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Life table of *Tetranychus urticae* (Koch) (Acari: Tetranychidae) on different Turkish eggplant cultivars under controlled conditions

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Original article

ABSTRACT

The life table parameters of *Tetranychus urticae* were evaluated on 7 eggplant cultivars namely, Anamur, Aydin Siyahi, Balikesir 76, Kemer, Pala 49, Topan 374, Yalova Topan, in controlled laboratory conditions in daylight for 16 hours 27 ± 1 °C temperature, 65% relative humidity. Assays were conducted on eggplant leaflets in Petri dishes. There was a significant difference in the durations of egg and juvenile development of *T. urticae*. However the survival rates of *T. urticae* were not significantly different on the tested eggplant cultivars. The values of the natural rate of increase, r_m , (0.218–0.269), net reproduction rate, R_0 , (26.74–45.51) and the mean generation time, T , (13.31–15.45) significantly differed among eggplant cultivars. Notably, the shortest development duration as indicated by the lowest r_m and R_0 values were observed on Pala 49 followed by Anamur and Balikesir 76 cultivars.

Keywords two-spotted spider mite; life table parameters; development; eggplant; cultivar

Introduction

More than thirty mite species have been identified on eggplants *Solanum melongena* L. (Solanaceae) around the world (Cobanoglu 1989, Grewal 1992, Kapoor *et al.* 1997, Singh & Singh 1999, Kumral & Kovanci 2005, Can & Cobanoglu 2010, Ozsisli & Cobanoglu 2011, Reddy *et al.* 2011, Kumral & Cobanoglu 2016). Amongst them, *Tetranychus urticae* is a common eggplant pest (Grbic *et al.* 2011, Migeon & Dorkeld 2016). Both red and green morphological forms of the spider mite are very harmful to Solanaceous (Soysal & Yayla 1988, Grewal 1992, Kapoor *et al.* 1997, Brar *et al.* 2003, Leite *et al.* 2003, Kumral & Kovanci 2005, Ozsisli & Cobanoglu 2011, Can & Cobanoglu 2010). During the production of eggplants, the mite causes high fruit losses due to it feeding on chlorophyll and pigments of eggplant leaves. These leaves, which have reduced assimilation and photosynthesis, are prone to desiccation and such effects lead to high product losses due to high water loss (Tomczyk & Kropczynska 1985, Grewal 1992, Kapoor *et al.* 1997, Singh & Singh 1999, Brar *et al.* 2003, Leite *et al.* 2003, Kumral & Kovanci 2005).

For controlling the pest, the intensive use of pesticides leads to both decreasing natural enemy populations and increasing environmental pollution (Kumral & Kovanci 2005, Simon 2014). When pesticides are used recurrently, the spider mite can develop resistance to some acaricides and insecticides (Van Leeuwen *et al.* 2010, Whalon *et al.* 2016). In recent years, as an alternative to pesticides, predator mites, phytoseiides, have been commercially produced and used for controlling *T. urticae* particularly in greenhouses (Moon *et al.* 2006, Stansly

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et al. 2009, Shibao *et al.* 2009, Kilincer *et al.* 2010). Instead of such a single application, combined strategies “Integrated Pest Management” could increase successes of the mite control. Therefore, one of the most important components of the strategy is the use of pest resistant cultivars or lines of host plants. As an alternative to pesticides, the use of resistant eggplant varieties may help keep the damage below the economic damage level. Although eggplants are more preferred by *T. urticae* than other solanaceous plants (Van Den Boom *et al.* 2003, 2004), some cultivars of the plant can be less suitable for the mite (Khanamani *et al.* 2013). Similarly, preference, development and reproduction differences in *T. urticae* were shown in different cultivars of some Solanaceous plants (Zatyko & Martinovich 1986, Hoy 2011, Atalay & Kumral 2013, Keskin & Kumral 2015). To date, the biology and life table parameters of *T. urticae* on the eggplant has been rarely investigated (Khanamani *et al.* 2013) and biological performances of different Turkish eggplant cultivars have not been determined yet.

The host plant preference of any pest species can be exhibited by determining developmental duration and survival of its immature stages and oviposition and longevity of its mature stages (Sedaratian *et al.* 2011). In addition, some biodemographic parameters can show the population growth potential of any pest on its hostplant (Birch 1948). For this purpose, the development, survival and biodemographic parameters of *T. urticae* were determined on leaf-disc in Petri dishes on seven Turkish eggplant cultivars in controlling conditions during 2015-2017.

Materials and methods

Eggplant cultivars and growth

Seven common Turkish cultivars of eggplant (*Solanum melongena* L.) were used in this study, namely Anamur, Aydin Siyahi, Kemer, Topan 374 (Bursa Tohum, Turkey), Balikesir 76, Pala 49, Yalova Topan (Ataturk Horticultural Central Research Institute, Yalova, Turkey). The seeds of these cultivars were sown in a peat medium (Klasmann TS 1–Deilmann, Geeste, Germany). Three weeks after sowing, the seedlings were transplanted into 1.5-L pots filled with peat and placed in a controlled growth room with a 16L:8D photoperiod at $27 \pm 1^\circ\text{C}$, $65 \pm 5\%$ RH. Seedlings were irrigated every three days with tap water and fertilized weekly with 100 mL water soluble fertilizer containing [3% total nitrogen, 7% phosphorus, 4.5% potassium, 0.1% sulphur, 0.25% iron, 0.01% copper, 0.1% zinc, 0.1% manganese, 0.01% Boron and 0.001% molybdenum] prepared by Uludag University, Department of Soil Science and Plant Nutrition (Bursa, Turkey). Four weeks after transplanting, five fully developed uniform plant leaves were used for experiments.

Spider mite colony

Mites *Tetranychus urticae* Koch (Acari: Tetranychidae), used in the experiment come from a mass culture maintained for at least 8 years on potted bean plants in our laboratory. The colony was mass reared in a climate-controlled growth room with a 16 h Light (L): 8 h Dark (D) photoperiod at $27 \pm 1^\circ\text{C}$, $65 \pm 5\%$ RH. Synchronous colonies of *T. urticae* were provided by rearing at least two generations on each experimental eggplant cultivar.

Development and survival of developmental stages

The leaf disc in Petri dish method described by Keskin & Kumral (2015) was used. But the Petri dishes and eggplant leaflet have a larger diameter (120 mm) in our study. For mating, a female teliochrysalid and two males were placed onto each leaf disc. The leaf discs were placed inside an insectarium (Nüve, Ankara, Turkey) with a 16L:8D photoperiod at $27 \pm 1^\circ\text{C}$, $65 \pm 5\%$ RH. After the females oviposited, both sex adults were removed from leaflets. The leaflets were checked twice a day in immature stages, and the duration and mortality of different immature

stages were recorded using a stereomicroscope. The leaves were changed every week and mites were transferred to these fresh leaves. Non-hatched eggs and dead immatures were recorded to calculate survival rates.

Oviposition and life table parameters

After a new generation of females emerged, the durations of preoviposition, oviposition, postoviposition, the daily fecundity and longevity of each female were recorded daily during her life. Daily age-specific survival (l_x) and fecundity (m_x) rates were calculated with the method identified for each eggplant cultivar by Birch (1948) by using RmStat-3 software (Ozgokce & Karaca 2010). The net reproductive rate (R_0), the mean generation time (T), the finite rate of increase (λ) and the doubling time (DT) were calculated based on Birch (1948) method by using RmStat-3 software (Ozgokce & Karaca 2010).

Statistical analysis

Some biological data (development and oviposition durations, fecundity, longevity, life table parameters) were compared among the seven eggplant cultivars with one-way analysis of variance (ANOVA) analysis followed by Tukey's multiple comparison tests using the statistical software SPSS 23. Differences of adult development in terms of gender were determined with two-way ANOVA using SPSS 23. Hatch and survival rates were compared with chi-square test by software SPSS 23. The bootstrap technique was used to estimate the means, variances and standard errors of the population parameters (r_m , R_0 and T) by software SPSS 23. To generate variable results, it was used for 1,000 replications using this method (Efron and Tibshirani 1993). The normality of the pseudovalues was tested with the Shapiro-Wilk test using software SPSS 23. Non-normality data was log-transformed, before subjected to the one-way ANOVA.

Results

Survival and Development

Tetranychus urticae successfully developed on all experimental eggplant cultivars at 16L:8D photoperiod at $27 \pm 1^\circ\text{C}$, $65 \pm 5\%$ RH and survival rates of immatures are given in Table 1. Although the survival rate of *T. urticae* was varied from 55.51 on Anamur to 83.52 on Kemer, the differences were not significant (Table 1). The total developmental time was 9.16 to 11.47 days for females and 7.67 to 10.12 days for males feeding on the seven eggplant cultivars (Table 2). Developmental times of egg ($F_{6,539} = 45.49$; $P < 0.01$) and all mobile juvenile stages (larva $F_{6,495} = 7.72$, protonymph $P < 0.01$ $F_{6,465} = 21.73$; $P < 0.01$, deutonymph $F_{6,406} = 10.18$; $P < 0.01$) were affected by the eggplant cultivar. Additionally, significant differences were observed for the total development time of *T. urticae* feeding on different eggplant cultivars ($F_{13,460} = 21.51$; $P < 0.01$). The development times were significantly longer on the Pala 49 cultivar and shorter on the Aydin siyahi, Topan 374 and Yalova Topan cultivars for both male and female development. In terms of two-way ANOVA, both gender and cultivar effects were found to be significant (cultivar $F_{6,6} = 20.51$; $P < 0.01$; gender $F_{1,1} = 23.39$; $P < 0.01$; cultivar x gender $F_{6,6} = 3.70$; $P < 0.01$).

Adult longevity and Oviposition

The female longevity of adult *T. urticae* was significantly different on tested cultivars ($F_{6,71} = 5.51$; $P < 0.01$). But a significant difference was not observed in the value of fecundity ($F_{6,71} = 1.74$; $P = 0.125$) (Table 3). The female mites lived longer on Aydin siyahi cultivar (20.62 days) followed by Topan 374 (20.38 days) compared with just Yalova Topan and Anamur cultivars. There was no significant differences between the five cultivars except for Yalova Topan and Anamur cultivars. Except postoviposition period, the preoviposition and oviposition durations

Table 1 Hatchability and survival rate of immature stages of *Tetranychus urticae* on different eggplant cultivars.

Stages		Hatchability (%)	Survival rate in larvae (%)	Survival rate in protonymph (%)	Survival rate in deutonymph (%)	Survival rate (egg to adult) (%)
Cultivars	n					
Anamur	107	83.70	89.47	85.88	86.30	55.51
Aydin Siyahi	106	91.51	86.59	91.67	97.41	70.75
Balikesir 76	65	81.54	84.91	86.67	94.87	56.92
Kemer	91	93.41	94.12	95.00	97.38	83.52
Pala 49	77	81.82	92.06	75.86	94.55	71.43
Topan 374	82	86.81	81.18	82.50	72.09	75.61
Yalova Topan	116	94.83	88.18	82.47	96.25	66.38
χ^2 (df = 6)		2.13	1.30	2.81	5.95	8.77
P		0.907	0.972	0.832	0.429	0.187

of varied significantly among the eggplant cultivars (preoviposition $F_{6,71} = 3.13$; $P < 0.01$, oviposition $F_{6,71} = 4.10$; $P < 0.01$, postoviposition $F_{6,71} = 0.56$; $P = 0.76$) (Table 3). Similarly, the oviposition period of Yalova Topan was significantly lower (9.42 days) than other cultivars. But, no significant differences among oviposition period on Yalova Topan, Anamur, Kemer and Pala 49 cultivars were determined. Although the longest oviposition period was observed on Aydin siyahi (16.85 days), Balikesir 76 (16.60 days) and Topan 374 (16.15 days) cultivars, there are no significant effects on the other cultivars except for Yalova Topan. The age-specific survival rate (l_x) and fecundity (m_x) curves of *T. urticae* on different eggplant cultivars are given in Figure 1.

The curves of age specific survival rate revealed that longevity of *T. urticae* is shortened depending on eggplant cultivars. Female longevity in Aydin Siyahi, Balikesir 76, Kemer and Topan 374 cultivars was much longer than other cultivars, Anamur, Pala-49 and Yalova Topan. The curves of age specific fecundity showed that oviposition pattern varied among the eggplant cultivars, however, *T. urticae* females gave the maximum amount of female individuals between the 13th and 16th days in all cultivars. The females began to oviposit on the 9th or 10th days in all cultivars and terminated until the 24th–28th days for Anamur, Pala-49 and Yalova Topan, the

Table 2 Mean ($\pm$ SE) developmental time (days) of *Tetranychus urticae* on different eggplant cultivars.

Stages	Egg	Larva	Protonymph	Deutonymph	Total development	Total development ♂
Cultivars						
Anamur	3.09 $\pm$ 0.04c	2.12 $\pm$ 0.03a	2.20 $\pm$ 0.04a	2.09 $\pm$ 0.07bc	9.83 $\pm$ 0.05bc	8.97 $\pm$ 0.03def
Aydin Siyahi	3.29 $\pm$ 0.05c	1.75 $\pm$ 0.05bc	1.55 $\pm$ 0.06cd	1.91 $\pm$ 0.05cd	9.16 $\pm$ 0.12de	8.54 $\pm$ 0.15efg
Balikesir 76	3.79 $\pm$ 0.12b	1.84 $\pm$ 0.09abc	1.93 $\pm$ 0.09ab	2.33 $\pm$ 0.12abc	10.31 $\pm$ 0.31b	9.85 $\pm$ 0.36bc
Kemer	3.75 $\pm$ 0.07b	1.74 $\pm$ 0.08bc	2.00 $\pm$ 0.07ab	1.88 $\pm$ 0.09cd	10.09 $\pm$ 0.18b	8.57 $\pm$ 0.15ef
Pala 49	4.39 $\pm$ 0.09a	2.02 $\pm$ 0.15ab	2.15 $\pm$ 0.12a	2.64 $\pm$ 0.23a	11.47 $\pm$ 0.35a	10.12 $\pm$ 0.27bc
Topan 374	3.66 $\pm$ 0.06b	1.54 $\pm$ 0.06c	1.40 $\pm$ 0.07d	2.33 $\pm$ 0.09ab	9.43 $\pm$ 0.15cd	7.67 $\pm$ 0.18g
Yalova Topan	3.70 $\pm$ 0.05b	1.92 $\pm$ 0.06ab	1.76 $\pm$ 0.06bc	1.59 $\pm$ 0.09d	9.18 $\pm$ 0.12de	8.41 $\pm$ 0.15fg

* Means followed by the same letter in a column are not significantly different (Tukey, $P < 0.05$).

Figure 1 Age-specific survival rate (l_x), age-specific fecundity rate (m_x) and $l_x m_x$ curves in *Tetranychus urticae* on different eggplant cultivars; l_x = (egg hatchability)*(proportion of females alive at age x), m_x = (proportion of females)*(age-specific oviposition).

Table 3 Mean ($\pm$ SE) daily egg production, oviposition duration and adult female longevity (days) of *Tetranychus urticae* on different eggplant cultivars.

Stages	Adult female longevity (days)	Preoviposition (days)	Oviposition (days)	Postoviposition (days)	Total number of eggs/female
Cultivars					
Anamur	14.00 $\pm$ 0.76bc	1.30 $\pm$ 0.15ab	12.20 $\pm$ 0.77ab	1.60 $\pm$ 0.16a	45.50 $\pm$ 6.28a
Aydin Siyahi	20.62 $\pm$ 1.56a	1.31 $\pm$ 0.18ab	16.85 $\pm$ 1.31a	2.46 $\pm$ 0.42a	69.69 $\pm$ 4.97a
Balikesir 76	19.40 $\pm$ 2.03abc	1.00 $\pm$ 0.21b	16.60 $\pm$ 2.31a	2.30 $\pm$ 0.89a	58.60 $\pm$ 8.46a
Kemer	16.14 $\pm$ 1.30abc	0.93 $\pm$ 0.07b	12.64 $\pm$ 1.49ab	2.50 $\pm$ 0.44a	71.14 $\pm$ 7.37a
Pala 49	14.33 $\pm$ 1.02abc	1.17 $\pm$ 0.31ab	11.83 $\pm$ 1.35ab	1.50 $\pm$ 0.96a	48.17 $\pm$ 4.19a
Topan 374	20.38 $\pm$ 1.38a	1.84 $\pm$ 0.25a	16.15 $\pm$ 1.34a	2.39 $\pm$ 0.49a	63.92 $\pm$ 7.77a
Yalova Topan	13.17 $\pm$ 0.64c	1.16 $\pm$ 0.11ab	9.42 $\pm$ 0.87b	2.58 $\pm$ 0.39a	55.50 $\pm$ 8.47a

* Means followed by the same letter in a column are not significantly different (Tukey, $P < 0.05$).

34th–35th days for Aydin Siyahi, Balikesir 76, Kemer and Topan 374.

Life table parameters

The values of life table parameters of *T. urticae* on the seven eggplant cultivars are shown in Table 4. The most important parameters, r_m , R_0 and T , of *T. urticae* differed between the eggplant cultivars ($r_m F_{6,56} = 22.82$; $P < 0.01$, $R_0 F_{6,56} = 237.92$; $P < 0.01$, $T F_{6,56} = 2.52$; $P = 0.03$). The r_m value of *T. urticae* was significantly the lowest for Pala 49 (0.218) followed by Anamur (0.242) and Topan 374 (0.242). The highest r_m value of the spider mite was found in the other cultivars, Aydin Siyahi, Balikesir 76, Yalova Topan and Kemer. Similarly, R_0 value was significantly lowest for Pala 49 (26.74) and Anamur (30.46) cultivars. The significant highest R_0 value of *T. urticae* was determined in Aydin Siyahi cultivar (45.51). Differently, the T value of *T. urticae* for Balikesir 76 and Yalova Topan was significantly the lowest (13.31 and 14.11, respectively) followed by Anamur, Aydin Siyahi and Kemer. The GRR of the mite showed similar results of its R_0 . The shortest doubling time (D) was found for Aydin Siyahi, Balikesir 76, Kemer and Yalova Topan cultivars. The λ value of *T. urticae* exhibited similar to its D value for all eggplant cultivars.

Table 4 Life table parameters of population growth in *Tetranychus urticae* on different eggplant cultivars.

Parameters	Intrinsic rate of natural increase (r_m)	Net reproductive rate (R_0) (female/female/generation)	Mean generation time in days	Gross reproduction rate (GRR) (female egg/female/generation)	Doubling time (D) days	Finite rate of increase (λ) (individual/female/day)
Cultivars						
Anamur	0.242b	30.46d	14.13c	32.79	2.87	1.274
Aydin Siyahi	0.269a	45.51a	14.15c	52.36	2.57	1.31
Balikesir 76	0.267a	35.11c	13.31d	40.94	2.59	1.307
Kemer	0.259a	42.69b	14.52c	57.32	2.68	1.295
Pala 49	0.218c	26.74e	15.06b	27.46	3.18	1.244
Topan 374	0.242b	42.09b	15.45a	47.76	2.86	1.274
Yalova Topan	0.265a	42.15b	14.11bcd	56.79	2.62	1.304

* Means followed by the same letter in a column are not significantly different (Tukey, $P < 0.05$).

Discussion

The present study indicated that eggplants are one of the favourable hosts for *T. urticae*, allowing shorter development durations of the immature stages. The development of the mite completed in 7.7–10.1 days for males and 9.2–11.5 days for females. The immature developmental time was very similar with the values (9.1–11.2) reported by Khanamani *et al.* (2013) on seven Indian eggplant cultivars. In addition, these durations are very close with previous studies performed on different suitable hosts in the same climatic condition: sweet pepper (11.7 days), cucumber (10.4 days), bean (10.9 days) and tomato (11.6 days) plants (Zatyko & Martinovich 1986; Kasap 2002; Razmjou *et al.* 2009; Atalay & Kumral 2013; Kumral *et al.* 2017). In the current study, a remarkable result is that the development durations of some eggplant cultivars are very close to bean values which are the most suitable host for *T. urticae* (Kasap 2002). This result is consistent with Van Den Boom *et al.* (2004) and suggests that eggplants have got a weak direct defense level against *T. urticae* due to poor defensive content of the host plant. In addition, compared with all experimental eggplant cultivars in this study, the lower immature development durations of the spider mite was determined in some eggplant cultivars: Aydin Siyahi, Yalova Topan and Topan 374. A faster developmental time of an arthropod species on its host indicates higher susceptibility of the host plant (Golizadeh *et al.* 2017). The other important factor that affects population growth of a spider mite is survival rates on its host plant (Crooker, 1985). In the present study, although high survivality rates were observed in some eggplant cultivars, Aydin Siyahi, Kemer, Pala 49 and Topan 374, the differences were not statistically significant.

It is well known that the host plant quality can affect fecundity rate of their herbivore (Price *et al.* 1980). In the current study, the oviposition period was found as 9.42–16.85 days and the number of eggs per female was 45.50–71.14. These durations and values were determined as 5–13 days and 85–276 eggs for tomato; 24 days and 231 eggs for bean; 19 days and 124 eggs for soybean; 21 days and 172 eggs in cucumber; 7–13 days and 22–56 eggs for sweet pepper plants (Kasap 2002, Dehghan *et al.* 2009, Razmjou *et al.* 2009, Atalay & Kumral 2013; Kumral *et al.* 2017). Compared the most favourable host plants, i.e. beans and cucumbers, the oviposition durations of *T. urticae* on our eggplant cultivars were found to be very similar, but its fecundity rate was found to be lower than the host plants. Similarly, the results of Khanamani *et al.* (2013) showed that *T. urticae* females can survive for a very long duration (17.8–19.1 days) on Indian eggplant cultivars, but the reproductivity is lower (5.25–29.23 eggs/female) compared with the most preferred host plants. Our results conform to the longevity results of Khanamani *et al.* (2013) that *T. urticae* feed on seven Indian eggplant cultivars. Differently, *T. urticae* females that fed on Aydin Siyahi, Kemer and Topan 374 cultivars showed the highest fecundity rates in our study, but the differences among the cultivars were not statistically significant.

Some biodemographic parameters can be shown in the population growth potential of any pest on its hostplant (Birch 1948). In the present study, the r_m and R_0 values of *T. urticae* that fed on the seven eggplant cultivars were found as 0.218–0.269 and 26.47–45.51. These values were much greater than the findings of Khanamani *et al.* (2013) when *T. urticae* females reared on Indian eggplant cultivars (0.031–0.157 and 1.5–11.6). On the other hand, our r_m values were very close compared with the results on the most favourable host plants beans (0.27), soybeans (0.26) and tomatoes (0.26–0.29) (Kasap 2002; Dehghan *et al.* 2009; Atalay & Kumral 2013). The r_m value of *T. urticae* varies between 0.22 and 0.34 in the optimum conditions and host plants conditions as reported by Sabelis (1985). Because fewer females for each generation are produced by *T. urticae* females feed on the seven eggplant cultivars, the R_0 values were found to be much less than the favourable host plants i.e. beans (185.4), soybeans (59–66) and tomatoes (49–131) (Kasap 2002; Dehghan *et al.* 2009; Atalay & Kumral 2013; Najafabadi *et al.* 2014). In addition, both the r_m and R_0 values of *T. urticae* were found to be significantly higher in Aydin Siyahi and Kemer, Topan 374 and Yalova Topan cultivars compared with the values of the other cultivars. This difference between the cultivars is likely related to the lack of nutrients that are effective in fecundity of the mite (Van Den Boom *et al.* 2004). As reported

by Crooker (1985), host plant nitrogen content is associated with increases in spider mite populations, often through effects on fecundity. Because the chemical and nutrient contents of the seven eggplant cultivars are not known, it is not possible to explain the reasons with the findings of this study.

Considering the results of these life table parameters, eggplants can be regarded as a less suitable host plant compared to beans and soybeans in accordance with the findings of Van Den Boom *et al.* (2003; 2004). But, eggplants are very much preferred by *T. urticae* due to its weak direct defense mechanism against *T. urticae* as indicated by the researchers. However, when compared to other resistant eggplant cultivars (Khanamani *et al.* 2013), it is not possible to declare that any Turkish eggplant cultivar tested in this study (i.e. Anamur, Pala 49 and Balikesir 76) is resistant to *T. urticae*. But, the four (Aydin Siyahi and Kemer, Topan 374 and Yalova Topan) have been found to be potentially susceptible cultivars to *T. urticae* because they have got high population growth parameters which are very close to their most favourable plant species.

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