Reproductive performance and life expectancy of *Tetranychus urticae* (Acari: Tetranychidae) on seven eggplant cultivars

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Abstract: Reproductive performance and life expectancy of the two-spotted spider mite (TSSM), *Tetranychus urticae* Koch were determined on seven eggplant cultivars (Isfahan, Dezful, Shend-Abad, Neishabour, Bandar-Abbas, Jahrom and Borazjan) at $25 \pm 1°C$, $60 \pm 5\%$ R.H. and a photoperiod of 16:8 (L:D) hours. The results revealed that the TSSM gross hatch rate varied from 59% on Bandar-Abbas to 83% on Dezful. The gross fecundity rate was 59.726, 31.430, 31.443, 14.461, 19.328, 16.035 and 20.560 eggs/female and the net fecundity rate was 25.804, 17.496, 15.139, 7.620, 5.931, 7.526 and 11.947 eggs/female on the above-mentioned cultivars, respectively. The highest and lowest value of the net fertility rate was 20.735 eggs/female on Isfahan and 3.495 eggs/female on Bandar-Abbas, respectively. Also, the gross fertility rate was the highest on Isfahan (47.994 eggs/female) and the lowest on Bandar-Abbas (11.390 eggs/female). The values of the mean eggs per day varied from 2.040 to 6.560 eggs/female, which was minimum on Neishabour and maximum on Isfahan. The life expectancy of one-day-old adults of the TSSM was estimated to be 7.550, 8.380, 5.820, 4.850, 5.440, 5.330 and 3.950 days on the above-mentioned cultivars, respectively. Comparison of the reproductive parameters of the TSSM on the examined cultivars revealed that Isfahan was the most susceptible cultivar and Neishabour was the most resistant cultivar to this pest. Using resistant host plants is one of the most important components of an integrated pest management program.

Keywords: Eggplant, *Tetranychus urticae,* Reproductive parameters, Life expectancy, Life table entropy

Introduction

The two spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae) is a major pest on a large number of host plants (Tsagkarakou *et al*., 2002). This mite causes considerable damage to eggplant, bean, melon, tomato, strawberry, pumpkin and many other outdoor and greenhouse crops (Chaudhri *et al.*, 1985; Ahmadi *et al.*, 2007). This mite now is one

of the most important pests of the eggplant, *Solanum melongena* L. (Solanaceae) in Iran and many other countries in the world (Khanjani, 2005). The rapid developmental rate and high reproductive potential of the TSSM allows it to achieve damaging population levels very quickly when growth conditions are appropriate, resulting in an equally rapid decline of host plant quality (Fathipour *et al*., 2006; Razmjou *et al*., 2009). The mobile stages of this mite suck the cell contents of leaves and young terminal shoots of plants with their piercing-sucking mouthparts, and cause yellow spots on the leaves; if the attack is continuous, leaves may fall and the number of

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flowers produced may be reduced considerably (Khodayari *et al.,* 2008). In addition to yield reduction, there may be a reduction in quality of the flowers produced (Karlik *et al.,* 1995).

Reproduction in the spider mites is very sensitive to a wide variety of both intrinsic and extrinsic factors. Intrinsic factors that influence reproductive potential of tetranychid mites include mite strain and level of inbreeding, colony density, age of females and of the population, fertility status of the females and various behavioral parameters (Adango *et al.,* 2006). Extrinsic factors include temperature, humidity, light, predation level, intra- and inter specific competition, and also various host plants features, such as strain, plant and soil nutrition and plant age (Adango *et al.,* 2006). For instance, quality and quantity of host plants during immature stage is a key determinant of both fecundity and fertility in imago (Awmack and Leather, 2002).

Host plant resistance to pests is one of the most important components of an integrated pest management program that affect pest population density, herbivores damage, efficiency of natural enemies and decrease of pesticide applications in agricultural ecosystems. 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).

Plant resistance is the relative amount of heritable qualities possessed by a plant, which influences the ultimate degree of damage done by the herbivore (Stanley and Beck, 1965), and can be caused by antixenosis, antibiosis, tolerance, or some combinations of these mechanisms (Painter, 1951; Kogan and Ortman, 1978). Among these mechanisms, antibiosis is the most important, which has a direct influence on the demographic parameters of a pest such as fecundity, mortality and development time (Sedaratian *et al.,* 2011).

Despite the economic importance of the TSSM, no information is available concerning the reproductive performance of this pest on different eggplant cultivars. Hence the present study was planned on seven commercial eggplant cultivars in Iran to compare reproductive parameters of the TSSM on these cultivars. The findings of this study could be used effectively for accurately predicting the TSSM population development on different eggplant cultivars to design a comprehensive scheme for IPM program of this pest.

Material and Methods

Plants
Seeds of seven eggplant cultivars (Isfahan, Dezful, Shend-Abad, Neishabour, Bandar-Abbas, Jahrom and Borazjan) were obtained from Karaj Plant and Seed Modification Research Institute (Karaj, Iran). They were planted in 30 cm diameter plastic pots filled with fertilized field soil at greenhouse of Faculty of Agriculture at Tarbiat Modares University in May 2010. As soon as the seedlings reached to the stage of 3 to 4 leaves, they were transported to the field. The leaves at the beginning of plant reproductive stage of the cultivars were used to prepare leaf discs.

Mite cultures
The specimens of the TSSM were obtained from the Iranian Research Institute of Plant Protection in Tehran, Iran. The mites were reared on planted beans (*Phaseolus vulgaris* cultivar Khomein) under greenhouse conditions and kept them as a colony. Prior to the experiments, the offspring of this colony were reared for two generations on the above-mentioned cultivars in a growth chamber at $25 \pm 1°C$, $60 \pm 5\%$ R.H. and a photoperiod of 16:8 (L:D) h., separately.

Reproductive parameters
In order to determine the reproductive parameters and life expectancy of the TSSM on

seven eggplant cultivars, the leaf discs taken from leaves of each cultivar (70 leaf discs for each cultivar) were used. Each leaf disc was placed with the upper surface facing down on a cotton layer in a Petri dish (3 cm in diameter), in which a 5 mm diameter hole was drilled. The leaf margin was surrounded by a cotton strip to prevent the escape of mites. The prepared Petri dishes were kept in larger dishes (6 cm in diameter). Water was added daily to the larger dishes to keep the leaves fresh. For each cultivar, 15 pairs of both sexes of the TSSM were transferred onto a leaf disc (similar to experimental unit) of each cultivar. After 12h, the laid eggs of these females were transferred individually on the leaf discs up to 70 replicates per treatment. These leaf discs were checked daily (at eight o'clock in the morning) and mortality and survivorship of different stages were recorded. After adults emergence, females were coupled with males obtained in the same experiment or taken from the colony of the mite on the same cultivars. Daily observations were made under a stereomicroscope to determine female fecundity and survivorship of individuals until the death of the last female mite. These experiments were carried out at 25 ± 1 °C, 60 ± 5 % R.H. and a photoperiod of 16:8 (L: D) in a growth chamber.

The reproductive parameters were as gross fecundity rate, gross fertility rate, gross hatch rate, net fecundity rate, net fertility rate, mean eggs per day and mean fertile eggs per day. The mentioned parameters were estimated by using the following equations (Carey, 1993):

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

$$\text{Gross fertility rate} = \sum_{x=\alpha}^{\beta} M_x h_x$$

$$\text{Gross hatch rate} = \sum_{x=\alpha}^{\beta} M_x h_x / \sum_{x=\alpha}^{\beta} M_x$$

$$\text{Net fecundity rate} = \sum_{x=\alpha}^{\beta} L_x M_x$$

$$\text{Net fertility rate} = \sum_{x=\alpha}^{\beta} L_x M_x h_x$$

$$\text{Daily eggs per female} = \sum_{x=\alpha}^{\beta} M_x / (\varepsilon - \omega)$$

$$\text{Daily fertile eggs per female} = \sum_{x=\alpha}^{\beta} M_x h_x / (\varepsilon - \omega)$$

where, L_x is the days lived in interval x and $x+1$, M_x is the average number of eggs produced by a female at age x and h_x is the hatching rate; α is the age of female at the first oviposition and β is the age of female at the last oviposition and ε-ω is the female longevity.

Life expectancy (e_x)
The life expectancy (e_x) gives the lifespan that an individual in age x is expected to live on different cultivars. In other words, life expectancy is the expectation of life at age x, and is calculated of the below equation:

$$e_x = T_x / l_x$$

where T_x is the total number of days to be lived by the average individual within a cohort from age x to the last day of possible life, and l_x is the proportion of a cohort surviving from birth to exact age x.

Life table entropy
Life table entropy, days gained per averted death (H) is a measure of heterogeneity in the distribution of deaths in a cohort. The survival schedule for values of $H < 0.5$ is convex and the survival schedule is concave for values of $H > 0.5$, and if $H = 0.5$ the survival schedule would be linear. If all individuals die at the same age, $H = 0$ and the shape of the survival schedule is rectangular. If all individuals have exactly the same probability of dying at each age,

the shape of the survival schedule exponentially decreases and $H = 1.0$ (Carey, 1993). The value of entropy parameter was calculated using life expectancy (e_x) and frequency of deaths (d_x) according the following equation:

$$H = \frac{\sum_{x=0}^{\omega} e_x d_x}{e_0}$$

Cluster analysis

The dendrogram of eggplant cultivars based on reproductive parameters of the TSSM on cultivars was constructed by Ward's method using the statistical software SPSS 16.0.

Statistical analysis

The pseudo-values of the reproductive parameters were calculated using jackknife procedure (Meyer *et al*., 1986). The estimated values for each cultivar were subjected to ANOVA. Based on the results, mean comparisons were done by Student-Newman-Keuls (SNK) Multiple Range Test ($P < 0.05$) (SAS Institute Inc 2003).

Results

Reproductive parameters

The results showed that the different eggplant cultivars significantly affected the reproductive parameters of the TSSM (Table 1). The TSSM gross hatch rate on different eggplant cultivars had a significant difference that varied from 59% on Bandar-Abbas to 83% on Dezful. Moreover, there was a significant difference in the gross fecundity rate of the TSSM on the tested cultivars ($F = 43.22$; $df = 6$, 124; $P < 0.0001$) as the highest value was 59.726 (eggs/female) on Isfahan, and the lowest value was 14.461 on Neishabour (Table 1). The highest value of the gross fertility rate was on Isfahan (47.994 eggs/female) and the lowest value was on Bandar-Abbas (11.390 eggs/female) ($F = 47.61$; df = 6, 124; $P < 0.0001$). The net fecundity rate was 25.804, 17.496, 15.139, 7.620, 5.931, 7.526 and 11.947 eggs/female and the net fertility rate was 20.735, 14.535, 11.591, 6.051, 3.495, 5.709 and 9.012 eggs/female on Isfahan, Dezful, Shend-Abad, Neishabour, Bandar-Abbas, Jahrom and Borazjan, respectively.

Table 1 The mean (±SE) reproductive parameters of *Tetranychus urticae* on different eggplant cultivars.

Eggplant cultivars	Gross fecundity rate	Net fecundity rate	Gross fertility rate	Net fertility rate	Gross hatch rate
Isfahan	59.726 ± 4.77[a]	25.804 ± 2.80[a]	47.994 ± 3.83[a]	20.735 ± 2.25[a]	0.80 ± 0.00[b]
Dezful	31.430 ± 2.12[b]	17.496 ± 1.67[b]	25.742 ± 1.70[b]	14.535 ± 1.39[b]	0.83 ± 0.00[a]
Shend-Abad	31.443 ± 1.19[b]	15.139 ± 0.77[bc]	24.074 ± 0.91[b]	11.591 ± 0.60[bc]	0.76 ± 0.00[d]
Neishabour	14.461 ± 1.21[c]	7.620 ± 0.70[de]	11.484 ± 0.96[c]	6.051 ± 0.56[ed]	0.79 ± 0.00[c]
Bandar-Abbas	19.328 ± 1.01[c]	5.931 ± 0.39[e]	11.390 ± 0.59[c]	3.495 ± 0.23[e]	0.59 ± 0.00[g]
Jahrom	16.035 ± 0.77[c]	7.526 ± 0.51[de]	12.164 ± 0.59[c]	5.709 ± 0.39[ed]	0.758 ± 0.00[e]
Borazjan	20.560 ± 0.97[c]	11.947 ± 0.53[cd]	15.510 ± 0.73[c]	9.012 ± 0.40[cd]	0.754 ± 0.00[f]

The means followed by same letters in each column are not significantly different ($P < 0.05$, SNK).

The values of mean eggs per day and mean fertile eggs per day of the TSSM on different eggplant cultivars are shown in Figs 1 and 2, respectively. The value of mean eggs per day varied from 2.04 to 6.56 eggs/female/day ($F = 33.93$; $df = 6, 126$; $P < 0.0001$), which was minimum on Neishabour, and maximum on Isfahan. In addition, the cohort reared on Isfahan had the highest mean fertile eggs per day, and those on Jahrom had the lowest mean fertile eggs ($F = 37.96$; $df = 6, 126$; $P < 0.0001$).
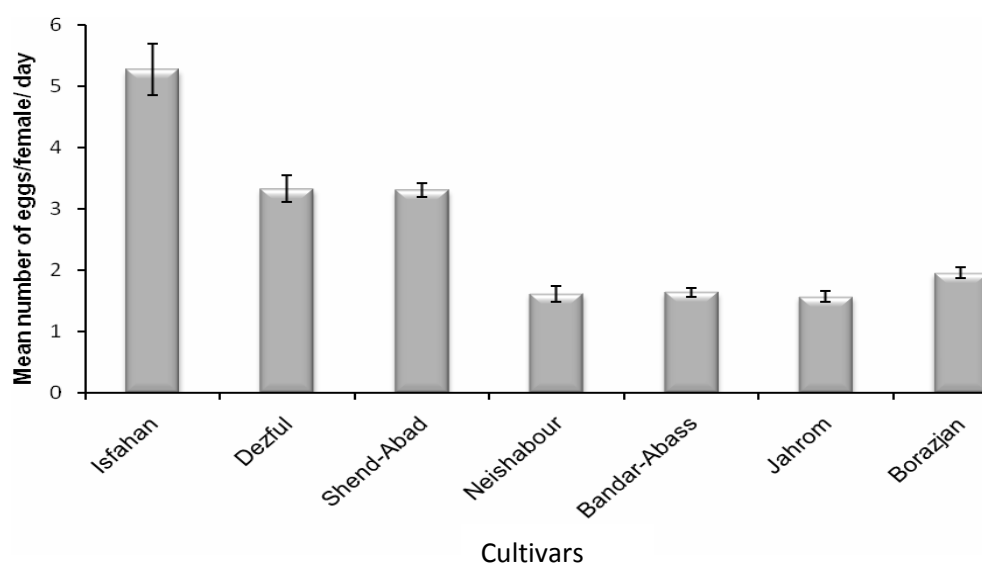

Figure 1 Mean eggs per day laid by *Tetranychus urticae* reared on different eggplant cultivars.
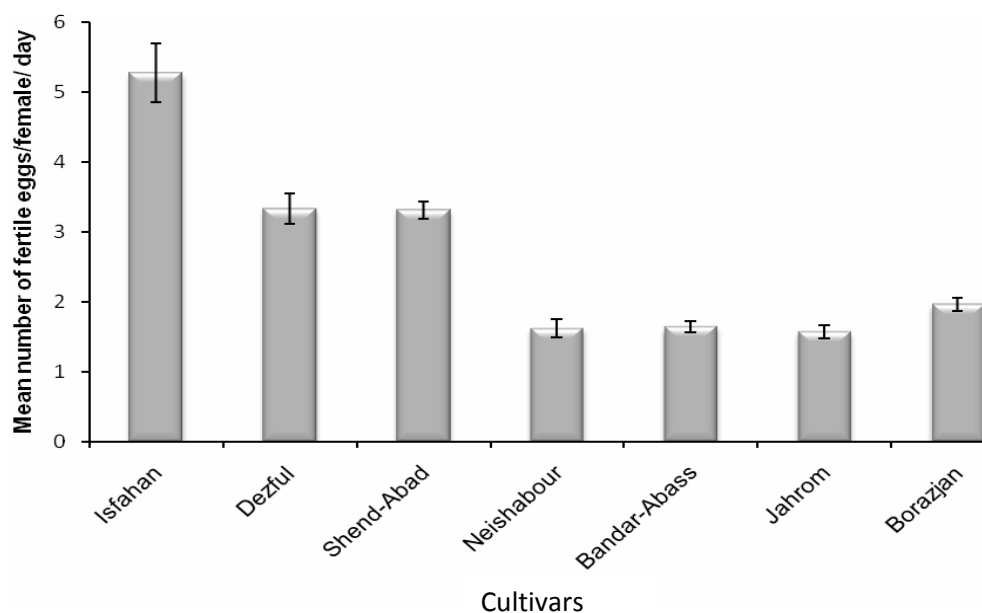

Figure 2 Mean fertile eggs per day laid by *Tetranychus urticae* reared on different eggplant cultivars.

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Life expectancy

The results revealed that the life expectancy (e_x) trend of the TSSM on different cultivars (Fig. 3), which is dominantly downward, rises in some little time intervals. The life expectancy of one-day-old adults of the TSSM was estimated to be 7.55, 8.38, 5.82, 4.85, 5.44, 5.33 and 3.95 days on the above-mentioned cultivars, respectively.
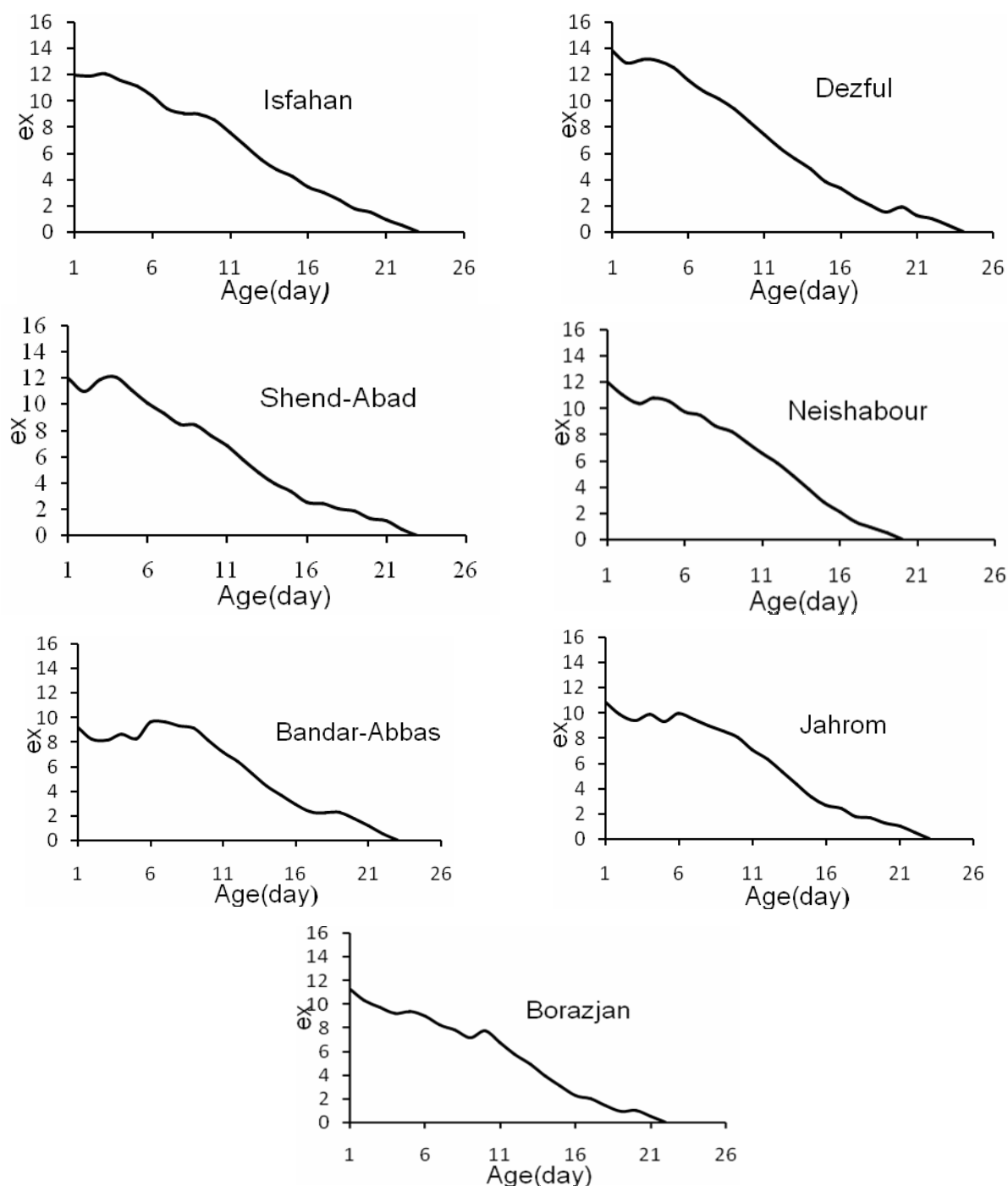

Figure 3 Life expectancy (e_x) of *Tetranychus urticae* on different eggplant cultivars.

Entropy parameter

The value of entropy parameter of two-spotted spider mite on the above-mentioned cultivars was 0.491, 0.350, 0.445, 0.383, 0.654, 0.523, and 0.447, respectively. These values indicated that the survival schedule of the TSSM on Isfahan, Dezful, Shend-Abad, Neishabour and Borazjan were convex (H < 0.5) and corresponded to Deevey's type I survivorship curves, but the shape of the survival schedule for Bandar-Abbas and Jahrom was concave (H > 0.5) and corresponded to Deevey's type III survivorship curves.

Cluster analysis

A dendrogram based on the reproductive parameters of the TSSM on different eggplant cultivars is shown in Fig 4. The dendrogram showed two distinct clusters labeled A and B. The cluster A consisted of the Isfahan, Shend-Abad and Dezful cultivars (susceptible group) and the cluster B consisted of the Neishabour, Jahrom, Borazjan and Bandar-Abass cultivars (partially resistant group).

Discussion

Using plant resistant cultivars is one of the core strategies of integrated pest management and secondary substances of plants or allelochemicals play a major role in plant resistance to pests (Wilson and Huffaker,

1976). Understanding the reproductive parameters of a pest is one of the essential components in developing an integrated pest management strategy (Naseri *et al.*, 2011). Shorter development time and greater total fecundity of a pest on a host crop indicate greater suitability of those crops (van Lenteren and Noldus, 1990).

Quality and quantity of host plants during immature stages of herbivorous insects is a key determinant of both fecundity and fertility in adult stage (Awmack and Leather, 2002). Our results indicated that females reared as larvae and nymphs on different eggplant cultivars had a significant difference in fecundity and fertility. The fecundity of the TSSM on different eggplant cultivars had a significant difference and Isfahan was the most suitable and Neishabour was the least suitable cultivar for the reproduction of the TSSM while other cultivars had an intermediate status. However, Neishabour showed more resistance to the TSSM due to lower fecundity, shorter life expectancy and higher mortality of the pest. The unsuitability of some cultivars as host plant of the TSSM may be due to the presence of some phytochemicals in these cultivars acting as antixenotic or antibiotic agents or the absence of some essential primary nutrients for growth and development of the TSSM.
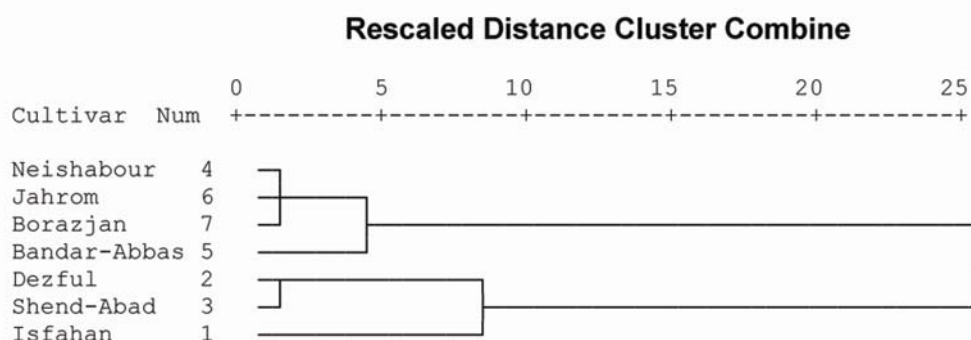

Figure 4 Dendrogram of different eggplant cultivars according to reproductive parameters of *Tetranychus urticae* reared on different eggplant cultivars.

Sedaratian *et al.* (2009) have reported that total fecundity of the TSSM varied from 33.62 to 153.22 eggs/female on different soybean genotypes. These results showed that soybean genotypes are more susceptible to the TSSM compared with all eggplant cultivars tested in our study. In addition, the total fecundity of the 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 mentioned three plants are more suitable to the TSSM than all eggplant cultivars tested. The differences between these findings may be due to the differences among quantity and quality of nutrients in host plants, source of the TSSM population, rearing techniques and experimental conditions. The profound effect of different bean cultivars on fecundity, population growth parameters, survivorship and population density of the TSSM has also been proved (Ahmadi *et al.*, 2005; Fathipour *et al.*, 2006; Ahmadi *et al.*, 2007).

In cluster analysis, the grouping of the eggplant cultivars within each cluster might be due to a high correspondence of physiological traits of eggplant cultivars in each cluster, and vice versa. The results of the comparison of the reproductive parameters of the TSSM on different cultivars of eggplant revealed that the cluster A and B were the most and least suitable host plants for the reproduction of the TSSM, respectively. In conclusion, the cluster A included the most susceptible host plants with higher fecundity and fertility of the TSSM reared on cultivars grouped in this cluster. However, the cultivars in cluster B were more resistant because of lower fecundity and fertility of the TSSM on them. Consequently, it is considerable that our findings may provide important information for planning a comprehensive program for IPM of the TSSM in eggplant fields. In addition, such information is required for a better understanding of herbivore–plant interactions. Biochemical studies for the isolation and identification of phytochemicals,

which adversely affect the build-up of the TSSM population on eggplant, is recommended.

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پارامترهای تولید مثل و امید به زندگی کنه‌ی (Acari: Tetranychidae) *Tetranychus urticae* روی هفت رقم بادمجان

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چکیده: پارامترهای تولید مثل و امید به زندگی کنه‌ی تارتن دولکه‌ای *Tetranychus urticae* Koch روی هفت رقم بادمجان (اصفهان، دزفول، شندآباد، نیشابور، بندرعباس، جهرم و برازجان) در شرایط آزمایشگاهی با دمای ۱±۲۵ درجه سلسیوس، رطوبت نسبی ۵±۶۰ درصد و دوره‌ی نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی مورد مطالعه قرار گرفت. نتایج به‌دست آمده نشان داد که نرخ ناخالص تفریخ کنه‌ی تارتن دو لکه‌ای از ۵۹ درصد روی رقم بندرعباس تا ۸۳ درصد روی رقم دزفول متغیر است. نرخ ناخالص باروری روی ارقام ذکر شده در بالا به‌ترتیب ۵۹/۷۲۶، ۳۱/۴۳۰، ۳۱/۴۴۳، ۱۴/۴۶۱، ۱۹/۳۲۸، ۱۶/۰۳۵ و ۲۰/۵۶۰ (تخم/ماده) و نرخ خالص باروری روی این ارقام، به‌ترتیب ۲۵/۸۰۴، ۱۷/۴۹۶، ۱۵/۱۳۹، ۷/۶۲۰، ۵/۹۳۱، ۷/۵۲۶ و ۱۱/۹۴۷ (تخم/ماده) بود. بیشترین و کمترین مقدار نرخ خالص بارآوری به‌ترتیب ۲۰/۷۳۵ (تخم/ماده) روی رقم اصفهان و ۳/۴۹۵ (تخم/ماده) روی رقم بندرعباس بود. همچنین، بیشترین مقدار نرخ ناخالص بارآوری (۴۷/۹۹۴ تخم/ماده) روی رقم اصفهان و کمترین مقدار این پارامتر (۱۱/۳۹۰ تخم/ماده) روی رقم بندرعباس بود. میانگین تخم گذاشته شده در هر روز از ۲/۰۴۰ تا ۶/۵۶۰ (تخم/ماده) متغیر بود که کمترین آن روی رقم نیشابور و بیشترین آن روی رقم اصفهان بود. امید به زندگی کنه‌های بالغ یک روزه، روی ارقام ذکر شده در بالا به‌ترتیب ۷/۵۵۰، ۸/۳۸۰، ۵/۸۲۰، ۴/۸۵۰، ۵/۴۴۰، ۵/۳۳۰، و ۳/۹۵۰ روز تخمین زده شد. مقایسه پارامترهای تولید مثل کنه‌ی تارتن دو لکه‌ای ارقام روی مطالعه مورد نشان داد که رقم اصفهان، حساس‌ترین رقم و رقم نیشابور، مقاوم‌ترین رقم نسبت به این آفت می‌باشند. یکی از مهمترین اجزای یک برنامه‌ی مدیریتی تلفیقی آفات، استفاده از گیاهان مقاوم می‌باشد.

واژگان کلیدی: بادمجان، کنه تارتن دولکه ای، پارامترهای تولید مثل، امید به زندگی، آنتروپی جدول زندگی