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Impact of temperature on the life history, reproduction and life table parameters of *Tetranychus urticae* Koch (Acari: Tetranychidae) under laboratory conditions

Heba M Nasr*, Naira S Elmasry, Noura F Abou-Elenien
Department of Plant Protection Research Institute, Agriculture Research Center, Dokki, Giza, Egypt

Abstract
The two spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae), is well known as a phytophagous mite causing considerable damages in major crops even in hot environments as indoor agricultural ecosystem. In order to clarify to what extent *T. urticae* could withstands high temperature, we experimentally investigated the life history of *T. urticae* under five different degrees of temperature (20℃, 25℃, 30℃, 35℃ and 40℃) under laboratory conditions. The study showed that *T. urticae* rapidly adapt to the increase in temperature, its incubation period, life cycle, generation period and reproduction all affected positively with the increase of temperature as showing high significant effect. Also, all measured life table parameters were indicated that the increase of temperature works to benefits of *T. urticae* female, as the generation doubling time decrease to almost only half day at the highest tested temperature, which eventually leads to shifting the threat from *T. urticae* to a higher latitude.

Keywords: *T. urticae*, temperature, biological aspects, life table parameters

Introduction
In cotton fields the two spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) considered as an economic serious pest worldwide, (Mahmoud jokar,2022, Alatawi *et. al*.,2002) [2, 16], because its polyphagous behavior and the wide range of hosts that infest (over 140 families and 1100 plant species), (Brown *et.al*., 2017, Scott *et.al*., 2013) [6, 23]. The population of *Tetranychus urticae* extended in cotton fields in all the territories of Egypt, causing a huge yield loss. Its population can easily outbreak because of its short life cycle and high reproductive rate (Shang *et.al*., 2002) [24]. The population density of mites on host plants is mostly depends on the environmental conditions (Lenort, 2005) [15].
Climatic changes parameters expected to have an important impact on all terrestrial organisms. Temperature considered the main abiotic factor that play a key role in pest population dynamics. (Bonato *et.al*., 1990, Mahmoud jokar, 2002) [5, 16]. The mean surface temperature is predicting to rise by the end of 21_{st} century by (0.3 to 4.8℃), (Ghazy *et.al*., 2019) [11], it's also predicted to interrupt with the biological timing of reproduction and distribution, all of that will depend on the ability of the species to adapt and adjust. The population of *Tetranychus urticae* was found to have positive and negative effect with temperature, (Kumral and Kovanci, 2005, Stavrinides and Mills, 2011) [14, 25]. Therefore, understanding how different mite species may adjust to climatic factors is a key challenge to researcher for having both biological and ecological data for predicting potential problems to conserve rare species and protect from invasive ones.
The current study aims to determine the potential effect of five different degrees of temperature on the two spotted spider mite, (*Tetranychus urticae*) developmental time, fecundity rate and life table parameters.

Material and methods
In this study the two spotted spider mite *Tetranychus urticae* Koch was obtained from cotton fields at Mansoura district which known as a susceptible strain, then mites were reared on cotton leaves in an incubator at 25±2 ℃, the cotton leaves with the lower surface up wards that located on moist- cotton pods in fiber dishes to prevent mite from escaping and providing moisture, the cotton pods were moistened every day. The newly emerged adult females and males were reared at (20℃, 25℃, 30℃, 35℃ and 40℃), each developmental time were calculated for each group and the daily laid eggs were also counted for calculating fecundity rate and life table parameters.

Statistical analysis
Results were analyzed by the life table program (Abou-Setta *et al*., 1986) [1] and L.S.D. values were calculated by Costat program (Costat Software, 1990) [8].

Result and discussion
Effect of different degrees of temperature on the number of days to development at each stage, adult longevity, generation period and life span of *Tetranychus urticae* Koch
Data at table (1) indicated that the incubation period of the two spotted spider mite *T. urticae* decreased as the temperature increased. It takes (6.40, 4.30,2.40, 2.00 &1.20 day) at (20℃, 25℃, 30℃, 35℃ & 40℃), respectively. The life cycle also affected with a huge degree, the longest life cycle was (15.30 days), while the shortest one was (4.10 days) at (20℃ &40℃), respectively. We also found that all the biological aspects durations have the same pattern of effect by the increase of temperature, that all these periods decreased in days with the increase of temperature, as in the generation period it varies from (18.50 day), at 20℃ to only (5.10 day), at 40℃, therefore the increasing of temperature had a huge effect on the two spotted spider mite *T. urticae* population it changed from having about two generations per month for having six generations per month. Also, life span period decreased from (33.90 days) at 20℃ to (21.10 days) at 40℃. These results agreed with (Bonato, 1999, Ebrahim, 2000; Riahi *et. al*., 2013) [4, 9, 20] which they also, illustrated that the temperature considered the main a biotic factor influencing the distribution and abundance of insects and mites in fields.

Table 1: Effect of different degrees of temperature on the number of days to development at each stage, generation period and life span of *Tetranychus urticae* Koch

Stages	20 ℃	25 ℃	30 ℃	35 ℃	40 ℃
Incubation period	6.40 ± 0.52	4.30 ± 0.48	2.40 ± 0.52	2.00 ± 0.00	1.20 ± 0.42
Larvae duration	3.60 ±0.52	3.10 ±0.57	1.80 ±0.42	1.30 ±0.48	1.00 ±0.00
Protonymph	2.70 ± 0.48	2.30 ± 0.48	1.60 ± 0.52	1.50 ± 0.53	1.00 ± 0.00
Tritonymph	2.60 ± 0.52	2.00 ± 0.00	1.30 ± 0.48	1.20 ± 0.42	0.90 ± 0.70
Total immature	8.90 ± 0.57	7.40 ± 0.52	4.70 ± 0.48	4.00 ± 0.47	2.90 ± 0.21
Life cycle	15.30 ± 0.48	11.70 ± 0.48	7.10 ± 0.74	6.00 ± 0.47	4.10 ± 0.52
longevity	18.60 ± 0.55	15.20 ± 0.45	12.00 ± 0.00	13.20± 1.30	17.00± 0.71
Generation period	18.50 ± 0.71	13.90 ± 0.57	8.50 ± 0.97	7.00 ± 0.47	5.10 ± 0.52
Life span	33.90 ± 0.48	26.90 ± 0.48	19.10 ± 0.74	19.20 ± 0.47	21.10 ± 0.52

Female longevity and fecundity were also affected by the change in temperature as shown in table (2). The longest longevity with longest oviposition period and lowest fecundity were (18.60, 12.00 day & 72.80 egg) at 20℃, respectively. While, the shortest female longevity with moderate oviposition period and highest fecundity were (12.00, 8.60 day & 137.20 egg) at 30℃, respectively. On the other hand at the maximum tested temperature (40℃) the fecundity of the female reduced to (30.20 egg), with daily rate of (7.88 egg/ female / day),which means that the female hadn't just only the ability to complete its whole life cycle in very short period of time (4.10 day), but also had the capacity of laying eggs (30.20 egg), clearly not as much as those reared at 30℃ (137.20 egg), but still survive and laying eggs even at 10 degrees higher than its optimum temperature. Also, decreasing the life cycle period about three days from (7.10 day) at 30℃ to (4.10 day) at 40℃ may equivalent that difference in total egg number laid by females. These results agreed with (Chinniah *et.al*.,2007, Maula and Khan 2015; Ghazy *et.al*.,2018) [7, 10, 17] which studied the effect of temperature on *T. urtcae*, and also agreed with (Saeidi and Nemati 2017) [22], who studied the relationship between temperature and developmental rate of mite from the same family (Tetranychidae), and also agreed with (Bhamare *et.al.*, 2018) [3], who studied the effect of weather parameters on population of sucking insect pests.

Table 2: Effect of different degrees of temperature on adult female *Tetranychus urticae* Koch longevity and fecundity

		20℃	25℃	30℃	35℃	40℃
Pre oviposition period		3.20 ± 0.45	2.20 ± 0.45	1.40 ± 1.05	1.00 ± 0.00	1.00 ± 0.00
Oviposition period		12.00 ± 0.71	10.40 ± 0.55	8.60 ± 0.55	5.20 ± 0.45	4.60 ± 0.45
Post oviposition period		3.40 ± 0.55	2.40 ± 0.55	2.00 ± 0.00	7.00 ± 1.22	11.40 ± 0.90
Longevity (Days)		18.60 ± 0.55	15.20 ± 0.45	12.00 ± 0.00	13.20 ± 1.30	17.00 ± 0.71
Fecundity	Egg/Female	72.80 ± 2.68	99.00 ± 3.16	137.20 ± 4.27	67.60 ± 4.45	30.20 ± 1.64
	Daily Rate	6.12 ± 0.50	9.54 ± 0.40	16.00 ± 0.89	13.08 ± 1.38	7.88 ± 1.02

Effect of different degrees of temperature on life table parameters of adult female *Tetranychus urticae* Koch

Life table considered to be the most convenient tool to assess the environmental effects on reproduction, population development and survival. The maximum value of the net reproductive rate, (Ro) which is (females/ female/ generation) was (8754.30 at 30 ℃) but it differed significantly from that at 40℃ to (1674.00) as shown in table (3).

Generation time was ranged from (6.44 to 22.45 days) at (40℃ &20℃), respectively. The intrinsic rate of increase (rm) was higher at increased temperature owing to the short developmental time, which ranged from (0.3665 to 1.1532) at (20℃ & 40℃), respectively. The finite rate of increase (exp $_{rm}$) which is (females/ female/ day) displayed a similar trend to (rm) which its value increased with the increase of temperature degree, while, Generation doubling time had the opposite trend it decreased as the temperature degree increased which ranged from (1.89 to 0.60 day) at (20℃ &40℃), respectively.

The differences among previous results highlight the importance and need for gathering biological measurements under conditions which mimic the new fluctuations in the environmental factors such as temperature. These results agreed with (Ghazy *et. al*, 2019) [11], who studied the impact of global warming scenarios on the life history of *Tetranychus evansi* (Acari: Tetranychidae).

Table 3: Effect of different degrees of temperature on life table of adult female *Tetranychus urticae* Koch

Parameters	20 ℃	25 ℃	30 ℃	35 ℃	40 ℃
Net reproduction rate (Ro)	3739.68	5791.50	8754.30	5366.70	1674.00
Mean generation time (T)	22.45	17.54	10.80	9.11	6.44
Intrinsic rate of increase (rm)	0.3665	0.4941	0.8404	0.9425	1.1532
Finite rate of increase (exp $_{rm}$)	1.443	1.6391	2.3172	2.5663	3.1684
Generation doubling time (days)*	1.89	1.40	0.82	0.74	0.60

* Generation doubling time (days) = In2/ rm

Data in table (4) illustrated that there were highly significant differences in all duration of life history of *T. urticae* except for, longevity of the females which had significant difference but not highly as other aspects. On the other hand, life span duration had non-significant difference regards to the increase of temperature.

Table 4: One- way ANOVA of different temperature degrees affecting all life history parameters of *Tetranychus urticate*

Stages	F	P	L.S.D. at 0.01
Incubation period	93.615	***	0.0895
Larvae duration	78.485	***	0.8008
Protonymph	43.342	***	1.0384
Tritonymph	36.674	***	2.1512
Total immature stages	107.657	***	1.3528
Life cycle	138.925	***	0.7529
longevity	3.706	*	4.4229
Generation period	102.030	***	1.0816
Life span	-1.120	ns	------
Pre oviposition period	28.621	***	2.7389
Oviposition period	35.500	***	1.6863
Post oviposition period	32.146	***	1.7672

ns= non-significant *= significant ***= highly significant

Conclusion

Our results indicated that the two spotted spider mite *Tetranychus urticae* Koch, is capable of adapting rapidly to the increase in temperature. Therefore, *T. uricae* will be able to spread mor widely with long- term adaptation, as well as possessing the advantages of a high thermal optimum, (high rate of population growth and short generation time), which leads to that, *Tetranychus urticae* Koch threat will be shifted to higher latitude.

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