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## THE IMPACT OF CUCUMBER NITROGEN NUTRITION ON LIFE HISTORY TRAITS OF *TETRANYCHUS URTICAE* (KOCH) (ACARI: TETRANYCHIDAE)

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**ABSTRACT** — The nutritional quality of the host plant is one of the most important factors of growth and reproduction for crop pests. In order to investigate the impact of nitrogen on the biology and demography of *Tetranychus urticae* Koch (Acari: Tetranychidae), cucumber plants were nourished by four levels of nitrogen: N<sub>1</sub> (10 meq /L NO<sub>3</sub><sup>-</sup>), N<sub>2</sub> (12 meq/L NO<sub>3</sub><sup>-</sup>), N<sub>3</sub> (15 meq/L NO<sub>3</sub><sup>-</sup>) and N<sub>4</sub> (20 meq /L NO<sub>3</sub><sup>-</sup>). The experiments were performed under laboratory conditions at 25±1 °C, 60±5 % RH and a photoperiod of 16:8 (L:D) hours. Based on the results, increasing nitrogen nutriment was associated with a diminution of pre-imaginal duration in female mites from 13.13 to 10.74 days. In the opposite direction, the population reared on nitrogen-deficient cucumbers exhibited the highest rates of net fecundity (36.79 eggs/female) and net fertility (27.22 eggs/female). However, no considerable variation was demonstrated in fertility life-table parameters. The greatest net reproductive rate ( $R_0$ ) was observed when using the deficient (N<sub>1</sub>) nitrogen solution (22.12 females/female/generation). Additionally, the intrinsic rate of natural increase ( $r_m$ ) was estimated to be 0.178, 0.171, 0.183 and 0.185 females/female/day on cucumbers which were nourished by 10 to 20 meq/L NO<sub>3</sub><sup>-</sup>, respectively. Finally, the mean population doubling time ( $DT$ ) ranged from 3.72 to 4.04 days, and was at a minimum with the excess (N<sub>4</sub>) nitrogen solution and at a maximum with the moderately deficient (N<sub>2</sub>) treatment.

**KEYWORDS** — two-spotted spider mite; biology; life table parameters; nitrogen; cucumber

### INTRODUCTION

The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae) has been considered as one of the most deleterious pests of many crops throughout the world (Zhang, 2003). TSSM as one of the most abundant pests of cucumber inflicts sever damages on this crop (Hussey and Parr, 1963). Leaves infected by this mite have more or less irregular yellow spots on upper surface owing to mites feeding from leaf cell contents. Moreover, dam-

age from this pest are mainly associated with webbing structures, thereby photosynthesis and transpiration are reduced in plants (Martinez-Ferrer *et al.*, 2006).

The population density, developmental periods, reproduction potential and survivorship of *T. urticae* are influenced by numerous characteristics of host plant such as varieties, nutritional quality, leaf structures, etc. (Wermelinger *et al.*, 1991; Steinite and Ievinsh, 2003; Razmjou *et al.*, 2009). Nitro-

gen (N) has been known as a pivotal macronutrient for plant nutrition that plays an important role for herbivore performance (Scriber and Slansky, 1981). This mineral nutrient is required in highest amounts by plants and most frequently limiting the growth and yield of crops (Daniel-Vedele *et al.*, 2010). Deficiency of nitrogen leads to breakdown proteins and redistribution from older leaves to younger organs in plants (Zhong-Xian, 2007). While, high levels of nitrogen diminish some secondary metabolites such as phenolic compounds which are major determinants of plant resistance to phytophagous pests (Muzika and Pregitzer, 1992). Several studies have been conducted to clarify the impact of nitrogen on biology and reproductive parameters of *T. urticae* and most of obtained results have revealed a positive correlation between nitrogen concentrations and fecundity of two-spotted spider mites (Hoffland *et al.*, 2000; Chow *et al.*, 2009). Hence, the aim of this research was to quantify the effect of different nitrogen concentrations in hydroponic solutions on biology and demographic parameters of two-spotted spider mite reared on cucumber under laboratory condition.

## MATERIALS AND METHODS

**Mite colony** — The stock population of two-spotted spider mite was collected from infested greenhouses of Pakdasht and Varamin in Tehran province in Iran during the summer 2011. The colony was maintained on bean plants (*Phaseolus vulgaris* L. cv. Khomein) in a growth chamber at  $25\pm 1$  °C,  $60\pm 5$  % RH and a photoperiod of 16:8 L:D h.

**Plant cultivation** — The seeds of *Cucumis sativus* L. Sultan variety were obtained from Fallat Iran seed producing Co. These seeds were sown in plastic pots filled by perlite (33 %), sand (33 %) and sawdust (33 %). The plants were grown in greenhouse condition at  $25\pm 5$  °C,  $50\pm 20$  % RH and a photoperiod of 16:8 L:D h. All plants were nourished hydroponically at 48 hours intervals by 150 milliliter (mL) of nutrient solutions from each treatment including  $N_1$  (10 milliequivalent/Liter  $NO_3^-$ , Nitrogen deficient nutrient solution),  $N_2$  (12 meq/L  $NO_3^-$ , Nitrogen deficient nutrient solution),  $N_3$  (15

meq/L  $NO_3^-$ , Standard nutrient solution) and  $N_4$  (20 meq/L  $NO_3^-$ , Nitrogen excess nutrient solution), separately.

**Nutrient solutions** — In order to prepare nutrient solutions of each treatment, first A, B, C and iron chelate stock solutions were prepared (Table 1). Then, 10 mL A, 10 mL B from each treatment, 5 mL C and 5 mL iron chelate were mixed together and finally were diluted in one liter distilled water (Morard, 1973; Morard *et al.*, 1990). The pH of the nutrient solutions was adjusted to 5.8 by 1 molar NaOH.

**Experiments** — Before starting the experiments, mites were separately reared at least one generation on cucumbers which were nourished by different nitrogen concentrations. In order to assess biology and demographic parameters of TSSM, leaf discs (2 cm diameter) were cut out from fifth and sixth leaves of 1.5 month-old plants (105 – 110 replications for each treatment). Male mites appeared earlier than females. They waited besides teleiochrysalis females and mated immediately after the emergence of adult females. Then, adult females from each treatment were transferred to leaf discs with a soft brush for laying eggs. Eight hours later, all eggs except one per leaf disc were removed. These leaf discs were kept inside the growth chamber at  $25\pm 1$  °C,  $60\pm 10$  % RH and a photoperiod of 16:8 L:D h. Thereafter, leaf discs were checked every 12 hours and the duration of developmental stages was noted for each treatment until attaining adulthood. After emergence, each female was paired with a male from the same rearing colony. Afterwards, the number of eggs laid by each female was recorded every 24 h until the last female died. Once the leaf discs lost its freshness, new leaf discs were punched out from cucumbers and mites were transferred to the new leaf discs during the trials.

**Statistical analysis** — All data of developmental times, longevity, reproduction and stable population growth were analyzed by using one-way ANOVA (PROC GLM, SAS Institute 2003). Age-specific survival rates ( $l_x$ ) and average number of female offspring ( $m_x$ ) for each age interval ( $x$ ) were used to construct age-specific fertility life tables. Using survivorship and fertility life table, the de-

TABLE 1: Components of stock solutions (gram/Liter).

Stock solutions	Components	g*L <sup>-1</sup>
<b>A</b>	KH <sub>2</sub> PO <sub>4</sub>	27.2
	MgSO <sub>4</sub> .7H <sub>2</sub> O	37
<b>B(N<sub>1</sub>)</b>	Ca( NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	118.1
	KCl	37.2
<b>B(N<sub>2</sub>)</b>	Ca( NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	118.1
	KNO <sub>3</sub>	20.2
	KCl	22.3
<b>B(N<sub>3</sub>)</b>	Ca( NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	118.1
	KNO <sub>3</sub>	50.5
<b>B(N<sub>4</sub>)</b>	Ca( NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	118.1
	KNO <sub>3</sub>	50.5
	NaN <sub>3</sub>	42.4
<b>C</b>	MnSO <sub>4</sub> .7H <sub>2</sub> O	1.5
	ZnSO <sub>4</sub> .7H <sub>2</sub> O	0.5
	CuSO <sub>4</sub> .5H <sub>2</sub> O	0.3
	Na <sub>2</sub> M <sub>10</sub> O <sub>4</sub> .2H <sub>2</sub> O	0.03
	B <sub>3</sub> H <sub>3</sub>	1.5
<b>Iron chelate</b>	Fe-EDDHA	16.7

N<sub>1</sub>: Nitrogen-deficient stock solution (10 meq/LN); N<sub>2</sub>: Nitrogen-deficient stock solution (12 meq/LN); N<sub>3</sub>: Standard stock solution (15 meq/LN); N<sub>4</sub>: Nitrogen-excess stock solution (20 meq/LN).

demographic parameters of TSSM including net reproductive rate ( $R_0$ ), intrinsic rate of increase ( $r_m$ ), finite rate of increase ( $\lambda$ ), mean lifetime ( $T$ ), doubling time ( $DT$ ) were calculated. All formulae for computing demographic parameters are consistent with Carey (2001) as follows:

$$\text{Net Reproductive Rate} = \sum_{x=1}^{\omega} l_x m_x$$

$$\text{Intrinsic Rate of Increase} = \sum_{x=1}^{\omega} l_x m_x e^{-rx} = 1$$

$$\text{Finite Rate of Increase} = e^r$$

$$\text{Doubling Time} = \frac{\text{Ln}2}{r}$$

$$\text{Mean Generation Time} = \frac{\text{Ln}R_0}{r}$$

Where  $e$  is the base of natural logarithms,  $x$  is the individual age,  $l_x$  is the probability of an individual surviving to age  $x$  and  $m_x$  is the age-specific number of female offspring. The Jackknife technique was applied to estimate the variance of the reproductive parameters and other estimates for the life table parameters (Maia *et al.*, 2000). If significant differences were observed, multiple comparison were made using Student – Newman – Keuls (SNK) test at 0.05 probability level. Normality test was carried out using Kolmogorov – Smirnov test prior to statistical analysis (MINITAB 2000).

## RESULTS

### Developmental time and adult longevity

Effects of different concentrations of nitrogen nutrient solution on pre-imaginal durations and adult longevity of two-spotted spider mite are summarized in table 2.

There were no statistical differences among the mean durations of protochrysalis, protonymph and deutonymph stages in both sexes. The male incubation period ranged from 4.11 to 5.50 days on  $N_4$  and  $N_2$  treatments, respectively ( $F=3.2$ ;  $df=3$ , 65;  $p=0.0291$ ), while female incubation period was shorter on plants which received 15meq/L  $NO_3^-$  ( $F=4.22$ ;  $df=3$ , 123;  $p=0.007$ ). In addition, the increase in nitrogen hydroponic solution concentration was associated with a diminution of larval period in male and female mites. Likewise, the deutochrysalis period with  $N_2$  level was longer than those with other levels in both sexes. Meanwhile, teleiochrysalis females duration was reduced on cucumbers fertilized by nitrogen standard ( $N_3$ : 1.01 days) and excess ( $N_4$ : 1.05 days) nutrient solutions ( $F=9.3$ ;  $df=3$ , 126;  $p<0.0001$ ). The mean pre-imaginal duration decreased with increasing nitrogen nutrient concentration of cucumber. It ranged from 9.38 to 13.25 days for males ( $F=4.93$ ;  $df=3$ , 66;  $p=0.0038$ ) and 10.74 to 13.13 days for female mites ( $F=7.09$ ;  $df=3$ , 127;  $p=0.0002$ ), respectively. Further-

more, it can be noticed that standard nutrient solution utilization ( $N_3$ ) led to shortest longevity and life span for both sexes.

### Reproductive periods

Effects of different nitrogen levels on reproductive periods of *T. urticae* are depicted in Table 3.

According to the data, the pre-oviposition period was statistically shorter on cucumbers nourished by  $N_3$  and  $N_4$  levels: 0.72 and 0.75 days, respectively ( $F=7.97$ ;  $df=3$ , 122;  $p=0.0001$ ). Furthermore, the mean oviposition period on plants receiving 10 to 20 meq/L  $NO_3^-$  took 9.96, 11.56, 11.08 and 13.16 days, respectively. Females lived more after oviposition on cucumbers which were nourished by 12 meq/L  $NO_3^-$  (Table 3).

### Age-specific survival rates ( $l_x$ ) and age-specific fecundity ( $m_x$ )

The values of age-specific survival rates ( $l_x$ ) and age-specific fecundity ( $m_x$ ) on various nitrogen treatments are presented in figure 1.

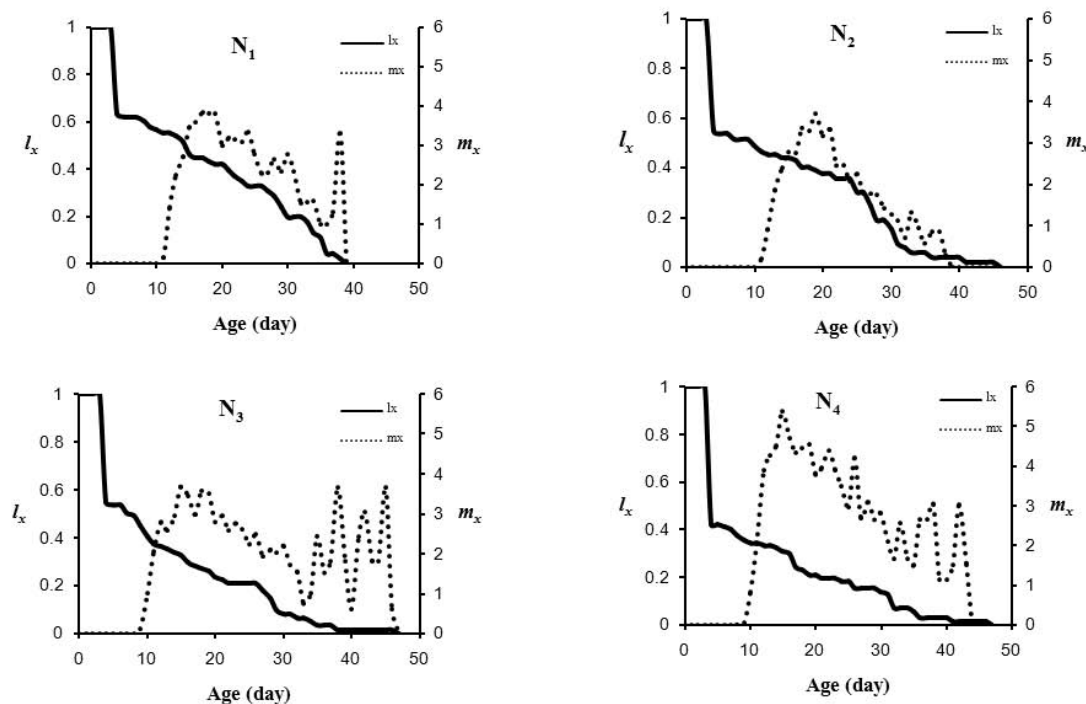


FIGURE 1: Age specific survival rate ( $l_x$ ) and fecundity ( $m_x$ ) of *Tetranychus urticae* on four nitrogen treatments

TABLE 2: Mean duration ( $\pm$ SE) (days) of successive developmental stages of *T. urticae* on cucumbers nourished with four levels of nitrogen.

Stages	sex	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>
Incubation	♀	4.88 $\pm$ 0.17 <sup>a</sup>	4.72 $\pm$ 0.15 <sup>ab</sup>	4.18 $\pm$ 0.18 <sup>b</sup>	4.20 $\pm$ 0.17 <sup>b</sup>
	♂	5.02 $\pm$ 0.24 <sup>ab</sup>	5.50 $\pm$ 0.31 <sup>a</sup>	4.85 $\pm$ 0.20 <sup>ab</sup>	4.11 $\pm$ 0.26 <sup>b</sup>
Larva	♀	1.96 $\pm$ 0.20 <sup>a</sup>	1.63 $\pm$ 0.07 <sup>ab</sup>	1.44 $\pm$ 0.16 <sup>ab</sup>	1.33 $\pm$ 0.10 <sup>b</sup>
	♂	1.73 $\pm$ 0.21 <sup>a</sup>	1.58 $\pm$ 0.14 <sup>ab</sup>	1.32 $\pm$ 0.15 <sup>ab</sup>	0.94 $\pm$ 0.10 <sup>b</sup>
Protochrysalis	♀	1.27 $\pm$ 0.08 <sup>a</sup>	1.30 $\pm$ 0.09 <sup>a</sup>	1.01 $\pm$ 0.09 <sup>a</sup>	1.05 $\pm$ 0.10 <sup>a</sup>
	♂	1.13 $\pm$ 0.06 <sup>a</sup>	1.20 $\pm$ 0.11 <sup>a</sup>	0.94 $\pm$ 0.09 <sup>a</sup>	0.88 $\pm$ 0.11 <sup>a</sup>
Protonymph	♀	1.02 $\pm$ 0.05 <sup>a</sup>	1.01 $\pm$ 0.08 <sup>a</sup>	1.00 $\pm$ 0.09 <sup>a</sup>	0.91 $\pm$ 0.10 <sup>a</sup>
	♂	1.02 $\pm$ 0.10 <sup>a</sup>	0.87 $\pm$ 0.09 <sup>a</sup>	1.05 $\pm$ 0.12 <sup>a</sup>	0.66 $\pm$ 0.08 <sup>a</sup>
Deutochrysalis	♀	1.08 $\pm$ 0.04 <sup>a</sup>	1.12 $\pm$ 0.05 <sup>a</sup>	1.03 $\pm$ 0.13 <sup>a</sup>	0.96 $\pm$ 0.08 <sup>a</sup>
	♂	1.16 $\pm$ 0.07 <sup>ab</sup>	1.26 $\pm$ 0.08 <sup>a</sup>	0.91 $\pm$ 0.07 <sup>b</sup>	0.88 $\pm$ 0.13 <sup>b</sup>
Deutonymph	♀	1.17 $\pm$ 0.06 <sup>a</sup>	1.27 $\pm$ 0.07 <sup>a</sup>	1.05 $\pm$ 0.11 <sup>a</sup>	1.07 $\pm$ 0.06 <sup>a</sup>
	♂	0.92 $\pm$ 0.09 <sup>a</sup>	0.98 $\pm$ 0.09 <sup>a</sup>	0.97 $\pm$ 0.10 <sup>a</sup>	0.77 $\pm$ 0.08 <sup>a</sup>
Teleiochrysalis	♀	1.39 $\pm$ 0.05 <sup>a</sup>	1.25 $\pm$ 0.06 <sup>a</sup>	1.01 $\pm$ 0.04 <sup>b</sup>	1.05 $\pm$ 0.06 <sup>b</sup>
	♂	1.45 $\pm$ 0.09 <sup>a</sup>	1.36 $\pm$ 0.11 <sup>a</sup>	1.14 $\pm$ 0.14 <sup>a</sup>	1.11 $\pm$ 0.21 <sup>a</sup>
Total	♀	13.13 $\pm$ 0.49 <sup>a</sup>	12.53 $\pm$ 0.36 <sup>a</sup>	10.98 $\pm$ 0.44 <sup>b</sup>	10.74 $\pm$ 0.38 <sup>b</sup>
	♂	13.25 $\pm$ 0.70 <sup>a</sup>	12.70 $\pm$ 0.60 <sup>a</sup>	11.20 $\pm$ 0.40 <sup>ab</sup>	9.38 $\pm$ 0.50 <sup>b</sup>
Longevity	♀	13.75 $\pm$ 1.44 <sup>a</sup>	15.47 $\pm$ 1.54 <sup>a</sup>	13.71 $\pm$ 1.52 <sup>a</sup>	16.47 $\pm$ 1.96 <sup>a</sup>
	♂	32.25 $\pm$ 1.25 <sup>a</sup>	29.25 $\pm$ 1.68 <sup>a</sup>	14.16 $\pm$ 2.33 <sup>b</sup>	31.33 $\pm$ 2.83 <sup>a</sup>
Life span	♀	26.42 $\pm$ 1.56 <sup>a</sup>	28.27 $\pm$ 1.51 <sup>a</sup>	24.82 $\pm$ 1.70 <sup>a</sup>	26.30 $\pm$ 1.93 <sup>a</sup>
	♂	44.00 $\pm$ 2.88 <sup>a</sup>	41.25 $\pm$ 2.98 <sup>a</sup>	25.70 $\pm$ 3.55 <sup>b</sup>	39.50 $\pm$ 2.84 <sup>a</sup>

The means in each row with the same letters are not significantly different at 5 % level (SNK)

TABLE 3: The means ( $\pm$ SE) of reproductive periods (days) of *T. urticae* on cucumbers nourished with four levels of nitrogen.

Stages	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>
Pre –oviposition	1.08 $\pm$ 0.07 <sup>a</sup> (41)	1.13 $\pm$ 0.10 <sup>a</sup> (30)	0.72 $\pm$ 0.05 <sup>b</sup> (27)	0.75 $\pm$ 0.04 <sup>b</sup> (28)
Oviposition	9.96 $\pm$ 1.29 <sup>a</sup> (29)	11.56 $\pm$ 1.31 <sup>a</sup> (25)	11.08 $\pm$ 1.18 <sup>a</sup> (23)	13.16 $\pm$ 1.67 <sup>a</sup> (24)
Post – oviposition	1.01 $\pm$ 0.22 <sup>a</sup> (24)	1.60 $\pm$ 0.34 <sup>a</sup> (22)	0.64 $\pm$ 0.13 <sup>a</sup> (21)	1.17 $\pm$ 0.26 <sup>a</sup> (19)

The means in each row with the same letters are not significantly different at 5 % level (SNK).

The numbers in the parentheses indicate the number of replications.

TABLE 4: Reproduction parameters of *T. urticae* on cucumbers nourished with four levels of nitrogen.

Parameter	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>
Gross fecundity rate (eggs/female)	119.87±6.98 <sup>b</sup>	110.83±6.88 <sup>b</sup>	146.43± 5.00 <sup>a</sup>	153.88±7.66 <sup>a</sup>
Net fecundity rate (eggs/female)	36.79±3.41 <sup>a</sup>	32.29±2.88 <sup>ab</sup>	26.68±2.31 <sup>b</sup>	23.48±2.50 <sup>b</sup>
Gross fertility rate (eggs/female)	87.11±6.91 <sup>a</sup>	62.81±5.56 <sup>b</sup>	85.87±4.45 <sup>a</sup>	78.47±3.90 <sup>ab</sup>
Net fertility rate (eggs/female)	27.22±2.52 <sup>a</sup>	21.31±1.90 <sup>b</sup>	16.54±1.43 <sup>bc</sup>	11.97±1.27 <sup>c</sup>
Gross hatch rate (%)	0.74	0.66	0.62	0.51
Mean egg per day (eggs/female/day)	4.05±0.32 <sup>a</sup>	2.64±0.23 <sup>b</sup>	3.64±0.18 <sup>a</sup>	3.66±0.24 <sup>a</sup>
Mean fertile egg per day (eggs/female/day)	3.00±0.23 <sup>a</sup>	1.74±0.15 <sup>b</sup>	2.25±0.11 <sup>b</sup>	1.86±0.12 <sup>b</sup>

The means in each row with the same letters are not significantly different at 5 % level (SNK).

TABLE 5: Population growth parameters of *T. urticae* on cucumbers nourished with four levels of nitrogen.

Parameter	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>
$R_0$ (females/female/generation)	22.12±3.54 <sup>a</sup>	17.71±2.45 <sup>a</sup>	18.26±2.49 <sup>a</sup>	20.32±2.89 <sup>a</sup>
$r_m$ (females/female/day)	0.178±0.009 <sup>a</sup>	0.171±0.008 <sup>a</sup>	0.183±0.009 <sup>a</sup>	0.185±0.007 <sup>a</sup>
$T$ (day)	17.36±0.62 <sup>a</sup>	16.86±0.37 <sup>a</sup>	15.84±1.04 <sup>a</sup>	16.24±0.73 <sup>a</sup>
$DT$ (day)	3.86±0.22 <sup>a</sup>	4.04±0.19 <sup>a</sup>	3.76±0.19 <sup>a</sup>	3.72±0.15 <sup>a</sup>
$\lambda$ (day <sup>-1</sup> )	1.195±0.011 <sup>a</sup>	1.186±0.009 <sup>a</sup>	1.201±0.011 <sup>a</sup>	1.204±0.009 <sup>a</sup>

The means in each row with the same letters are not significantly different at 5% level (SNK).

Comparison of the age-specific survivorship ( $l_x$ ) trends showed approximately similar pattern on all treatments. All the mites were dead after 39.5, 46.5, 46.5 and 46.5 days on plants receiving  $N_1$ ,  $N_2$ ,  $N_3$  and  $N_4$  nitrogen levels, respectively. According to figure 1, the age-specific fecundity varied among different levels of nitrogen. All of age-specific fecundity ( $m_x$ ) peaked soon after the beginning of reproduction period. The age of females at the first day of oviposition were 11, 11, 9 and 9 days, respectively. Also, the maximum fecundity rates were 3.84, 3.70, 3.68 and 5.39 egg/female/day on cucumbers which were nourished by 10, 12, 15 and 20 meq/L nitrogen, respectively.

### Reproductive parameters

The impact of nitrogen on reproductive parameters revealed that further nitrogen led to enhance the mean gross fecundity rate of TSSM ( $F=9.46$ ;  $df=3, 69$ ;  $p<0.0001$ ) (Table 4).

The cohort reared on  $N_2$  treatment exhibited the lowest gross fertility rate (62.81 eggs/female), and those reared on N-deficient cucumber didn't differed from standard and excess nitrogen solutions (87.11 eggs/female) ( $F=4.19$ ;  $df=3, 81$ ;  $P=0.0083$ ). Beside, the highest net fecundity rate ( $F=4.43$ ;  $df=3, 88$ ;  $P=0.006$ ) and net fertility rate ( $F=12.33$ ;  $df=3, 88$ ;  $P<0.0001$ ) were 36.79 and 27.22 eggs/female on cucumbers nourished by 10 meq/L nitrogen. Meanwhile, the hatching rate ranged from 51 % on  $N_4$  to 74 % on  $N_1$  treatments, respectively. Likewise, the mean eggs per day (2.64 eggs/female/day) and mean fertile eggs per day (1.74 eggs/female/day) was the smallest when female mites fed on cucumber with  $N_2$  treatment (Table 4).

### Fertility life-table parameters

The fertility life-table parameters of *T. urticae* on cucumbers which were nourished by different levels of nitrogen are given in table 5.

The net reproductive rate ( $R_0$ ) on nitrogen-deficient treatment ( $N_1$ ) was greater than on the others (22.12 females/female/generation), although not statistically significant. Likewise, the cohort reared on cucumbers with excessive nitrogen ( $N_4$ ) showed

the highest mean intrinsic rate of natural increase ( $r_m$ ) value (0.185 females/female/day). In contrast, those reared on cucumbers which were nourished by 12 meq/L  $NO_3^-$  ( $N_2$ ) achieved the smallest  $r_m$  value (0.171 female/female/day). Additionally, the longest mean generation time ( $T$ ) lasted 17.36 days when fed on plants which were treated by 10 meq/L  $NO_3^-$  ( $N_1$ ). Also, the smallest mean doubling time ( $DT$ ) was 3.72 days on N-excess cucumbers ( $N_4$ ). Meantime, the mean finite rate of increase ( $\lambda$ ) of mites which fed on  $N_4$  treatment had the highest value (1.204  $day^{-1}$ ), whereas  $N_2$  treatment yielded the lowest value (1.186  $day^{-1}$ ) of this parameter.

## DISCUSSION

Host plant quality is an effectual factor affecting the performance of phytophagous pests, survival, fecundity and life expectancy. The nutritional quality of host plant is defined as the amount of critical elements and secondary metabolites in the plants (Awmack and Leather, 2002). Many investigations have been devoted to the study of the impact of nitrogen on crop pests. The present study explicitly elucidated that different nitrogen concentrations in host plant nutrient solution had an influence on some biological and life table parameters of the mite *T. urticae*.

It came out from this research that the pre-imaginal durations of TSSM decreased as the nitrogen concentration in nutrient solution increased from 10 to 20 meq/L  $NO_3^-$ . Parallel to our findings, Wermelinger *et al.* (1985) and Wermelinger *et al.* (1991) found an inverse relationship between pre-adult duration of *T. urticae* and nitrogen effective concentration in apple leaves (75 – 0.6 mmol  $NO_3^-$  i.e. 5N, 1N, 0.2N and 0.04 N). To contrary, the mean developmental time of females (9.2 days) on higher nitrogen-containing apples found by Wermelinger *et al.* (1991) was lower than the value reported in this study. In our opinion, this discrepancy between the results presumably occurred due to different nutritive quantities, plant species and temperature in the trials. Meantime, statistical comparisons showed no significant difference in female

longevity which is in accordance with the results found for *T. urticae* on apple leaves (Wermelinger *et al.*, 1991).

It was especially noteworthy that the mean pre-oviposition period of *T. urticae* feeding on lower nitrogen cucumbers was significantly longer which corroborates the result reported by Wermelinger *et al.* (1991). However, neither oviposition period nor post-oviposition period showed significant variation.

Afterward, we showed that the age specific survival rate dwindled with increasing the mite age, and the highest mortality rate was recorded early in the lifetime on all the nitrogen treatments. These values decreased rapidly and then tend to zero. Also, the immature mortality of mites increased with higher nitrogen concentrations. It might be owing to the repulsion of the host plant quality and its negative effect on the survival of mites.

It is important to mention here that the highest gross fecundity rate was observed with the highest nitrogen concentration in nutrient solution and showed significant differences with N<sub>1</sub> and N<sub>2</sub> treatments. These findings are consistent with results of Chow *et al.* (2009) on roses. But, Wermelinger and Delucchi (1990) found just a slight correlation between level of nitrogen nutriment in host plants and fecundity of TSSM.

Under our study conditions, increase in nitrogen level of nutrient solution had no significant influence on all fertility life-table parameters. In a field trial, Modarres Najafabadi and Vafaei Shoushtari (2010) reported an increasing trend for fertility life-table parameters of *T. urticae* when nitrogen concentration was increased in beans. Also, the application of high nitrogen concentration revealed significant effects on  $r_m$  (0.255 female/female/day) in apple (Wermelinger *et al.*, 1991). According to various demographic studies, several parameters of pests are positively influenced by higher nitrogen nutriment plant. This could be related to some likely reasons. It is well documented in the literature that increasing in plant nitrogen diminishes phenolic compounds which are involved in plant defense (Muzika and Pregitzer, 1992). Deficiency in phenolic compounds may increase sus-

ceptibility of plants to herbivores. Likewise, it has been reported that an increase in nitrogen supply lead to elevated chlorophyll content of leaves and consequently increase intensity of photosynthesis (Baranisrinivasan, 2011). Hence, it seems more likely that food sources are less suitable for mite growth due to low chlorophyll content in N-deficient plants. Besides, water-deficiency occurs in nitrogen-poor plants (Hosseini *et al.*, 2010). Mites tend to feed on well-watered host plants (Sadras *et al.*, 1998). Moreover, it is known that higher nitrogen concentration commonly contributes to an increase in leaf area and a reduction in trichome density of leaves (Kerpel *et al.*, 2006; Leite *et al.*, 2006; Haghghi *et al.*, 2011). So, these characteristics may improve TSSM activities (Alba *et al.*, 2009), because it is difficult for mites to settle on leaves which have a great density of trichomes. Also, the last likely reason is related to potassium quantities in plant. Excess levels of nitrogen content reduce the absorption of potassium in plants (Malvi, 2011). In addition, potassium-deficient plants are most susceptible to pests (White and Karley, 2010). To compare, our data conflict with some published data like Wermelinger and Delucchi (1990) and Wermelinger *et al.* (1991) trials. Some possible reasons for disagreement may be owing to the source of *T. urticae* and implementation methods. There are several reasons for explaining this discrepancy, such as differences in the type of host plant, type of pest, host plant nutritional quality, the concentrations of nutrient solutions, structural features of leaves, secondary metabolites, nutritional inhibitors, experimental condition, genetic differences between races of the pest in different areas, the rate of repellents, plant toxins, food digestion and even the intrinsic resistance of the host plant and differences in nutrient requirements (Dale, 1988; Wermelinger *et al.*, 1991; Alba *et al.*, 2009) Furthermore, few previous studies demonstrated that the quality of food resources used by arthropods is an important factor in plant growth (Hagley and Barber, 1992).

According to Roustae (2005), with excessive use of hydroponic cultivation in greenhouses, presence of a plant nutrition management is inevitable. The foraging results, demonstrate that *T. urticae* has the

potential to achieve high longevity and survival rate when nourished by different levels of nitrogen. There is a possibility that appropriate nutrition of plants in integrated management of pests could increase the effects of other control methods and decline unprincipled use of chemical pesticides. Because proper and moderate nutrition increases host plant resistance against pests due to the characteristics of structural strength and plant anatomical and physiological changes (Hell and Mendel, 2010). Therefore, in the absence of proper management of plant nutrition, farmers bear high costs of fertilizers.

Nevertheless, further research on their biology and evaluation of some important plant indicators, under the field condition are needed. In the present paper, we did not suggest any recommendation. We just provided some data in the case of nitrogen nutriment. Although we did not have any significant difference among the fertility life-table parameters of *T. urticae* on cucumbers which were nourished by different levels of nitrogen, but some important data were found in pre-imaginal period, longevity and survival rate.

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