Temperature-Dependent Development, Life Table Parameters and Predation Rate of *Euseius scutalis* (A.- H.) Fed on the Two-Spotted Spider Mite

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ABSTRACT

Biological aspects, thermal requirement, predation rate and life table parameters of the phytoseiid predatory mite *Euseius scutalis* (A.– H.) fed on nymphs of *Tetranychus urticae* Koch was determined at four temperature degrees, 15, 20, 25 and 30 °C. The total developmental durations of female was correlated negatively with increasing temperature. Minimum developmental thresholds (T_o) of egg, larva, protonymph, deutonymph, total immature stages and life cycle of *E. scutalis* female averaged, 4.26, 10.98, 6.90, 1.20, 2.49 and 2.89; respectively. On the other hand *E. scutalis* female required 208.33 DD to reach adulthood. The net rate of natural increase (r_m) was 0.008, 0.126, 0.166 and 0.193, whereas the finite rate of increase (e^{rm}) averaged 1.092, 1.134, 1.181 and 1.213 at 15, 20, 25 and 30 ^{o} C; respectively.

Key Words: *Euseius scutalis*, *Tetranychus urticae*, Biology, Life table, Thermal requirement, Predation rate.

INTRODUCTION

Mites of the family phytoseiidae are cosmopolitan and important natural enemies of several phytophagous mite pests on various agricultural crops. The phytoseiid mite *Euseius scutalis* (A.-H.) was firstly recorded in Algeria as *Typhlodromus scutalis* by Athias-Henriot (1958). It was reported as a widespread phytoseiid mite in Middle East countries and North Africa on a variety of host plants (Bounfour & McMurtury, 1987 and Momen & Abdel-Khalek 2008). In Egypt, it is considered one of the most predominant and widely distributed phytoseiid mite (Zaher, 1986 and El-Laithy &Fouly, 1992). It is a facultative predator, which is not only mite predator but also feed on other preys and food nutrients such as whiteflies and pollens (Abdel halim et *al.*, 2000 and Osman, 2000). However, on the basis of the classification of McMurtry and Croft (1997) and Croft et *al.*, (2004), *E. scutalis* is a specialized pollen feeder and generalist predator which is belonging to the type IV life style.

Although, numerous studies on the influence of temperature on development and reproduction of phytoseiid species have been reported, yet no information has been cited about thermal requirements of *E. scutalis*. The present work aims to study the influence of temperature on it's biology, life table and predation rate. The thermal requirements and thresholds of *E. scutalis* when fed on *T. urticae* at four temperatures as a prerequisite to develop a better prediction of the predator populations will be studied.

MATERIALS AND METHODS

I. Influence of different temperatures on development of *E. scutalis*:

Leaf discs of *R. communis*, one square inch each, were used as a substrate for rearing the predator. Newly deposited eggs were singly transferred to leaf discs placed on wet cotton pads in Petri dishes (15 cm in diameter).

Predatory eggs of *E. scutalis* were separated into four major groups according to the tested temperature degrees (15, 20, 25 and 30 ± 1 ^{o}C) and 70 ± 5 % R.H. All groups were provided daily with nymphs of *T. urticae* as prey.

II Statistical analysis:

Data were analyzed by one way analysis of variance (ANOVA), and the means were separated using Duncan's Multiple Range Test (CoHort Software, 2004). Durations of eggs, larvae, protonymphs, deutonymphs were used to calculate developmental rates (1/developmental time) according to Omkar and James (2004), which were regressed against temperature. The regression parameters and slopes were used to estimate the lower temperature threshold for development (To) and the thermal constant K, (Campbell *et al.*, 1974).

Degree-Day requirements: Algorithms have been developed using a variety of non-linear functions that describe the temperature/growth rate relationship (Wagner *et al.*, 1984), but for most species the linear approximation is acceptable (Taylor and James, 1993).

III. Life table analyses:

Life table parameters were calculated using a BASIC computer program (Abou-Setta *et al.*, 1986) for females reared on various tested temperature degrees. 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 increase (R_o), the intrinsic rate of increase (r_m), and the finite rate of increase (λ). The doubling time (DT), cohort generation time (T_c), capacity of increase (r_c) and annual rate of increase (ARI) were calculated according to Carey (1993). The life tables were prepared from data recorded daily on developmental time, sex ratio, number of deposited eggs, 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.

IV. Predation rate:

The daily consumption of all individuals, including males, females, and immatures, was used to calculate the age-stage specific consumption rate c_{xj}. This is the mean number of *T. urticae* consumed by individual *E. scutalis* in age x and stage j. The age-specific predation rate (k_x) is the mean number of *T. urticae* consumed by *E. scutalis* at age x and was calculated by the following formula proposed by Chi and Yang (2003):

$$k_x = \frac{\sum_{j=1}^{\beta} s_{xj} c_{xj}}{\sum_{j=1}^{\beta} s_{xj}}$$

According to Chi and Yang (2003), the net predation rate (C_o) gives the mean number of prey consumed by an average individual predator during its entire life span, and is calculated as:

$$C_0 = \sum_{x=0}^{\infty} k_x l_x$$

The transformation rate from prey population to predator offspring (Q_p) is the ratio of the net predation rate to the net reproductive rate (Chi and Yang, 2003). It is calculated as:

$$Q_p = C_o / R_o$$

Predation rate data were analyzed using the computer program CONSUME-MSChart as designed by Chi (2005).

RESULTS AND DISCUSSION

I. Influence of different temperatures on development of *E. scutalis*:

Table (1) showed that eggs of *E. scutalis* hatched after 5. 10 days at 15 °C; while 20, 25 and 30 °C clearly accelerated hatching to 3.00, 2.31 and 2.00 days, respectively. Increasing temperature significantly shortened the developmental periods. Total immatures and life cycle averaged 11.50 & 16.50; 10.12 & 13.12 and 7.06 & 9.37 days for female when reared at 15, 20 and 25°C, respectively. Total immatures and life cycle averaged 5.68 and 7.68 days when reared at 30 °C.

II. Influence of different temperatures on adult longevity and female fecundity of *E. scutalis*:

The pre-oviposition period of average *E. scutalis* female was 6.56, 5.56, 3.37and 2.81 days; while the female laid an average of 13.12, 18.75, 29.68 and 35.68 eggs at 15, 20, 25 and 30 °C, respectively (Tables 2 & 3). Sex ratio was 0.65, 0.72, 0.64 and 0.76 at the same temperatures. Adult female lived for 44.06, 38.18, 30.68 and 27.25 days; while, its lifespan averaged 60.56, 51.12, 40.06 and 34.93 days at 15, 20, 25 and 30 °C, respectively.

El-Laithy and Fouly (1992) found that *E. scutalis* adult female longevity durated 27.12 days, when reared on *T. urticae* at 25° C. In 2010 Osman *et al.*, stated that adult female longevity and life span of *E. scutalis* reared on immatures of *T. urticae* at 28 °C were 17.66 and 23.93 days, respectively; while, Al – Shammery in the same year recorded that these periods averaged 26.4 and 34.42 days, when reared on immatures of *T. urticae* at 26 ° C. The differences in findings regarding total developmental times may be due to differences in prey quality, local populations, and experimental conditions.

III. Degree-Day Requirements:

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).

Minimum developmental thresholds (T_o) of egg, larva, protonymph, deutonymph, immatures and life cycle of *E. scutalis* female were 4.26, 10.98, 6.90, 1.20, 2.49 and 2.89, respectively; when fed on nymphs of *T. urticae*. Whereas, *E. scutalis* female required 208.33 DD to complete development from egg to adult when reared on nymphal stages of *T. urticae* (Table 3 & Fig. 1).

Lower thermal threshold for development and

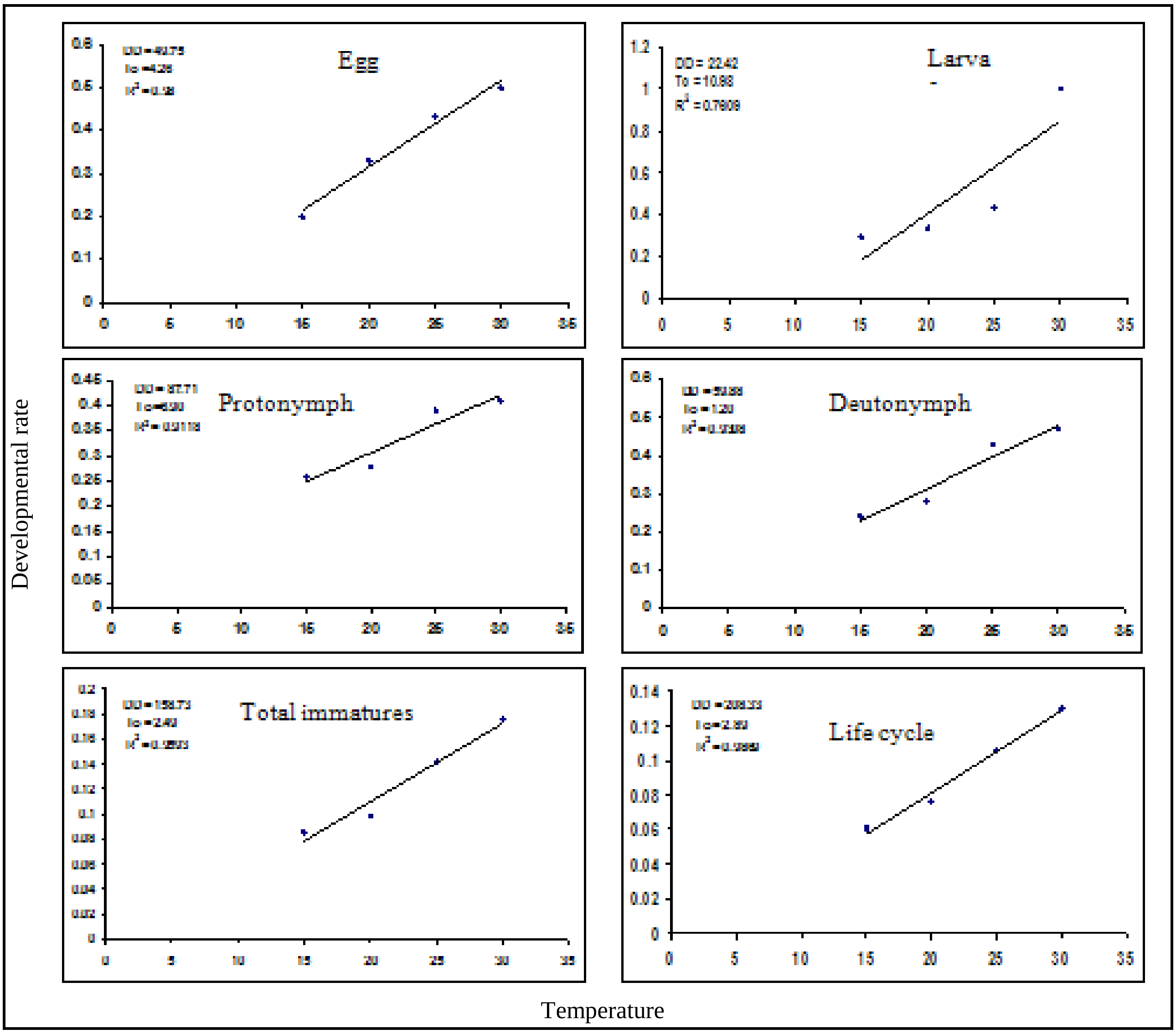

Fig.(1). Linear regression analysis of temperature versus developmental rate, degree-days requirements, and minimum developmental thresholds of *E. scutalis* female reared on nymphs of *T. urticae*

Table (1): Duration in days of developmental stages of *Euseius scutalis* fed on nymphs of *Tetranychus urticae* at different temperatures

Temp.	Egg	Larva	Protonymph	Deutonymph	Total immatures	Life cycle
15	5.10 ± 0.13 $_a$	3.33 ± 0.12 $_a$	3.80 ± 0.12 $_a$	4.12 ± 0.12 $_a$	11.50 ± 0.22 $_a$	16.5 ± 0.22 $_a$
20	3.00 ± 0.15 $_b$	3.10 ± 0.09 $_b$	3.46 ± 0.12 $_a$	3.56 ± 0.12 $_b$	10.12 ± 0.42 $_b$	13.12 ± 0.39 $_b$
25	2.31 ± 0.11 $_c$	2.31± 0.11 $_c$	2.56 ± 0.12 $_b$	2.31 ± 0.11 $_c$	7.06 ± 0.19 $_c$	9.37 ± 0.22 $_c$
30	2..00± 0.11 $_d$	1.00± 0.00 $_d$	2.43 ± 0.12 $_b$	2.12 ± 0.08 $_c$	5.68 ± 0.15 $_d$	7.68 ± 0.15 $_d$

Table (2): Duration in days of *Euseius scutalis* adult females fed on nymphs of *Tetranychus urticae* at different temperatures

Temp.	Preoviposition	Oviposition	Postoviposition	Longevity	Lifespan
15	6.56 ± 0.12$_a$	21.62 ± 0.34$_a$	15.93 ± 0.24$_a$	44.06 ± 0.28$_a$	60.56 ± 0.30$_a$
20	5.56 ± 0.12$_b$	18.62 ± 0.34$_b$	14.00 ± 0.27$_b$	38.18 ± 0.1$_b$	51.12 ± 0.31$_b$
25	3.37 ± 0.125$_c$	16.06 ± 0.28$_c$	11.25 ± 0.37$_c$	30.68 ± 0.49$_c$	40.06 ± 0.56$_c$
30	2.81 ± 0.10$_d$	14.31 ± 0.50$_d$	10.12 ± 0.30$_d$	27.25 ± 0.61$_d$	34.93 ± 0.60 $_d$

Means in each column having different letters are significantly different ($P < 0.05$).

Table (3). Linear regression analysis of temperature versus developmental rate, degree-days requirements, and minimum developmental thresholds of *E. scutalis* female reared on nymphys of *T. urticae*

Stage	Regression	R^2	K(DD)	T_o
Egg	Y = - 0.0858 + 0.0201x	0.980	49.75	4.26
Larva	Y = - 0.4898 + 0.0446x	0.760	22.42	10.98
Protonymph	Y = - 0.0787 + 0.0114x	0.911	87.71	6.90
Deutonymph	Y = - 0.0202 + 0.0167x	0.930	59.88	1.20
Immatures	Y = - 0.0157 + 0.0063x	0.959	158.73	2.49
Life cycle	Y = - 0.0139 + 0.0048x	0.986	208.33	2.89

Table (4): Effect of different temperatures on the life table parameters of *Euseius scutalis*

Temp. ° C	Mean Total Fecundity	R_0	T	r_m	e^{rm}	GRR	DT	T_c	r_c	ARI
15	13.12 ± 0.22	8.019	23.63	0.008	1.092	8.021	7.830	24.83	0.083	1.074×10^{14}
20	18.75 ± 0.47	12.690	20.13	0.126	1.134	12.694	5.471	22.20	0.144	1.211×10^{20}
25	29.68 ± 1.09	14.318	15.97	0.166	1.181	20.360	4.15	17.25	0.154	2.98×10^{26}
30	35.68 ± 0.83	15.880	14.30	0.193	1.213	23.420	3.570	15.85	0.174	5.98×10^{30}

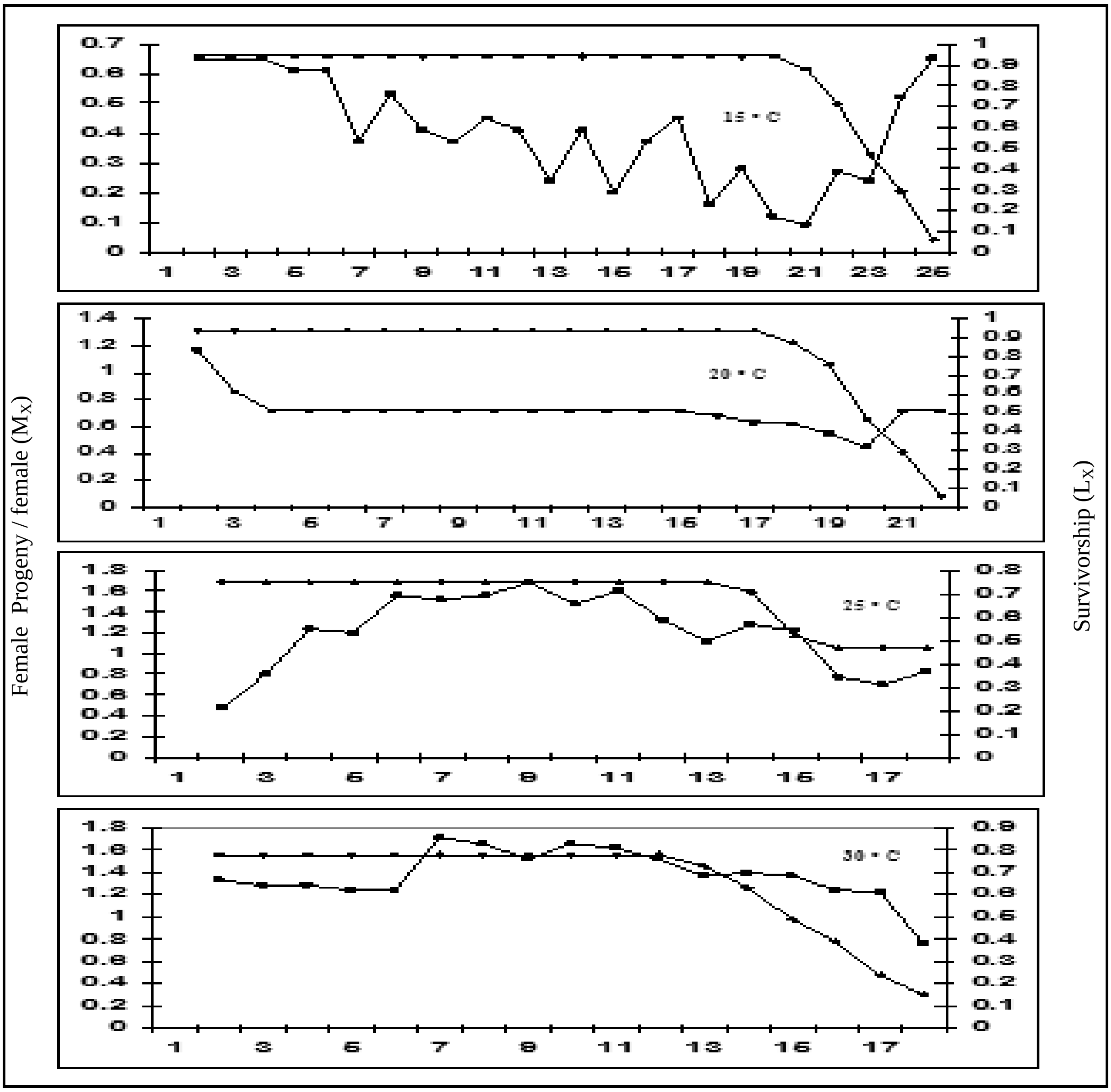

Fig.(2): Age- specific fecundity (M_x) and survivorship (L_x) of *Euseius scutalis* fed on nymphal stages of *T. urticae* at four constant temperature degrees.

thermal constant are useful indicators for an insect's potential distribution (Campbell *et al.,* 1974). The results in this study showed that a threshold temperature of 2.89 ^{o}C and 208.33 accumulated day degrees were required for *E. scutalis* to complete one generation. Rencken and Pringle (1998) showed that *N. californicus* T_o and K(DD) were 8.30 and 100.10, respectively when reared on *T. urticae*. whereas, Gotoh *et al.* (2004) reported that T_o and K(DD) for *N. californicus* was 10.90 and 59.20 when reared on *T. urticae*. Also, Rasmy et *al*.(2010) found that T_o and K (DD) for *P. plumifer* was 13.22 and 126.58. For instance, El Taj and Jung (2012) stated that T_o and K (DD) for *N. californicus* was 10.98 and 55.15 when fed on *Panonychus ulmi*. From previous results, *E. scutalis* had the lowest thermal constant and highest lower threshold suggesting that *E. scutalis* remained active at lower temperature and had a potential to develop over a wide range of temperatures.

IV. Life table parameters:

The present study indicated that thermal factor has a great influence on life table parameters (Table 4).

The survival curves of *E. scutalis* fed on *T. urticae* under different temperatures followed a type I pattern in which most eggs developed to maturity and death occurred gradually over an extended ovipositional period (Fig. 2). These results agree with that of Fouly and El-Laithy (1992); Osman (2000); Osman, 2005 and Al-Shammery (2010).

The net reproductive rate (R_0) was significantly affected by temperature as (R_0) values averaged 8.019, 12.690, 14.318 and 15.880 when *E. scutalis* was kept at 15, 20, 25 and 30 ^{o}C, respectively. Also, the mean generation time (T) averaged 23.63, 20.13, 15.97 and 14.30 when the predator individuals were kept at the same temperature. El-Laithy and Fouly (1992) found that R_0 of *E. scutalis* and *T. swirskii* were 17.22 and 22.97 when reared on *T. urticae*. Osman (2000) showed that R_0 and T of *E. scutalis* was 16.03 and 28.63, respectively when reared on *T. urticae* immatures at 25 ^{o}C, while Ali and Zaher (2007) recorded that R_0 and T of *T. swirskii*, when reared on immatures and eggs of *T. urticae* were 7.40, 25.92 and 6.92, 25.52, respectively. Also, Al-Shammery (2010) reported that R_0 and T of *E. scutalis* were 26.373 and 14.88 when reared on *T. urticae* at 26 ^{o} C., whereas Osman *et al*.(2010) recorded it 16.84 and 12.28.

However, 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 (Birch, 1948), because r_m reflects an overall effect on development, reproduction and survival (Southwood and Henderson ,2000). Theoretically, a predator that has a population growth rate (r_m) equal or greater than its prey could be able to regulate the population of the prey (Sabelis, 1992). The biotic potential (r_m) of the main phytoseiid species constitutes 0.18–0.334. Data in table (3) showed that r_m values were 0.008, 0.126, 0.166 and 0.193 individuales/ female/day when *E. scutalis* was reared at 15, 20, 25 and 30 ^{o}C, respectively. McMurtry and Croft (1997) stated that the intrinsic rates of natural increase (r_m) of generalist mite predators were sometimes below 0.1 but increased to 0.25 when fed on spider mites or pollen. For instance, Nomikou *et al.* (2001) showed that r_m of *E. scutalis* fed on *Panonychus citri* averaged o.23 - 0.29 according to the temperature. Also, Kasap and Lu (2004) recorded that r_m value of *E. scutalis* fed on *P. citri* was between 0.16 and 0.29 by increasing temperature; while Momen and El-sawi (2008) stated that r_m value did not exceed 0.14 when the same predatory fed on eggs of cotton leaf worm. However, Al-Shammery (2010) and Osman *et al.* (2010) reported that r_m value of *E. scutalis* was 0.220 and 0.229 when reared on *T. urticae*. Therefore, it can be concluded that the net rate of natural increase was highly influenced by thermal factor, as soon as e^{rm} ranged between 1.092 and 1.213 at the same temperatures. On the other hand, the doubling time (DT) of *E. scutalis* was 7.830, 5.471, 4.150 and 3.570 at 15, 20, 25 and 30 ^{o}C. Also, gross reproductive rate (GRR) ranged between 8.021 and 23.420 at the same temperatures**.**

In the present study, the cohort generation time (T_c) of *E. scutalis* was 24.83, 22.20, 17.25 and 15.85, at 15, 20, 25 and 30 ^{o} C; while capacity of increase (r_c) ranged between 0.083 and 0.174. Also, Annual Rate of Increase (ARI) ranged between 1.074×10^{14} and 5.98×10^{30} when *E. scutalis* was kept at the aforementioned temperatures, respectively. Hoque *et al*.(2008) reported that (T_c) for *P. persimilis* was 10.754, 13.747 and 22.252 in summer, autumn and winter seasons, Also, (r_c) was 0.1747, 0.1715 and 0.0960 in the same seasons. (T_c) and (r_c) of *T. urticae* were 13.057, 15.934 and 28.972 and 0.1676, 0.1735 and 0.0544 in summer, autumn and winter, respectively. Osman *et al.*, (2010) recorded that the cohort generation time (T_c), capacity of increase (r_c) and annual rate of increase (ARI) of *E. scutalis* were 14.35, 0.196 and 2.39 x 10^{36} when reared on *T. urticae* at 28 ^{o} C. Whereas, the net predation rate C_o for *E. scutalis* at 15, 20, 25 and 30 °C ranged between 47.84 and 124.64, nymphs, respectively.

Temp. °C	C_o	Q_p
15	47.84	5.96
20	112.97	8.90
25	124.64	8.70
30	100.68	6.34

The net predation rate gives the mean number of prey consumed by an individual during its life span. It is a demographic parameter that represents the predation capacity of the predator population including all individuals of both sexes and those that died before the adult stage. The ratio of the net predation rate to the net reproductive rate gives the transformation rate from the prey population to predator offspring. This ratio is defined as Q_p (Chi and Yang, 2003). The transformation rate from prey population to predator offspring Q_p for *E. scutalis* fed on nymphs of *T. urticae* was 5.96, 8.90, 8.70 and 6.34 at same temperatures. This means that it needs 17.7 prey individuals for the reproduction of one predator egg. This Q_p gives an demographic estimation for the relationship between the reproduction rate and predation rate of predator. Tommasini *et al.* (2004) reported that net predation rate of the four *Orius* species (*O. laevigatus*, *O. majusculus*, *O. niger and O. insidiosus*) reared at 26 °C on *Frankliniella occidentalis* (Pergande) adults was 68.8, 62.9, 59.4 and 76.5, respectively. On other hand, Bailey *et al.* (2011) stated that the net predation rate *Cybocephalus flavocapitis* Smith was 1874 scales when reared on *Aulacaspis yasumatsui* Takagi.

As a result, it can be concluded that temperature has a considerable effect on the biology, life table, predation rate of *E. scutalis* when reared on *T. urticae* nymphs. Therefore, for an ecological and economical pest management program, the temperature should be integrated with the life tables of predator and prey to optimize the efficiency of biological control.

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