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BIOLOGICAL AND LIFE TABLE PARAMETERS OF *Stethorus gilvifrons* (Muls.) (Coleoptera: Coccinellidae) REARED ON *Tetranychus urticae* Koch*.*

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ABSTRACT

Developmental time and rate of immature stages, growth index, survival percentage, longevity, fecundity, and life table parameters of *Stethorus gilvifrons* (Muls.) when reared on *Tetranychus urticae* Koch were studied at three constant temperatures (20, 25, and 30^{o}C).

There were significant variations in total developmental time of immature stages of the predator (male and female) among the three tested temperatures when the predator was reared on *T. urticae*. Growth index and developmental rate of *S. gilvifrons* males and females were higher at 30^{o}C than 20 and 25^{o}C when reared on the tetranychid mite.

There were significant differences in pre-oviposition period among the three tested temperatures. In addition, there were significant variations among inter-oviposition, oviposition, and total longevity when the predator was reared at the three tested temperatures. Male longevity was significantly shorter at 30^{o}C than at 20 and 25^{o}C when fed on *T. urticae*. Fecundity rate was significantly higher at 30^{o}C than at 20 and 25^{o}C when fed on *T. urticae*. The mean generation time (T) and doubling time (DT) were shorter at 30^{o}C than at 20 and 25^{o}C which fed on *T. urticae* at 30 ^{o}C. Generally, the value of gross reproductive rate (GRR), the net reproduction rate (R_o), the intrinsic rate of increase (r_m), the finite rate of increase (λ) were higher at 30^{o}C than at 20^{o}C and 25^{o}C.

Keywords: *Stethorus gilvifrons*, biological characteristic, life table, *Tetranychus urticae*.

INTRODUCTION

Family Coccinellidae is potentially an important predatory insect group found throughout the world on many economic crops. Some species may have a significant role in biological controltetrancyid mites, aphids, whiteflies, and other soft-bodied insects. *Stethorus gilvifrons* (Muls.) is considered a useful biological control candidate for limiting the abundance of tetranychid mite (Ahmed and Ahmed*,* 1989). Several studies drew attention to the importance of this coccinellid species as a predator. This coccinellid predator could make a good candidate for mass rearing and release in pest hot spot infestations in open fields and greenhouses, because it has a good search activity and a high consumption rate (Ahmed and Ahmed*,* 1989). In order to use this predator in biological control programs, it is necessary to understand biological and life table attributes for it prior to mass production and release. Knowledge of biological parameters is essential for assessing the potential rate of increase for a population.

Life table parameters are essential to know the general biology of an insect and provide a valuable picture for the fecundity and growth potential of *S. gilvifrons* under prevailing environmental conditions. Population growth rate is a basic ecological characteristic. It is usually expressed as the intrinsic rate of natural increase (r_m) which is regarded as the best available single description of the population growth of species under given conditions (Shih *et al.,* 1991; Southwood and Henderson, 2000; Roy *et al*., 2003.). The intrinsic rate of natural increase (r_m) can be used for predator's selection. Morever, r_m is a suitable for evaluation of the mass rearing quality of biological control agents. It can be determined by its developmental time and reproduction rate. It has been used to compare a species under different environmental conditions and as an index of population rate response to selected preys (Birch, 1948; Hulting *et al*., 1990).

However, scanty attention has been paid to the developmental time and rate, growth index, longevity, fecundity and life table parameters of this predator to measure these parameters for mass rearing and release. Therefore, the present study was designed to study certain biological characters and life table parameters of *S. gilvifrons* at three constant temperatures.

MATERIALS AND METHODS

Rearing of immature stages:

Adults of *S. gilvifrons* were collected from the fields at the Experimental Research Station, Faculty of Agriculture, Mansoura University and reared on *Tetranychus urticae* Koch. The eggs laid by females were collected daily, and monitored until hatching. To avoid cannibalism, hatched larvae were reared individually in tubes (10 cm in diameter) in the incubators at 20±0.5, 25±0.5 and 30±0.5^{o}C. The relative humidity was 60.0±5.0% and the photoperiod was 14:10 (L: D) with each temperature. Twenty larvae from the predator were reared on *T. urticae*. Each reared larva was considered a replicate. The developmental time and rate (1/developmental time) (Omakar and James, 2004) of immature stages, survival from eggs to adult eclosion, and sex ratio were recorded. The ability of the larvae to moult and metamorphose on the tested preys was determined as (a) percentage of individuals transforming into adults, and (b) average period required o. The ratio of (a) to (b) then represented the insect's "growth index" (Saxena, 1969).

Rearing of adult stage:

After eclosion, 10 males and 10 females from this predator were also fed on the *T. urticae* until development was completed. The longevity of females was divided to three periods according to Phoofolo and Obrycki (1995) and Lanzoni *et al.* (2004). The pre-oviposition period was measured as the number of days among female eclosion and initiation of egg laying, while inter-oviposition one as the number of days among two successive ovipositions, and finally the oviposition period was the number of days during which oviposition occurred. The fecundity of female, fecundity rate (number of progeny produced per female per day) and the longevity of males were recorded.

Life table parameters were calculated using a BASIC computer program (Abou-Setta *et al.* 1986) for females reared on *T. urticae*. 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 increase (R_o), the intrinsic rate of increase (r_m), and the finite rate of increase (λ). The doubling time (DT) was calculated according to Mackauer's method (Mackauer, 1983). 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.

Data analysis:

Data of developmental times of immature stages, pre-oviposition, inter-oviposition, and oviposition periods, total longevity of females, fecundity, fecundity rate, and the males longevity of *S. gilvifrons* reared on *T. urticae* at three tested temperatures were subjected for one way analysis of variance (ANOVA), and the means were separated using Duncan's Multiple Range Test (Costat Software, 2004).

RESULTS

Developmental times of immature stages

A. Male

Analysis of variance (ANOVA) indicated that there were significant variations in the incubation periods for male among the three tested temperatures (20, 25, and 30^{o}C) when the predator reared on *T. urticae* (Table 1). Data in Table (1) showed that developmental time of the four larval instars was 4.7, 3.3, 3.3, and 4.1 days, respectively at 20^{o}C, 2.7, 2.9, 2.7, and 2.5 days at 25 ^{o}C, and 1.9, 1.9, 2.1, and 2.3 days in succession at 30^{o}C.

Table (1): Developmental times (mean±SE) in days of immature stages of *S. gilvifrons* male when reared on *T. urticae* at three constant temperatures.

Temp. (^{o}C)	Egg	Larval instars					Pupal stage	Total
		1st	2nd	3rd	4th	Total		
20	5.5± 0.5 a 0.5 a	4.7± 0.7 a	3.3± 0.8 a	3.3± 0.7 a	4.1± 0.60 a	15.4± 0.60a	6.3± 0.7 a	27.2± 0.4a
25	2.5± 0.52 b	2.7± 0.60 b	2.9± 0.7 a	2.7± 0.8 b	2.5± 0.7 b	13.3± 0.7b	2.4± 0.6 b	18.2± 0.7 b
30	1.6± 0.7 c	1.9± 0.6 c	1.9± 0.7 b	2.1± 0.6 c	2.3± 0.8 b	8.2± 0.6 c	2.2± 0.7 b	12.0± 0.6 c

[a] **Means followed by the same small letter in a column among the three temperatures are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).**

The developmental time of larval stage was 15.4, 13.3, and 8.2 days, with significant differences among the three tested temperatures. The pupal stage averaged 6.3, 2.4, and 2.2 days at 20, 25, and 30°C, with significant differences. The total developmental time of immature stages was 27.2, 18.2, and 12.0 days at 20, 25, and 30°C, with significant differences.

B. Female

Based on the statistical analysis, there were significant variations in the incubation period for females among the three tested temperatures (20, 25, and 30°C) when the female reared on *T. urticae* (Table 2). Data in Table (2) showed that developmental times of the four larval instars were 4.3, 3.3, 2.9, and 5.0 days, respectively at 20°C; 2.4, 3.0, 2.7, and 2.5 days at 25°C, and 2.0, 2.1, 2.9, and 2.0 days in succession at 30 °C,. The developmental time of larval stage was 15.5, 13.2, and 10.8 days with a significant difference among the three tested temperatures. The pupal stage averaged 6.3, 2.3, and 2.2 days at 20, 25, and 30°C, with a significant difference. The total developmental time of immature stages was 27.6, 15.5, and 13.0 days at 20, 25, and 30°C, with a significant difference.

Table (2): Developmental times (mean±SE) in days of immature stages of *S. gilvifrons* female when reared on *T. urticae* at three constant temperatures.

Temp. (°C)	Egg	Larval instars					Pupal stage	Total
		1st	2nd	3rd	4th	Total		
20	5.8± 0.7a	4.3± 0.7 a	3.3± 0.7 a	2.9± 0.6 a	5.0± 0.7 a	15.5± 0.2 a	6.3± 0.1 a	27.6± 0.6 a
25	2.6± 0.80 b	2.4± 0.80 b	3.0± 0.80 a	2.7± 0.5 a	2.5± 0.80 b	13.2± 0.6 b	2.3± 0.02 b	15.5± 0.8 b
30	1.8± 0.2 c	2.0± 0.6 c	2.1± 0.7 b	2.9± 0.7 b	2.0± 0.7 b	10.8± 0.7 c	2.2± 0.1 b	13.0± 0.3 c[A]

[a] **Means followed by the same small letter in a column among the three temperatures are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).**

Growth index (GI) and developmental rate (DR)

Growth index of *S. gilvifrons* male was 2.89, 4.94, and 7.51 at the three tested temperatures (20, 25, and 30 °C, respectively) when reared on *T. urticae* (Table 3). Meanwhile for female, they were 2.81, 5.16, and 6.92 at the three tested temperatures.

Table (3): Growth index of male and female of *S. gilvifrons* reared on *T. urticae* at three constant temperatures.

Sex	Temp. (°C)	Growth index	Developmental rate
♂	20	2.89	0.03
	25	4.94	0.05
	30	7.51	0.08
♀	20	2.81	0.03
	25	5.16	0.06
	30	6.92	0.07

Developmental rates of *S. gilvifrons* were 0.03, 0.05, and 0.08 for male and 0.03, 0.06, and 0.07 for female at the three tested temperatures (20, 25, and 30 ^oC) when reared on *T. urticae* (Table 3).

In general, GI and DR were better for *S. gilvifrons* adults (male and female) when reared on *T. urticae* at 30^{o}C than at 20 and 25^{o}C.

Survival percentage:

Survival percentages of larval instars, pupal stage, and total immature stages of *S. gilvifrons* male were 96, 95, 100,100, 86 and 80% at 20^{o}C, 90, 100, 100, 100, 100, and 90% at 25^{o}C, and 100, 100, 100, 90, 100, and 90% at 30 ^{o}C, when reared on *T. urticae* (Table 4). Meanwhile for female, they were 92, 91.3, 95.24, 100, 100, and 80% at 20^{o}C, 96, 92, 95.24, 100, 100, and 80% at 25^{o}C, and 100, 100, 100, 100, 90, and 90% at 30 ^{o}C.

Table (4): Survival percentages of immature stages of of male and female of *S. gilvifrons* reared on *T. urticae* at three constant temperatures.

Sex	Temp. (^{o}C)	Larval instars				Pupa	Total
		1st	2nd	3rd	4th		
♂	20	96.0	95.0	100.0	100.0	86.0	80.0
	25	90.0	100.0	100.0	100.0	100.0	90.0
	30	100.0	100.0	100.0	90.0	100.0	90.0
♀	20	92.0	91.3	95.24	100.0	100.0	80.0
	25	96.0	92.0	95.24	100.0	100.0	80.0
	30	100.0	100.0	100.0	100.0	90.0	90.0

Longevity and fecundity of adult stage:

Longevity and fecundity of *S. gilvifrons* when reared on *T. urticae* at the three tested temperatures (20, 25, and 30^{o}C) are given in Table (5). On *T. urticae* as a prey, pre-oviposition, inter-oviposition, oviposition, and total longevity periods lasted 5.2, 9.5, 51.7, and 66.4 days, respectively at 20^{o}C, while these periods lasted 3.3, 8.3, 39.1, and 50.7 days at 25^{o}C, and 2.5, 3.8, 36.2, and 42.5 days at 30^{o}C.

Table (5): Longevity (mean ±SE) in days of *S. gilvifrons* when reared on *T. urticae* at three constant temperatures.

Temp. (^{o}C)	Sex	Longevity (in days)				Mean total fecundity	Fecundity rate (No. Eggs/♀/ day)
		Pre-oviposition	Inter-oviposition	Oviposition	Total longevity		
20	♂	-	-	-	62.3±0.6a	-	-
	♀	5.2± 0.8 a	9.5± 0.5 a	51.7± 1.3 a	66.4± 1.1 a	166.9± 3.2 a	3.22± 0.9 a
25	♂	-	-	-	40.7±0.8 b	-	-
	♀	3.3± 0.8 b	8.3± 0.7 a	39.1± 0.3 b	50.7± 2.2 b	272.0± 2.8 b	6.9± 0.8 b
30	♂	-	-	-	38.3±0.75 c	-	-
	♀	2.5± 0.7 b	3.8± 1.3 b	36.2± 0.8 b	42.5± 2.3 b	353.5± 3.2 c	9.7± 0.3 b

[a] Means followed by the same small letter in a column among the three temperatures are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).

There were significant differences in pre-oviposition period among the three tested temperatures. In addition, there were significant variations among inter-oviposition, oviposition, and total longevity when the predator was reared at the three tested temperatures (Table 5). Male longevity was significantly shorter (38.3 days) at 30°C than at 20°C and 25°C (62.3 and 40.7 days) which fed *T. urticae*. Concerning the fecundity of females, the average number of eggs per female was 166.9, 272.0, and 353.3, with significant differences among the three tested temperatures (Table 5). In addition, results in Table (5) showed that fecundity rate was significantly higher (9.7) at 30°C than at 20°C and 25°C (3.22 and 6.9), when fed *T. urticae*.

Life table parameters

Data presented in Table (6) illustrate the life table parameters of *S. gilvifrons* females when reared on *T. urticae* at the three tested temperatures (20, 25, and 30°C). The mean generation time (T) was 42.55, 30.72, and 26.02 days at 20, 25, and 30°C, respectively when reared on *T. urticae*. The population of this predator could be doubled every 70.85, 4.44, and 3.53 days at 20, 25, and 30°C, respectively when reared on *T. urticae*. The value of gross reproductive rate (GRR) was higher (183.28) at 30 °C than at 20 and 25 °C (84.4 and 156.47). GRR refers to the sum of the average number of females produced per living female per day. This value is greater than the simple mean estimate of total fecundity per female per generation. The net reproduction rate (R_o), representing the total female births was 165.24 at 30°C. This meant that the population of this predator would be able to multiply 165.24 times when fed on *T. urticae* at the end of each generation. R_o was 66.160 at 20°C and 120.68 at 25°C. The value of the intrinsic rate of increase (r_m) was 0.0097826, 0.1560222, and 0.1962508 when the predator was reared on *T. urticae* at the three tested temperatures (20, 25, and 30°C). The finite rate of increase (λ) was 1.10277, 1.16885, and 1.21682 at the three tested temperatures (20, 25 and 30°C) that the population had the capacity to multiply 1.0277, 1.16885, and 1.2168 times per female per day.

Table (6): Life table parameters of *S. gilvifrons* females when reared on *T. urticae* at three constant temperatures.

Temp. (°C)	Life table parameters					
	Mean generation time (T) (in days)	Doubling time (DT) (in days)	Gross reproductive rate (GRR)	Net reproductive rate (R_o)	Intrinsic rate of increase (r_m)	Finite rate of increase (λ)
20	42.55	70.85	84.40	66.16	0.0097826	1.10277
25	30.72	4.44	156.47	120.68	0.1560222	1.16885
30	26.02	3.53	183.28	165.24	0.1962508	1.21682

From the data illustrated in Figure (1), it could be noted that the survivorship (*Lx*) for female age intervals was 90 at 30°C and 80 at 20 and 25°C tested temperatures which means that most of eggs had developed to maturity, and death happened gradually after an extended ovipositional period. Maximum oviposition rate per female per day (*Mx*) was 9.6 on 15th

day, 5.35 on 25th day, and 2.25 on 22nd day at the three tested (30, 25 and 20°C) temperatures, respectively (Figure 1).

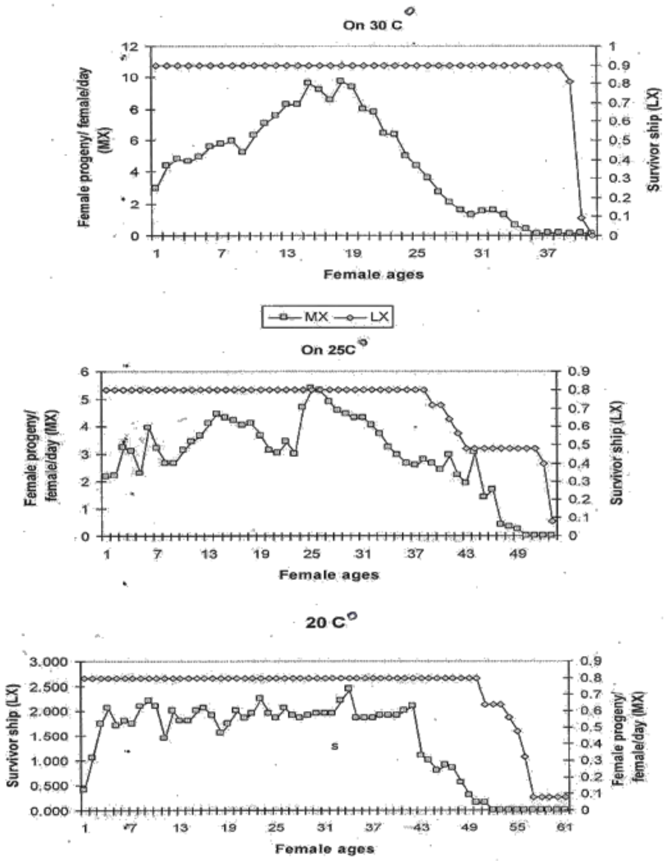

Figure 1. Age-specific fecundetiy Mx and survivleship Lx of *S. gilvifrons* when reared on *T. urticae* at three constant temperatures.

DISCUSSION

Mass production of coccinellid predators in biological control programs requires huge numbers at low costs. It is desirable to choose the predator, which has short developmental times, a high survival rate, and a high reproductive capacity.

Ahmed and Ahmed (1989) studied the life history of the predator coccinellid *S. gilvifrons* using *Tetranychus turkestani* (Banks) as prey in laboratory at 20, 25, 30 and 35°C and 65-75% RH. The average incubation period of the eggs was 2.9-5.3 days and the larvae and pupal period was 5.3-12.1 days and 2-5.6 days at 35 and 30°C, respectively. The longest life span for male and female was 167.6 and 124.8 days, respectively at 20°C and 47.0 and 42.6 days at 35°C, respectively. Shih *et al.* (1991) reported that the coccinellid predator, *Stethorus loi* Sasagi completed the development within 15.27±1.46 days in the laboratory at 23.8 ±1.5°C and 70.84 ± 4.3% RH. The durations of the egg, 1st, 2nd, 3rd, and 4th instar larvae and pupal stage were 1.79±0.58, 1.55±0.52, 1.60±0.59, 2.38 ±0.85 and 3.33±0.76 days, respectively. The mortality rate of the immature stages was 47.87%, most of these died as eggs. The pre-oviopisitional and oviopisitional of females were 4.14±1.75 and 28.52±3.67days. Females and males lived 48.38±15.46 and 56.62±18.75 days, respectively. The sex ratio was 1.063 females to one male. The intrinsic rate of natural increase was calculated to be 0.160. The mean generation time was calculated to be 24.40 days. Iskander *et al*. (1994) estimated the development of *S. punctillum* in the laboratory on the phytophagous mite, *Tetranychus arabicus* Attiah. The durations of the egg, larval and pupal stages of *S. punctillum* were 3.67±0.49, 6.67±0.62 and 3.27±0.46 days, respectively. The life was completed in 13.60±0.83 days. Longevity of female was 64.0±7.42 days. The total number of eggs/female was 143.93 with a daily rate of 2.59 eggs. Mirdul *et al.* (2002) studied the life history and feeding potential of *S. gilvifrons* a major predator of the spider mite, *Oligonychus coffeae* (Nietner). The beetle laid eggs singly on both surface of tea leaves and rear or in the middle of a mite colony. There were four instars larvae, pupation occurred on both surfaces of the leaves and one end of the pupa was attached to the leaf surface or on the site of pupation. The authors noticed also that the male adults were smaller in body size than female. The predator completed its development in 16.33±1.13 days. The duration of the egg, larval and pupal stages were 4.15±0.94, 8.36±0.48 and 3.82 ± 0.94 days, respectively, the authors added that both larvae and adults were voracious feeders, and the larvae fed by sucking while adults fed chewing the whole mite. The highest consumption was exhibited by the 3rd instar larvae (51.7±9.55), followed by the adult beetles (44.6±7.97).

In conclusion, *S. gilvifrons* had a shorter developmental time of immature stages, a relatively higher survivorship, a moderately longevity, a higher fecundity, and a higher intrinsic rate of natural increase (r_m). Therefore, it has a fine potential for mass rearing and periodic release. This predator presents excellent opportunity of a biological control agent that could be monitored and manipulated in an integrated pest management (IPM).

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المقاييس البيولوجية وجداول الحيـــاة للمفترس *Stethorus gilvifrons* (muls) عند تربيته على *Tetranychus urticae* Koch.

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تم دراسة تأثير درجات الحرارة 20 ،25 ، 30 °م وذلك على العنكبوت الأحمر العادي كل من فترات النمو وفهرس النمـــو ومعدل النمو والبقاء وفترات الحياة ومقاييس جداول الحيــاة للمفترس *Stethorus gilvifrons*.

أوضحت النتائج وجود فروق معنوية في طول فترة النمو للأطوار غير الكاملة للذكور والإناث للمفترس عند التربية على درجات الحرارة المختبرة على العنكبوت الأحمر العادي. كما أوضحت النتائج أن فهرس النمو ومعدل النمو كان مرتفعاً عند التربية على درجات الحرارة 30 °م بالمقارنة بدرجتي 20 °م ، 25 °م .

كما أظهرت النتائج أيضا أن قيم جداول الحياة المحسوبة لمتوسط فترة الجيل (T) والزمن اللازم للتضاعف (DT) كانت أقصر عند التربية على درجة حرارة 30 °م بالمقارنة بدرجتي 20 °م ، 25 °م . وكذلك كانت قيم معامل التضاعف (R_o) ، معدل التكاثر (GRR) ، معدل الزيادة الطبيعي (r_m) ، ومعدل الزيادة النهائي (λ) أعلى عند التربية على درجـة حرارة 30 °م بالمقارنة بدرجتي 20 °م ، 25 °م .

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