The impact of Temperature on Development and Demographic Parameters of *Tetranychus urticae* (Koch)

M. A. Osman[*]; A. A. Tawfik[**] and G. M. Abou-Elella[***]

[*] Agric. Zoology Dept., Faulty of Agric., Mansoura Univ., Mansoura, Egypt. mesoma20@mans.edu.eg

[**] Plant Protect. Rese. Institute, Agric. Res. Center, Dokki, Cairo, Egypt.

[***] Pests and Plant Protec. Dept., National Research Center, Dokki, Cairo, Egypt.

ABSTRACT

Biological aspects and life table parameters of the two-spotted spider mite *Tetranychus urticae* Koch was determined at five temperature degrees. Total immatures averaged 8.30, 7.50, 6.85, 5.15 and 4.50 days, while life cycle averaged 14.95, 12.95, 10.50, 7.65 and 6.30 days for female when reared at 15, 20, 25, 30 and 35°C, respectively. Life span averaged 35.40, 31.00, 20.50, 15.30 and 12.35 days at the same temperatures. The mean generation time (T) averaged 20.259, 18.345, 14.029, 10.282 and 8.775 days. The net reproductive rate (R_o) values were 22.842, 27.024, 27.846, 22.738 and 9.790 when *T. urticae* was kept at the same temperatures. The intrinsic rate of natural increase (r_m) was 0.1543, 0.179, 0.237, 0.303 and 0.259 and the finite rate of increase (exp r_m) averaged 1.166, 1.196, 1.267, 1.355 and 1.296 at 15, 20, 25, 30 and 35°C, respectively.

Key Words: Tetranychidae, *Tetranychus urticae*, Biology, Life tables.

INTRODUCTION

The two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae), is an extremely polyphagous pest that has been reported from more than 900 host species and is described as a serious pest of at least 150 economically important agricultural and ornamental plants (Zaher, 1986; Krips, et al., 1998; Zhang, 2003; Mondal & Ara, 2006). Indeed, temperature is a critical abiotic factor influencing the dynamics of arthropod pests and their natural enemies (Huffaker and Gtierrez 1999). Temperature has distinct effect on the different biological aspects of arthropods, and upper and lower developmental threshold temperatures as well as optimal temperature can be estimated for each pest mite organism and its natural enemies (Roy *et al.* 2002). Biological knowledge, in particular life table attributes is a significant step to an improved reorganization of the population dynamics of pests. This information may be used as an important mean in planning successful integrated pest management (IPM) program for this spider mite.

The present work aimed to study the different biological aspects of *T. urticae* at five temperatures (15, 20, 25, 30 and 35°C) in the laboratory.

MATERIALS AND METHODS

I. Mite culture

The two-spotted spider mite, *T. urticae* Koch was collected from leaves of castor bean plant, *Ricinus communis* L. Samples were collected from the farm of Faculty of Agriculture, Mansoura University.

II. Influence of different temperatures on development of *T. urticae*:

Leaf discs of *R. communis*, one square inch each, were used as a substrate for rearing newly deposited eggs of *T. urticae* which were singly transferred to leaf discs placed on wet cotton pads in Petri dishes (15 cm in diameter). *T. urticae* eggs were separated into five major groups, 30 eggs each, according to the tested temperatures. Five temperatures were tested (15, 20, 25, 30 and 35 ±1°C) at 70 ± 5 % RH. Observations on life development were recorded twice a day during mite life span.

Statistical analysis

Life table parameters were calculated using a BASIC computer program (Abou-Setta *et al.* 1986) for females reared on various tested temperature degrees. This computer program is based on Birch's method (1948) for the calculation of an animal's life table. Constructing a life table, using rates of age-specific (Lx), and fecundity (Mx) for each age interval (x) was assessed. The following population growth parameters were determined: the mean generation time (*T*), gross reproductive rate (GRR) (=ΣMx), the net reproductive rate (R_o), the intrinsic rate of increase (r_m) and the finite rate of increase (exp r_m). The doubling time (DT), Cohort Generation Time (T_c), Capacity of increase (r_c) and Annual rate of increase (ARI) were calculated according to Laughlin, 1965; May, 1976 and Carey, 1993. The life tables were prepared from data recorded daily on developmental time (egg to first egg laid), sex ratio, the number of deposited eggs, the fraction of eggs reaching maturity, and the survival of females. Interval of one day was chosen as the age classes for constructing the life table.

RESULTS AND DISCUSSION

I. Immature stages:

Data in Table (1) show that eggs of *T. urticae* female hatched after 6.65 days at 15°C, while 20, 25, 30 and 35°C clearly accelerated hatching which

averaged 5.45, 3.65, 2.60 and 1.80 days, respectively. Rising temperature had an obvious effect on the development of immature stages where increasing temperature significantly shortened the developmental periods. Sabelis (1981) reported that a female *T. urticae* developed from egg to adult in approximately 6.5 days at 30°C. Bounfour and Tanigoshi (2001) stated that life cycle of *T. urticae* was 25.30, 16.00, 13.9 and 7.40 days when reared at 15, 20, 25 and 30°C respectively. Praslicka and Huszar (2004) showed that life cycle of *T. urticae* was fast at 35°C (6.50 day); while at 15°C it took 16.23 days. Also, Osman *et al.* (2010) stated that life cycle of *T. urticae* was 9.80 days when reared at 28°C.

II. Adult stage:

The pre-oviposition period of *T. urticae* female averaged 5.15, 4.50, 2.00, 1.45 and 0.70 days; average female laid 49.15, 51.9, 65.25, 53.90 and 27.9 eggs at 15, 20, 25, 30 and 35°C, respectively (Tables 2 & 3), whereas sex ratio was 0.58, 0.61, 0.64,0.66 and 0.71 at the same temperature . Average female lived for 20.45, 18.05, 10.00, 7.65 and 6.05 days, while, its lifespan averaged 35.40, 31.00, 20.50, 15.30 and 12.35 days at 15, 20, 25, 30 and 35°C, respectively.

Saito (1979) showed that the longevity and life span of *T. urticae* female were 19.41 and 29.07 days at 25°C. Bounfour and Tanigoshi (2001) reported that *T. urticae* adult female longevity and life span when reared under 15, 20, 25, 30°C were 22.00, 26.90, 20.90 and 17.10 days and 47.30, 42.90, 34.20 and 27.9 days, respectively. They noticed that all stages died at 35°C. Osman *et al.* (2010) observed that longevity and life span of *T. urticae* adult female was 14.60 and 23.86 days, respectively; when reared at 28°C. Hazan *et al.*, (1973) recorded lower fecundity of the spider mite at temperatures above 30 °C. Tsai *et al.*, (1989) showed that *Tetranychus kanzawi* female laid 27.8 eggs at 15°C and 76.0 eggs at 30°C. Shih (1999) observed that *T. urticae* female laid maximum of 100 eggs in 10 days. He stated that temperature 23–30°C was optimal for its development. Bounfour and Tanigoshi (2001) reported that *T. urticae* fecundity was 38.10, 124.7, 92.8 and 121.20 when reared on 15, 20, 25 and 30°C, respectively. Praslicka and Huszar (2004) noticed that fecundity of *T. urticae* was highest at a 30°C as 89.1 eggs/female, and lowest at 15°C as 58.6 eggs/female. The fecundity of female mite increased with temperature increase up to 30°C, but at 35°C it decreased to 71.08 eggs/female. Naher *et al.*, (2008) reported that *T. urticae* fecundity was 58.21, 82.46 and 62.96 eggs/female in winter, autumn and summer, respectively. Osman *et al.* (2010) showed that fecundity of *T. urticae* was 64.8 eggs/female at 28 °C.

The relationship between temperature and rate of development in insects and mites is usually calculated as linear, but it is actually curvilinear (Sharpe and De Michele 1977). The simple linear regression between temperature (independent variable X) and the developmental rate (dependent variable Y) of *T. urticae* egg indicated $R^2 = 0.948$ and the regression equation as: Developmental rate (Y) = 0.0205x - 0.2007 Temperature (X) (Fig. 1). R^2 values of larva, protonymph, deutonymph, total immatures and life cycle were 0.9102, 0.9232, 0.9013, 0.9388 0.96, respectively. The regression equations were (Y) = 0.0152(X) + 0.0334, (Y) = 0.0157(X) + 0.1385, (Y) = 0.0167 (X) + 0.1346, (Y) = 0.0053 (X) + 0.0305 and (Y) = 0.0047 (X) - 0.0126 for larva, protonymph, deutonymph, total immatures and life cycle, respectively. Also, the value of R^2 of preoviposition, oviposition, postoviposition, longevity and life span were 0.8867, 0.9612, 0.9569, 0.969 and 0.9928, respectively. The regression equations were (Y) = 0.0528 (X) - 0.7425, (Y) = 0.0074 (X) - 0.0192, (Y) = 0.0356 (X) - 0.4173, (Y) = 0.0062(X) - 0.0549 and (Y) = 0.0031(X) - 0.0296 for preoviposition, oviposition, postoviposition, longevity and life span, respectively.

As a result, it was noted that thermal factor had negative relationship with duration of each stage as increasing temperature accelerated development and shortened, longevity and life span of *T. urticae.*

III. Life table parameters:

The calculated life table parameters considered were: mean generation time (T), net reproductive rate (R_0), doubling time (DT), intrinsic rate of

Table (1): Duration in days of developmental stages of *Tetranychus urticae* (Koch) female at different temperatures.

Temp.	Developmental stages					Life cycle
	Egg	Larva	Protonymph	Deutonymph	Total immatures	
15	6.65 ± 0.13	3.35 ± 0.10	2.50 ± 0.11	2.45 ± 0.11	8.30 ± 0.20	14.95 ± 0.26
20	5.45 ± 0.15	3.10± 0.06	2.25 ±0.09	2.15 ± 0.08	7.50 ± 0.13	12.95 ± 0.21
25	3.65 ± 0.10	2.70 ± 0.14	2.10 ± 0.10	2.05 ± 0.08	6.85 ± 0.13	10.50 ± 0.19
30	2.50 ± 0.11	2.15 ± 0.08	1.55 ± 0.11	1.45 ± 0.11	5.15 ± 0.16	7.65 ± 0.22
35	1.80 ± 0.11	1.65 ± 0.10	1.45 ± 0.11	1.40 ± 0.11	4.50 ± 0.13	6.30 ± 0.17

Means ± SE

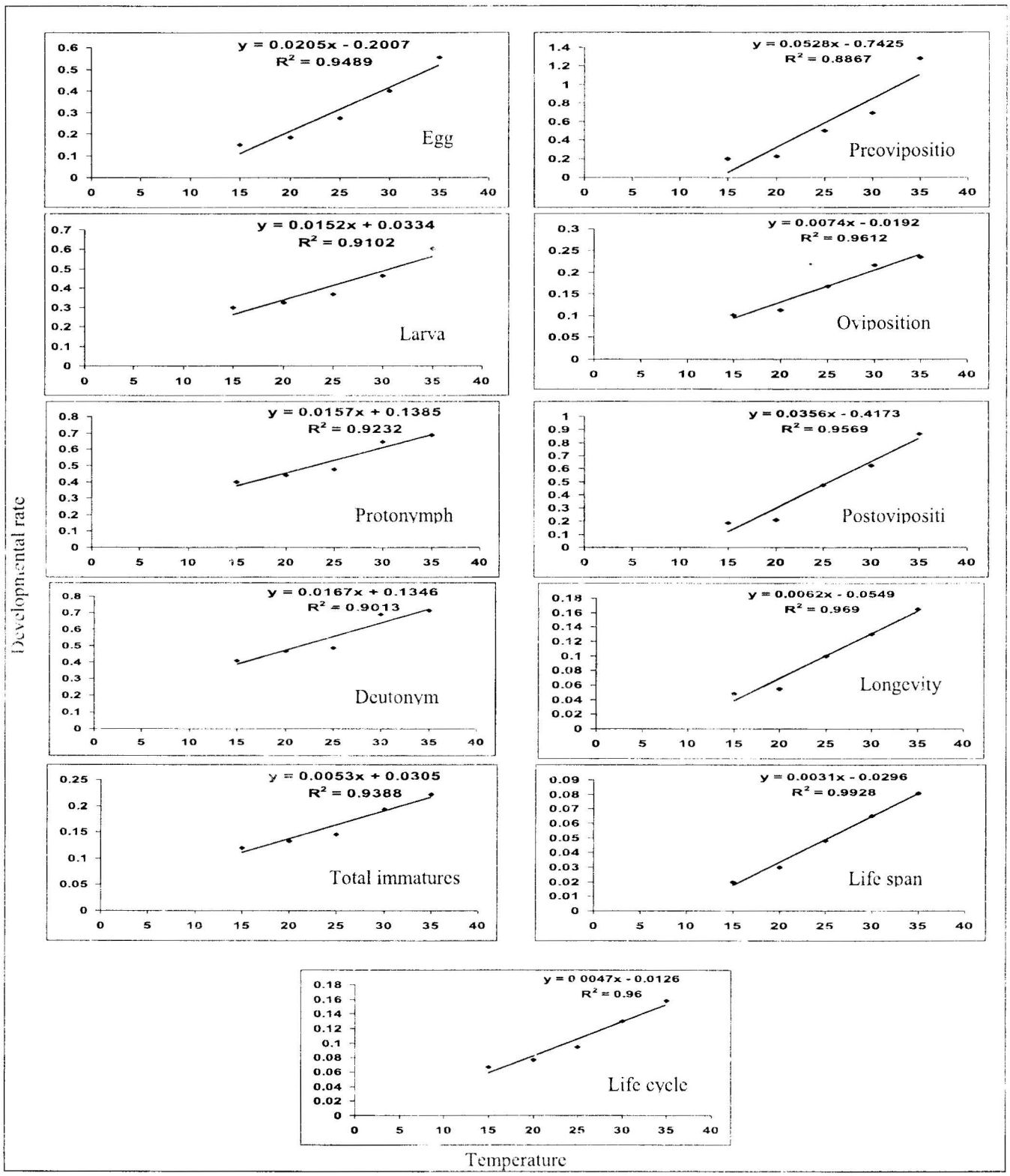

Fig.(1): Linear regression analysis of temperature versus developmental rates of *T. urticae* (Koch) female.

Table (2): Duration in days of of *Tetranychus urticae* (Koch) female at different temperatures

Temp.	Adult stage				Life span
	Preoviposition	Oviposition	Postoviposition	Longevity	
15	5.15 ± 0.16	9.90 ± 0.27	5.35 ± 0.19	20.45 ± 0.35	35.40 ± 0.43
20	3.50 ± 0.13	8.80 ± 0.15	4.75 ± 0.12	18.05 ± 0.24	31.00 ± 0.30
25	2.00 ± 0.12	5.95 ± 0.21	2.10 ± 0.16	10.00 ± 0.20	20.50 ± 0.26
30	1.40 ± 0.11	4.60 ± 0.16	1.60 ± 0.15	7.65 ± 0.25	15.30 ± 0.30
35	0.70 ± 0.12	4.25 ± 0.14	1.15 ± 0.15	6.05 ± 0.30	12.35 ± 0.31

Means ± SE

Table (3): Effect of different temperatures on the life table parameters of *Tetranychus urticae* (Koch)

Temp. °C	Mean Total Fecundity	R_0	T	r_m	exp r_m	GRR	DT	T_c	r_c	ARI
15	49.15 ± 1.88	22.82	20.25	0.154	1.166	23.07	4.46	21.01	0.148	3.846×10^{24}
20	51.90 ± 0.92	27.02	18.34	0.179	1.196	27.30	3.83	18.87	0.174	3.961×10^{28}
25	65.25 ± 2.09	27.84	14.02	0.237	1.267	28.19	2.91	14.38	0.231	5.730×10^{28}
30	53.90 ± 1.67	22.73	10.28	0.303	1.355	23.84	2.27	10.59	0.294	1.799×10^{48}
35	27.90 ± 0.89	9.79	8.77	0.259	1.296	12.91	2.65	9.00	0.253	2.881×10^{41}

natural increase (r_m), finite rate of increase (exp r_m), gross reproductive rate (GRR) cohort generation time (T_c), capacity of increase (r_c) and annual rate of increase (ARI) (Table 3).

Concerning life table parameters of *T. urticae*, the present study indicated that thermal factor has a great influence. R_0 values averaged 22.842, 27.024, 27.846, 22.738 and 9.790 when *T. urticae* was kept at 15, 20, 25, 30 and 35 °C, respectively. Also, the mean generation time (T) averaged 20.259, 18.345, 14.029, 10.282 and 8.775 when *T. urticae* individuals were kept at the same temperatures. From previous results, it could be noticed that *T. urticae* population could multiply 22.842, 27.024, 27.846, 22.738 and 9.790 times in a generation time 20.259, 18.345, 14.029, 10.282 and 8.775 (Table 3).

Bounfour and Tanigoshi (2001) recorded that the net reproductive rate (R_0) and the mean generation time (T) of *T. urticae* were 24.66, 80.99, 54.86 and 86.01 and 38.29, 26.48, 21.25 and 13.86 days when reared at 15, 20, 25 and 30 °C, respectively. Razmjou *et al.,* (2009) reported that R_0 and T ranged between 12.57 and 30.51 and 10.66 and 11.66 days when reared *T. urticae* at 25 °C on five bean cultivars, whereas, Osman *et al.* (2010) showed that R_0 and T of *T. urticae* were 36.98 and 16.19 at 28 °C.

The intrinsic rate of natural increase (r_m) is a key demographic parameter useful for predicting the population growth potential of an animal under given environmental conditions, as it reflects an overall effect on development, reproduction and survival (Southwood and Handerson 2000). Estimates of r_m are difficult to compare between studies, because of genetic variation, differences in rearing methods, other environmental conditions, and variable assumptions entering these estimations (Roy *et al.* 2002). Temperature is a key determinant of r_m as developmental period, fertility and other life history parameters (Birch, 1948).

Accordingly, data in Table (3) showed that r_m values were 0.1543, 0.179, 0.237, 0.303 and 0.259 individuales/female/day when *T. urticae* was reared at 15, 20, 25, 30 and 35 °C, respectively, Therefore, it can be concluded that the net rate of natural increase was highly influenced by thermal factor. Sabelis (1985) showed that spider mites (Acari: Tetranychidae) are a well documented example of plant-feeding pests with high r_m values and are notorious for their ability to develop damaging outbreaks on a wide range of cultivated crops . The highest reported r_m for tetranychid mites was 0.48 for the Banks grass mite, *Oligonychus pratensis* (Banks) at 36°C (Perring *et al.* 1984). Sabelis (1991), in an extensive review of life-history parameters of tetranychid mites, found the $r_m$values for *Tetranychus* mites ranged from 0.200 to 0.336 day^{-1} at 25°C. Bounfour and Tanigoshi (2001) recorded that r_m value of *T. urticae* at 15, 20, 25 and 30 ° C was 0.084, 0.166, 0.188 and 0.321 respectively. Osman *et al.* (2010) reported that r_m value of *T. urticae* was 0.222 individuales/ female/day.

The doubling time (DT) of *T. urticae* was 4.46, 3.83, 2.91, 2.27 and 2.65. Also, gross reproductive rate (GRR) was 23.07, 27.30, 28.19, 23.84 and 12.91 at the same temperatures.

In the present study, the cohort generation time (T_c) of *T. urticae* was 21.01, 18.87, 14.38, 10.59 and 9.00, while capacity of increase (r_c) recorded 0.148, 0.174, 0.231, 0.294 and 0.253. Also, annual rate of increase was (ARI) 3.846×10^{24}, 3.961×10^{28}, 5.730×10^{28}, 1.799×10^{48} and 2.88×10^{41} at 15, 20, 25, 30 and 35°C, respectively.

Hoque *et al.* (2008) reported that (T_c) and (r_c) of *T. urticae* were 13.057, 15.934 & 28.972 and 0.1676, 0.1735 & 0.0544 in summer, autumn and winter seasons, respectively. Bounfour and Tanigoshi (2001) noticed that (T_c) and (r_c) of *T. urticae* when reared under 15, 20, 25, 30 °C were 39.28 29.53 22.97 & 17.19 days and 0.082, 0.149, 0.174 & 0.259, respectively. Osman *et al.* (2010) showed that (T_c), (r_c) and (ARI) of *T. urticae* were 17.20, 0.209 and 2.13×10^{35} at 28 °C.

The afor-mentioned results revealed that thermal factor has a great influence on development and life table parameters of *T. urticae.*

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