resistance in 14 soybean genotypes to *Tetranychus urticae* (Acari: Tetranychidae). *J. Pest. Sci.* 82: 163-170.
- Shanks CH, Barritt BH. 1975. Resistance of strawberry to the twospotted spider mite. *J. Econ. Entomol.* 68: 7-10.
- Shanks CH, Barritt BH. 1980. Twospotted spider mite resistance of Washington strawberry to the. *J. Econ. Entomol.* 73: 419-423.
- Shanks CH, Barritt BH. 1984. Resistance of *Fragaria chiloensis* clones to the twospotted spider mite. *HortScience.* 19: 640-641.
- Shanks CH, Chandler CK, Show ED, Moore PP. 1995. *Fragaria* resistance to spider mites at three locations in the United States. *HortScience.* 30: 1068–1069.
- Shanks CH, Doss RP. 1989. Population fluctuation of twospotted spider mite (Acari: Tetranychidae) on strawberry. *Environ. Entomol.* 18: 641- 645.
- Shanks CH, Moore PP. 1995. Resistance to twospotted spider mite and strawberry aphid in *Fragaria chiloensis*, *F. virginiana*, and *F. ananassa* clones. *HortScience* 30: 596–599.

- Shih CIT, Poe SL, Cromroy HL. 1976. Biology, life table, and intrinsic rate of increase of *Tetranychus urticae*. *Ann. Entomol. Soc. Am.* 69: 362-364.
- Skirvin DJ, Williams MC. 1999. Differential effect of plant species on a mite pest (*Tetranychus urticae*) and its predator (*Phytoseiulus persimilis*): implications for biological control. *Exp. Appl. Acarol.* 23: 497-512.
- Skorupska A. 2004. Resistance of apple cultivars to spotted spider mite, *Tetranychus urticae* Koch (Acarina, Tetranychidae) Part II. Influence of leaf pubescence of selected apple cultivars on fecundity of two-spotted spider mite. *J. Plant Protec. Res.* 44: 69-74
- Sokal RR, Rohlf FJ. 1995. *Biometry* 3rd ed., W. H. Freeman and Company, San Francisco, CA.
- Steinite I, Levinsh G. 2003. Possible role of trichomes in resistance of strawberry cultivars against spider mite. *Acta. Univ. Lativiensis.* 662: 59-65.
- Steinite I, Levinsh G. 2002. Wound- induced responses in leaves of strawberry cultivars differing in susceptibility to spider mite. *J. Plant Physiol.* 159: 491-497.
- Stonneveld T, Wainwright H, Labuschagne L. 1996. Development of twospotted spider mite (Acari: Tetranychidae) populations on strawberry and raspberry cultivars. *Ann. Appl. Biol.* 129:405-413.
- Ullah F, Lee JH, Farhatullh BF. 2006. Evaluation of cucumber (*Cucumis sativus*) accessions (cultivars and lines) against the two-spotted spider mite (*Tetranychus urticae* Koch) and Kanzawa spider mite (*T. kanzawai* Kishida, Acari: Tetranychidae). *Songklanakarin J. Sci. Technol.* 28: 710-715.
- van de Vire M, McMurtry JA, Huffaker CB. 1972. Ecology of tetranychid mites and their natural enemies. A review. III. Biology, ecology, and pest status and host- plant relation of tetranychids. *Hilgardia.* 41: 343-432.
- Walsh DB, Zalom FG, Shaw DV, Larson KD. 2002. Yield reduction caused by twospotted spider mite feeding in an advanced-cycle strawberry breeding population. *J. Am. Soc. HortScience.* 127:230-237
- Wermelinger B, Oertli JJ, Baumgartner J. 1991. Environmental factors affecting the life table of *Tetranychus urticae* (Acari: Tetranychidae). II. Host plant nutrition. *Exp. Appl. Acarol.* 12: 259-274.
- Wheatley J, Boethel DJ. 1992. Populations of *Phytoseiulus persimilis* (Acari: Phytoseiidae) and its host, *Tetranychus urticae* (Acari: Tetranychidae), on resistant and susceptible soybean cultivars. *J. Econ. Entomol.* 85: 731-738.
- Wilson LJ. 1994. Plant-quality effect on life-history parameters of the twospotted spider mite (Acari: Tetranychidae) on cotton. *J. Econ. Entomol.* 87: 1665-1673.
- Wyman JA, Oatman ER, Voth V. 1979. Effects of varying twospotted spider mite infestation levels on strawberry yield. *J. Econ. Entomol.* 72:747-753
- Yang TC, Chi H. 2006. Life tables and development of *Bemesia argentifolii* (Homoptera: Aleyrodidae) at different temperature. *J. Econ. Entomol.* 99: 691-698.
- Yano S, Wakabayashi M, Takabayashi J, Takafuji A. 1998. Factors determining the host plants range of the phytophagous mite, *Tetranychus urticae* (Acari: Tetranychidae): a method quantifying host plant acceptance. *Exp. Appl. Acarol.* 22: 595- 661.