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Effects of six greenhouse cucumber cultivars on reproductive performance and life expectancy of *Tetranychus turkestani* (Acari: Tetranychidae)

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**ABSTRACT** — The strawberry spider mite *Tetranychus turkestani* Ugarov & Nikolskii is an important pest of greenhouse cucumber. Reproductive parameters, life expectancy and life table entropy of this mite on six greenhouse cucumber cultivars (Puia, Hedieh, Milad Jadid, Milad Ghadim, Khasib and Negin) were evaluated. These parameters were estimated by a leaf disc bioassay with six treatments and 40 replications under laboratory conditions (Tempt. 28 ± 1 °C, RH: 60 ± 5%, L: D = 16:8 h) in a walk-in growth chamber. The results of this study show that the highest total fecundity of the strawberry spider mite was observed on the Hedieh cultivar (29.784 egg/female) and the lowest on the Puia cultivar (15.773 egg/female). The highest gross and net fecundity rates of this pest were seen on the Hedieh cultivar (91.721 and 41.171 egg/female) and the lowest on the Puia cultivar (35.765 and 9.154 egg/female, respectively). The strawberry spider mite had the highest gross and net fertility rates on the Hedieh cultivar (44.913 and 26.720 egg/female, respectively). Moreover, *T. turkestani* gross hatching rate on the six cucumber cultivars differed significantly, varying from 0.18 on Negin to 0.48 on Hedieh. The life expectancy of one-day-old adults of the strawberry spider mite was estimated to be 6.140, 7.800, 5.733, 6.551, 6.543 and 6.822 days on the above-mentioned cultivars, respectively. The values of the entropy parameter (*H*) of the strawberry spider mite on the cultivars were 6.600, 1.177, 8.468, 2.300, 1.249 and 0.247, respectively. These results suggest that Puia, Milad Jadid, Milad Ghadim, Khasib and Negin cultivars may have the highest resistance levels to this mite compared to the Hedieh cultivar. The use of resistant host plants is one of the most important components of an integrated pest management program.

**KEYWORDS** — *Tetranychus turkestani*; reproductive parameters; life expectancy; life table entropy; greenhouse cucumber

**INTRODUCTION**

The strawberry spider mite, *Tetranychus turkestani* Ugarov & Nikolskii (Acari: Tetranychidae), is a polyphagous pest that causes damage to many greenhouse crops, especially cucumber (*Cucumis sativus* L.: Cucurbitaceae). It has a wide host range and has been reported on more than 300 plant species (Popove *et al.* 1983; Nemati *et al.* 2005). Feeding and silk production of this mite affects the quality and quantity of crop yield. The high reproductive potential and rapid developmental rate of this pest makes the population growth very quickly in suitable conditions and can lead to heavy commercial losses (Razmjou *et al.* 2009). Heavy infestation by feeding of strawberry spider mites on host plants causes leaves to turn brown and die. It also considerably decreases the quality and quantity of yields (Martinez-Ferrer *et al.* 2006; Khodayari *et al.* 2008).
Management of *T. turkestani* is very difficult and pesticides have a substantial role to play in the achievement of this purpose. Superfluity and irregular use of acaricides contributed to the development of resistance to many acaricides, thereby making the chemical control of mites difficult (Lee et al. 2007; Cranham and Helle 1985; Ganjisaffar et al. 2011). Recently, due to the effect of pesticides on the environment and human health, it is necessary to devise other control methods and IPM programs to reduce the use of pesticides (Sedaratian et al. 2009; Lorenzen et al. 2001). One of the important control methods against spider mites is the use of resistant host plants. The use of resistant plants could affect pest population density, herbivore damage, and the efficiency of natural enemies and decrease pesticide applications in agricultural ecosystems.

Nutritional quality, host-plant species, cultivar, physiological, ecological and chemical traits of the host-plant may influence the life history parameters of spider mites (Wilson 1976), and therefore the degree of plant resistance.

Currently, resistance to spider mites has been reported in different crops such as melon, watermelon, tomato, bean, soybean and eggplant (Mansour et al. 1987; Fadel et al. 1994; Lopez et al. 2005; Saeidi 2006; Mohammadi et al. 2008; Sedaratian et al. 2011; Khanamani et al. 2012, 2013). Although the general life history of *T. turkestani* has been documented on some crops, more detailed information on the basic biology of this mite on the different cultivars is essential.

The aim of the present study was to determine the effect of six commercial greenhouse cucumber cultivars on the reproductive parameters of strawberry spider mite.

**Materials and Methods**

**Cultures**

In this study, six greenhouse cucumber (*Cucumis sativus* L.) cultivars, namely Puia, Hedieh, Milad Ghadim, Milad Jadid, Khasib and Negin were used as host plants. The cultivars were selected by advisement of plant protection experts in Khuzestan province, Iran. Seeds were bated 24 h before planting. Then, seedlings were planted in pots (pot in size 10 lit) that were filled by cocopeat and perlite (1:1) in a hydroponic system. The pots were kept in a greenhouse at 30 ± 2°C, with a light intensity of 13000 lux and were fed by the nutrient solution (Rash) three times daily. The initial populations of mites (*T. turkestani*) were collected from infested European bindweed, *Convolvulus arvensis* (Convolvulaceae), in the agricultural College campus of Shahid Chamran University, Ahvaz, Iran. Collected mites were separately reared on cucumber leaves of each experimental cultivar.

Mite rearings and experiments were done in a walk-in growth chamber at 28 ± 1°C, 60 ± 5% RH and a photoperiod of 16:8 (L: D) h.

**Experimental design**

The effect of cucumber cultivars on reproductive parameters of the spider mite was assessed on leaf discs (2 cm diameter) placed on soaked cotton in a Petri-dish (3 cm diameter). To keep the leaves fresh, distilled water was daily added to cotton. Each greenhouse cucumber cultivar was tested with 40 replicates.

Spider-mite cohorts were formed by placing a pair (female and male) of strawberry spider mites on a leaf disc. Mites were then eliminated after three hours and only one egg was maintained on each leaf disc. Mortality checked every 12 h (at 7 am and 7 pm). After adult emergence, females were coupled with males taken from the colony of the mite on the same cultivars. Then reproductive parameters involving gross fecundity rate, gross fertility rate, gross hatching rate, net fecundity rate, net fertility rate, mean eggs per day and hatching rate were calculated according to the following equations (Carey, 1993):

\[
\text{Gross fecundity rate} = \sum_{x=\alpha}^{\beta} \alpha M_x
\]

\[
\text{Gross fertility rate} = \sum_{x=\alpha}^{\beta} M_x h_x
\]
Gross hatchrate = \frac{Gross fertility rate}{Gross fecundity rate}

Net fecundity rate = \sum_{x=0}^{\alpha} L_x M_x

Net fertility rate = \sum_{x=0}^{\alpha} L_x h_x M_x

Daily egg per female = Gross fecundity rate \left( \epsilon - \omega \right)

Hatching rate = Gross fertility rate \left( \epsilon - \omega \right)

Where, \( L_x \) defines the number of days lived by the average individual in the interval \( x \) to \( x+1 \), \( M_x \) (gross maternity) is the average number of offspring produced by living females in \( x \) and \( h_x \) is at the hatching rate; \( \alpha \) corresponds to the first age oviposition of female and \( \beta \) is the last age oviposition of female and \( \epsilon - \omega \) show the female longevity (Carey, 1993).

Age-stage life expectancy (\( e_{xj} \)) and age-stage specific reproduction value (\( v_{xj} \))

The age-stage life expectancy (\( e_{xj} \)) represents the length of time that an individual of age \( x \) and stage \( j \) is expected to survive, in other words, \( e_x \) is the lifetime that a mite in age \( x \) and stage \( j \) is hoping to live on different cultivars. The \( v_{xj} \) value represents the contribution of an individual at age \( x \) and stage \( j \) to the future population (Tuan et al. 2014). The \( e_{xj} \) and \( v_{xj} \) were calculated according to Chi and Su (2006).

Life table entropy

Life table entropy (\( H \)) is a measure of heterogeneity in the distribution of deaths in a cohort. If \( H \) is smaller than 0.5 (\( H < 0.5 \)), then the shape of the \( l_x \) schedule is convex and for values of \( H > 0.5 \) it is concave (Khanamani et al. 2012). If \( H = 0 \), this means that all deaths happen at exactly the same age and shape of \( l_x \) schedule is rectangular, and if \( H = 1 \), then the \( l_x \) schedule is exponentially reduced. \( H = 0.5 \) demonstrates a linear \( l_x \) schedule. To compute the value of life table entropy needs to ex and frequency of death (\( d_x \)) parameters according to following formula (Carey 1993):

\[
H = \frac{\sum_{x=0}^{\alpha} e_x d_x}{e_0}
\]

Statistical analysis

Both the age-stage specific reproduction value (\( v_{xj} \)) and age-stage life expectancy (\( e_{xj} \)) were calculated with the TWOSEX-MSChart (Chi 2015) and drawn with SigmaPlot 12.0. The standard errors were estimated using the bootstrap technique (Efron, 1979; Huang and Chi, 2012, 2013). Mean compression of the data was subjected to a one-way Analysis of Variance (ANOVA) using the ProcGLM procedure of SAS 9.2 and LSD tests at \( P < 0.05 \) (SAS Institute Inc, 2006). The dendrogram of cucumber cultivars based on the reproductive parameters of the strawberry spider mite on cultivars, was constructed by Ward’s method using the SPSS 18.0 statistical software.

RESULTS

Life expectancy

The results show that the trend age – stage life expectancy of the strawberry spider mite on the Hedieh cultivar is different from that on other cultivars (Figure 1). The life expectancy of one-day-old adults of the strawberry spider mite was estimated to be 6.140, 7.800, 5.733, 6.551, 6.543 and 6.822 days on the Puia, Hedieh, Milad Jadid, Milad Ghadim, Khasib and Negin cultivars, respectively.

Reproductive parameters

A significant difference between the means of reproductive parameters of \( T. turkestani \) reared on the different greenhouse cucumber cultivars was found (Table 1). The gross fecundity rate of this pest differed significantly according to the cultivars (\( F = 173.59; \) \( df = 5.54; \) \( P < 0.0001 \)), with the highest value 91.721 on Hedieh, and the lowest 35.765 on Puia. The highest and lowest net fecundity rate of \( T. \)
Net fecundity rate

<table>
<thead>
<tr>
<th>Cucumber cultivars</th>
<th>Gross fecundity rate</th>
<th>Net fecundity rate</th>
<th>Gross fertility rate</th>
<th>Net fertility rate</th>
<th>Gross hatch rate</th>
<th>Total fecundity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puia</td>
<td>35.765±1.99</td>
<td>9.154±0.59</td>
<td>10.000±2.56</td>
<td>4.861±0.30</td>
<td>0.27±0.02</td>
<td>15.773±2.53</td>
</tr>
<tr>
<td>Hedieh</td>
<td>91.721±0.79</td>
<td>41.171±0.62</td>
<td>44.913±1.82</td>
<td>26.72±1.64</td>
<td>0.48±0.03</td>
<td>29.784±1.97</td>
</tr>
<tr>
<td>Milad Jaded</td>
<td>86.524±1.09</td>
<td>16.324±0.49</td>
<td>18.803±4.73</td>
<td>5.828±0.60</td>
<td>0.21±0.01</td>
<td>19.795±1.93</td>
</tr>
<tr>
<td>Milad Ghadim</td>
<td>70.117±2.87</td>
<td>15.789±0.22</td>
<td>17.627±4.33</td>
<td>5.569±0.56</td>
<td>0.25±0.03</td>
<td>20.938±2.30</td>
</tr>
<tr>
<td>Khasib</td>
<td>44.481±0.75</td>
<td>16.121±0.90</td>
<td>18.379±1.67</td>
<td>9.623±0.35</td>
<td>0.41±0.06</td>
<td>19.757±1.49</td>
</tr>
<tr>
<td>Negin</td>
<td>69.794±1.19</td>
<td>14.285±0.48</td>
<td>12.956±1.87</td>
<td>5.270±0.35</td>
<td>0.18±0.02</td>
<td>19.755±2.75</td>
</tr>
</tbody>
</table>

*Means followed by same letters in each column are not significantly different (P < 0.05, LSD).

The values of the entropy parameter (H) of the strawberry spider mite on Puia, Hedieh, Milad Jadid, Milad Ghadim, Khasib and Negin were 6.600, 1.177, 8.468, 2.300, 1.249 and 0.247, respectively. These values indicate that the survival schedule of *T. turkestani* was convex (H < 0.5) on Negin cultivar and corresponds to Deevey’s type I survivorship curves, but the values of the entropy parameter of this mite on other cultivars were concave (H > 0.5) and reduced exponentially and on recent cultivars, according to Deevey’s survivorship curves, were type III.

Cluster analysis

Figure 5 shows the reproductive parameters of the strawberry spider mite on six greenhouse cucumber cultivars. The dendrogram provided two distinct groups specified as A and B. The cluster A involved just the Hedieh cultivar (favorite host plant for the reproduction of the strawberry spider mite) and the cluster B consisted of the remaining cultivars (partially unpleasant group for the reproduction of this mite). In the cluster analysis, the cucumber cultivars grouping within each cluster are likely to share morphological and physiological characters. The results of the comparison of the reproductive parameters of the strawberry spider mite on different cultivars of greenhouse cucumber cultivars revealed that the clusters B and A were the least and most suitable host plants for the repro-

**Life table entropy (H)**

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Figure 1: Age-stage life expectancy ($e_{ij}$) of *Tetranychus turkestani* fed on six greenhouse cucumber cultivars. Age life expectancy of *T. turkestani* in each stage was shown by solid black circle (egg), solid white circle (larva), solid white triangle up (nymph 1), solid black triangle up (nymph 2), simple line (female) and long dash line (male) on six greenhouse cucumber cultivars. a- cultivar Puia, b- cultivar Hedieh, c- cultivar Milad Jadid, d- cultivar Milad Ghadim, e- Khasib, f- Negin.
FIGURE 2: Mean (±SE) oviposition rate *Tetranychus turkestani* reared on six greenhouse cucumber cultivars. Means followed by same letters in each column are not significantly different (*P* < 0.05, LSD).

FIGURE 3: Mean (±SE) hatching rate of *Tetranychus turkestani* reared on six greenhouse cucumber cultivars. Means followed by same letters in each column are not significantly different (*P* < 0.05, LSD).
Figure 4: Age – stage reproductive value ($v_x$) of *Tetranychus turkestani* fed on six greenhouse cucumber cultivars. Age reproductive value of *Tetranychus turkestani* in each stage was shown by solid black circle (egg), solid white square (larva), solid black triangle up (nymph 1), solid white diamond (nymph 2), solid white circle (female) on six greenhouse cucumber cultivars. a- cultivar Puia, b- cultivar Hedieh, c- cultivar Milad Jadid, d- cultivar Milad Ghadim, e- Khasib, f- Negin.
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FIGURE 5: Ward’s dendrogram of six greenhouse cucumber cultivars based on reproductive parameters of *Tetranychus turkestani* on six greenhouses cucumber cultivars. A- favorite host plant for the reproduction of the strawberry spider mite, B- partially unpleasant group for the reproduction of this mite, B<sub>1</sub>- comparatively semi-resistant group and B<sub>2</sub>- partly more resistant compared to cultivars in the B<sub>1</sub> cluster.
duction of this pest, respectively. In conclusion, the Group B included the most resistant host plants to *T. turkestani* with lower fecundity and fertility rate. Group B is divided into two branches (B₁ and B₂), such that B₁ consisted of Puia and Khasib cultivars (comparatively semi-resistant group) and in the B₂ cluster, Milad Ghadim and Negin were regarded as partly more resistant compared to cultivars in the B₁ cluster.

**DISCUSSION**

To control pests and increase yield, farmers are inclined to applying chemical pesticides. Daily increases of pesticides are dangerous to environmental health. On the other hand, consumption of fresh and raw greenhouse produce enhances risk safety of consumers. Therefore, the application of non-chemical methods of pest control in greenhouses is unavoidable. In this regard, a combination of the different methods of pest control in integrated pest management programs based on resistant cultivars is an appropriate solution to reduce the use of pesticides (Fathipour and Sedaratian 2013). The result of this study could be used to reduce the application of pesticides in greenhouses and to increase healthy food consumption and improve the environment.

Studying the reproductive parameters of a pest is very important in designing a successful integrated pest management program (Naseri *et al.* 2011; Khanamani *et al.* 2012). The difference of population parameters may depend on variation in host plant nutrient levels, particularly the effects of nitrogen content and protein quality on the fecundity of pests (Awmack and Leather 2002; Blanco *et al.* 2006; Lee 2007; Hwang *et al.* 2008).

Sedaratian *et al.* (2009) reported that the total fecundity of the spider mite varied from 33.62 to 153.22 on different soybean genotypes. These results show that soybean genotypes are more susceptible to *T. turkestani* compared with cucumber cultivars tested in this study. In addition, the total fecundity of the two spotted spider mite (TSSM) reported by Razmjou *et al.*, (2009) on soybean, cowpea and bean (83.16, 65.53 and 34.50 eggs/female, respectively) was more than the values obtained in the present study, indicating that the three mentioned plants are more suitable to this pest than the cucumber cultivars tested. The differences between these findings may be due to the differences between quantity and quality of nutrients in the host plants, sources of the two spotted-spider mite population, rearing techniques and experimental conditions (Khanamani *et al.* 2012).

Several studies have revealed that the quantity and quality of food resources used by arthropods is an important factor in their growth (Fathipour *et al.* 2006; Saeidi 2006; Mohammadi *et al.* 2008; Sedaratian *et al.* 2009; Khanamani *et al.* 2012, 2013). The quality and quantity of host plants during the immature stages of herbivorous insects and mites, is a considerable factor that affects fecundity and fertility in the adult stage (Awmack and Leather 2002). The current study shows that females fed as a larva and nymphs on different cucumber cultivars had a significant difference in fecundity and fertility. The fecundity of spider mite in this study had a significant difference and Hedieh cultivar was the most suitable while Negin and Milad Ghadim were the least suitable host plant for the reproduction of this pest, and the other cultivars had a median status. The trend of life expectancy (λₓ) of this pest on Hedieh cultivar was the highest and occurred at a longer interval time than the life expectancy (λᵧ) on the other cultivars. As well, the contribution of an individual strawberry spider mite in the future population (vₓ) on the current cultivar is high. The contribution of an individual in an immature stage of this pest in the future population (vᵧ) on the current cultivar was short. Therefore, Negin, MiladJadi and Milad Jadid was small. Also, the reproductive parameters and life expectancy of *T. turkestani* on the current cultivars were short. Therefore, Negin, MiladJadi and Milad Ghadim showed more resistance to this mite because of lower fecundity, and short life expectancy of the pest. These cultivars could not support the reproduction and survival of the strawberry spider mite. The unsuitability of some cultivars as a host plant of the strawberry spider mite may be due to the presence of some phytochemicals (deterrent and fatal substance), as antixenotic or antibiotic agents, in these cultivars and also present in high concentration of...
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special structural materials, for example lignin and silis, as a result of digestive disorders. Also, antibiosis may happen because of the absence of some suitable values required by the primary alimentary canal to grow and develop (Smith 2005).

In this study, the values of \( H \) for strawberry spider mite were lower than 0.5 on Negin cultivar, and therefore, the survival schedule of this mite was convex. This shows that the survival possibility was lower in the later ages compared to the early ones. The value of \( H \) in the other mentioned cultivars was larger than 0.5, and then \( l_i \) schedule of this pest was concave and exponentially reducing. This outcome means that the death probability of \( T. turkestani \) was high in the early ages compared with larger ones.

Accordingly, the reproductive parameters of strawberry spider mite indicate that Hedieh cultivar is an appropriate host plant for reproduction of the strawberry spider mite. The adverse effects of antibiotic resistance of host plants on pest biology were reported to reduce their reproduction and prolongation of life (Smith 2005). In this study, the least reproductive parameters and life expectancy at the beginning of each stage of the strawberry spider mite were observed on the Negin and Milad Ghadim cultivars. This result suggests that these cultivars may have some levels of antibiotic resistance to this mite.

Among the available control methods, host plant resistance is widely recognized as the basis of integrated pest management programs (Zehnder et al. 2007). Moreover, host plant resistance reduces the application of pesticides (Desneux et al. 2007). Consequently, these findings have important implications for planning a comprehensive program for the integrated control of the strawberry spider mite on cucumber in the greenhouse. This information with other ecological data may be used for the development of management programs for this pest in cucumber greenhouses. A study of the reproductive potential of this pest will be useful to provide information on the economic injury level on host plant and identify the best predators against spider mites attack on cucumber. Besides, investigation of the quality of resistant cultivars for host taste and sell well (in market) are unavoidable. A further study with more focus on biochemical studies for the detection and identification of phytochemicals, which adversely affect the \( T. turkestani \) population on greenhouse cucumber cultivars, is therefore suggested.

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