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Role of four Phytoseiid mite species and Acarophagous Ladybird, *Stethorus gilvifrons* (Mulsant) as Bioagents of the Two Spotted Spider Mite *Tetranychus urticae* Koch.

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ABSTRACT

Predaceous insects and mites are important biological control agents of the two spotted spider mite *Tetranychus urticae* Koch. Biology and life table parameters of *Stethorus gilvifrons* Mulsant, *Phytoseiulus persimilis* A.- H., *Neoseiulus cucumeris* (Oud.), *Typhlodromips swirskii* (A.- H.) and *Euseius scutalis* A.- H. fed on *T. urticae* immatures was studied at 28 ± 1 °C. Their female life cycle and life span averaged 17.66, 5.80, 4.40, 6.26 & 6.26 days and 47.60, 19.13, 38.00, 43.20 & 23.93 days, respectively. During its life span, average female fed on 1647.13, 343.53, 353.53, 345.66 & 200.33 with a daily rate 34.60, 17.96, 9.30, 8.00 and 8.37 *T. urticae* immatures respectively. The net rate of natural increase (r_m) and the finite rate of increase (e^{rm}) of the aforementioned predators were 0.139, 0.294, 0.349, 0.261 & 0.229; and 1.15, 1.34, 1.41, 1.29 & 1.25, respectively. These of *T. urticae* were 0.222 and 1.24, respectively.

Key Words: *Stethorus gilvifrons, Phytoseiulus persimilis, Neoseiulus cucumeris, Typhlodromips swirskii, Euseius scutalis, Tetranychus urticae,* Life tables.

INTRODUCTION

The two spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is a world wide pest commonly found on many agricultural crops. More than 900 species of host plants have been recorded for *T. urticae* (Bolland *et al.* 1998). Its most important predators are phytoseiid mites and coccinellid insects of the genus *Stethorus* (Roy *et al.*, 2005). Phytoseiids, are generally more effective than predatory insects in controlling mites at low population levels because of lower food requirements, short life cycle, ability to survive on alternative food sources and good host-searching ability. (Huffaker *et al.*, 1970 ; McMurtry *et al.*, 1970 and Gerson *et al.*, 2003). Phytoseiids have been divided in four categories according to feeding habits. Type I, consists only of *Phytoseiulus* spp. that are predators of heavily webbing spider mites, mostly *Tetranychus* spp. Type II, species feed on spider mites, but are not restricted to *Tetranychus* spp., feeding on other small mites as well as on pollens. Type III, phytoseiids that often prefer prey other than spider mites (because of being entangled in prey webs), such as tarsonemids and thrips. Type IV comprises genus *Euseius,* generalist predators that develop and reproduce successfully on pollens, but it can become entangled within spider mite webbing (McMurtry and Croft, 1997). The species most often used in greenhouses are *Phytoseiulus persimilis* Athias-Henriot (a type I species), *Typhlodromips swirskii* (A.-H.) and *Neoseiulus cucumeris* (Oudemans) (type III) (Gerson and Weintraub, 2010). The major impact of generalists predators, such as *Euseius* species, prefer low population densities of spider mites, where they may prevent the widespread colonization (James, 1990; McMurtry, 1992; McMurtry *et al.*, 1992 and Badii *et al.*, 2004).

Members of *Stethorus* have been reported as obligate predators of spider mites (Felland and Hull, 1996; Obrycki and Kring, 1998; Rott and Ponsonby, 2000 and Biddinger *et al.*,2009) and several species have been reported to be effective biological control agents (Gotoh *et al.*, 2004 and Mori *et al.*, 2005). They are feeding on all prey stages, having high host-finding, high dispersal potential, and long-living adults (Tanigoshi and McMurtry, 1977a, b; Roy *et al.*, 2003). *Stethorus gilvifrons* Mulsant is a native beneficial coccinellid in Egypt (El-Adawy *et al.*, and 2001 Osman, 2005), Middle East and Southern Europe Aksit *et al.* (2007). Therefore, the present work aims to study and evaluate the different biological aspects and food consumption of *S. gilvifrons, P. persimilis, N. cucumeris, T. swirskii* and *E. scutalis* (A-H.) fed on immatures of *T. urticae*.

MATERIALS AND METHODS

Biological studies of *S. gilvifrons, P. persimilis, N. cucumeris, T. swirskii, E. scutalis* and the prey *T. urticae*

Newly deposited 30 eggs from each predator were singly transferred to modified Huffaker cells (Sabelis, 1981; Overmeer, 1985), reared to the adult stage and observed daily until death. The cell was prepared by a piece of Plexiglas (8 × 4 cm and 5 mm of thickness) with a circular hole of 1.5 cm diameter in the middle. A second Plexiglas plate of the same size forms the base of the cell. On this second plate, a moistened filter paper was laid on which a piece of castor plant leaf placed upside down. A transparent coverslip closed the cell and all the pieces were held together with rubber bands. Predatory mites were reared with ample of prey that was replenished daily. Observations on development and food consumptions were recorded twice a day for the whole life span. On other hand, leaf discs of *R. communis*, one square inch, were used as a substrate for rearing newly deposited eggs of *T. urticae* .The leaf discs were placed on a wet cotton pad in Petri dishes (15 cm in diameter). at 28 ± 1 ^{0} C and 70 ± 5 % RH.. Observations on life development for both predators and prey were recorded twice a day during its life span.

Statistical analysis

Data were analysed by one way analysis of variance (ANOVA), and the means were separated using Duncan's Multiple Range Test (CoHort Software, 2004).

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 (Laughlin, 1965; May, 1976; Carey, 1993).

RESULTS AND DISCUSSION

I. Immature stages:

Table (1) shows that larvae *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* hatched after 3.53, 2.13, 1.00, 2.13 and 1.80 days, respectively at 28± 1 °C. On the other hand, *T. urticae* female larvae hatched after 3.60 days. Female life cycle of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* averaged 17.66, 5.80, 4.40, 6.26 and 6.26 days, respectively when fed on immatures of *T. urticae*. whereas, *T. urticae* female life cycle was 9.80 days. No significant difference between *P. persimilis*, *T. swirskii* and *E. scutalis* females life cycle but the difference was significant between predators and *T. urticae*. Similar results were obtained by Mridul and Badal (2002) who noticed that *S. gilvifrons* fed on *Oligonychus coffee* Neither completed life cycle in 16.33 days under laboratory conditions. Also, Fiaboe *et al.*, (2007) showed that life cycle of *S. tridens* Gordon durated 17.4 days when fed *T. evansi* Baker & Pritchard at 27 ^{0} C. while, Taghizadeh *et al.*, (2008a) stated that *S .gilvifrons* completed its life cycle after 12.49 days when fed on *T. urticae* at 30 ^{0} C. On the other hand, most phytoseiid species completed their life cycle at a constant temperature of 25-28 °C with in a range of 5-8 days (Fouly and El-Laithy, 1992; Osman, 2000; Popov and Kondryakov, 2008; Abou-Awad *et al.*, 2009 and Abad-Moyano *et al.*, 2009). Whereas, Mahgoub (2006) stated that life cycle of *N. cucumeris* feamale durated 4.4, 6.6 and 6.3 days when reared on eggs, immatures and adults of *T. urticae* respectively at 30 °C. Ali and Zaher (2007) reported that life cycle of *T. swirskii* durated 14.2 days when fed on immatures of *T. urticae* at 25 °C.

Developmental durations and number of eggs laid per female of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and *T. urticae* were recorded in Tables (1 & 3). Osman (2000) stated that longevity and life span of *S. gilvifrons* were 36.46 and 56.40 days respectively when reared *T. urticae* on immature at 25 ^{0} C. Imani *et al.*, (2009) showed its longevity averaged 58.00 and 45.05 when reared on *T. turkestani* and *E. orientalis* respectively. On the other hand, El-Laithy and Fouly (1992) found that adult female longevity of *E. scutalis* and *T. swirskii* durated 27.12 and 29.32 days, respectively when reared on *T. urticae* at 25^{0} C. Takahashi and Chant (1994) stated that life span of *P. persimilis* was 23 days at 26 °C. Osman (2000) reported that adult female longevity and life span of *E. scutalis* reared on immatures of *T. urticae* at 26 ^{0} C were 21.76 and 29.04 days, respectively. Also, Mahgoub (2006) stated that female adult longevity and life span of *N. cucumeris* reared on eggs, immatures and adults of *T. urticae* at 30 °C were 18.7, 32.1 and 36.4 days and 23.1, 38.7 and 42.7 respectively., Ali and Zaher (2007) showed that female adult longevity and life span of *T. swirskii* durated 53.3 and 67.5 days, when reared on immatures of *T. urticae* at 25 °C. Also, Al-Shammery (2010) recorded that adult longevity and life span of *E. scutalis* female durated 26.4 and 34.42 days, when reared on immatures of *T. urticae* at 26 °C.

Table (2) shows feeding capacity of immature

Table (1): Comparative duration (Mean ± S.E. in days) of female of *Stethorus gilvifrons*, *Phytoseiulus persimilis*, *Neoseiulus cucumeris*, *Typhlodromips swirskii*, *Euseius scutalis* and *Tetranychus urticae* at 28 ± 1 ^{0} C.

Sp.	Developmental durations		Life cycle	Adult stage				Lifespan
	Egg	Total immatures		Pre-oviposition	Oviposition	Post-oviposition	Longevity	
S. gilvifrons	3.53±0.19^{a}	14.13±0.36^{a}	17.66±0.39^{a}	2.93±0.20^{a}	20.66±1.27^{b}	6.33±0.77^{b}	29.60±1.91^{c}	47.60±1.83^{a}
P. persimilis	2.13±0.09^{b}	3.66±0.12^{de}	5.80±0.10^{c}	1.66±0.15^{d}	8.66±0.21^{d}	2.86±0.33^{c}	13.33±0.46^{e}	19.13±0.42^{e}
N. cucumeris	1.00±0.00^{c}	3.40±0.13^{e}	4.40±0.13^{d}	2.20±0.10^{bc}	21.26±0.61^{ab}	10.26±0.28^{a}	33.60±0.65^{b}	38.00±0.61^{c}
T. swirskii	2.13±0.09^{b}	4.13±0.09^{cd}	6.26±0.11^{c}	2.33±0.12^{b}	23.13±0.70^{a}	11.40±0.63^{a}	36.80±0.86^{a}	43.20±0.95^{b}
E. scutalis	1.80±0.10^{b}	4.46±0.23^{c}	6.26±0.28^{c}	1.80±0.14^{cd}	12.66±0.47^{c}	3.20±0.14^{c}	17.66±0.52^{d}	23.93±0.62^{d}
T. urticae	3.60±0.13^{a}	6.20±0.14^{b}	9.80±0.17^{b}	1.86±0.19^{bcd}	10.26±0.45^{d}	1.93±0.20^{c}	14.06±0.39^{e}	23.86±0.46^{d}

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

Table (2): Feeding capacity (Mean ± S.E. in days) of immature stages and adult female of *Stethorus gilvifrons*, *Phytoseiulus persimilis*, *Neoseiulus cucumeris*, *Typhlodromips swirskii* and *Euseius scutalis* fed on immatures of *Tetranychus urticae* at 28 ± 1 ^{0} C.

Sp.	Total immatures	Daily rate	Longevity	Daily rate	Lifespan	Daily rate
S. gilvifrons	84.73±2.82*a*	5.99 ± 0.34*b*	1562.40± 51.89*a*	52.78 ± 1.59 *a*	1647.13 ± 128.54 *a*	34.60 ± 2.03 *a*
P. persimilis	25.46±0.51*b*	6.95 ± 0.30*a*	318.06±4.88*b*	23.86 ± 1.19 *b*	343.53 ± 5.14 *b*	17.96 ± 0.92 *b*
N. cucumeris	11.86±0.30*c*	3.48 ± 0.16*c*	341.66 ± 14.75*b*	10.17 ± 0.67 *c*	353.53 ± 14.68 *b*	9.30 ± 0.42 *c*
T. swirskii	9.93±0.39*c*	2.40 ± 0.16*d*	335.73±10.63*b*	9.12 ± 0.41 *c*	345.66 ± 10.58 *b*	8.00 ± 0.18 *c*
E. scutalis	8.20±0.29*c*	1.83 ± 0.15*d*	192.13±7.39*c*	10.88 ± 0.49 *c*	200.33 ± 7.29 *b*	8.37 ± 0.25 *c*

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

Table (3): Life table parameters of *Stethorus gilvifrons*, *Phytoseiulus persimilis*, *Neoseiulus cucumeris*, *Typhlodromips swirskii*, *Euseius scutalis* and *Tetranychus urticae* at 28 ± 1 ^{0} C.

Sp.	Mean Total Fecundity	R_0	T	r_m	e^{rm}	GRR	DT	T_c	r_c	ARI
S. gilvifrons	91.80 ± 3.06 *a*	56.36	28.83	0.139	1.15	64.16	4.96	31.31	0.129	1.41×10^{22}
P. persimilis	35.60 ± 1.56 *d*	22.02	10.51	0.294	1.34	24.02	2.35	11.17	0.277	5.66×10^{46}
N. cucumeris	46.86 ± 1.08 *c*	27.78	9.51	0.349	1.41	35.33	1.97	14.31	0.232	3.77×10^{55}
T. swirskii	45.06 ± 0.96 *c*	26.70	12.58	0.261	1.29	32.28	2.64	16.62	0.197	3.58×10^{41}
E. scutalis	29.73 ± 0.85 *e*	16.84	12.28	0.229	1.25	18.84	3.01	14.35	0.196	2.39×10^{36}
T. urticae	64.80 ± 5.40 *b*	36.98	16.19	0.222	1.24	42.23	3.11	17.20	0.209	2.13×10^{35}

R_0: Net reproductive rate, T: Mean generation time, r_m: Intrinsic rate of increase, e^{rm}: Finite rate of increase, GRR: Gross reproductive rate, DT: Doubling time, T_c: Cohort generation time, r_c: Capacity of increase, ARI: Annual rate of increase

stages and adult females of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* . Osman (2005) reported that *S. gilvifrons* female consumed 2384.53 with a daily rate 42.27 immatures of *T. urticae* at 25 ^{0} C. while, Fiaboe *et al*., (2007) stated that *S. tridens* Gordon consumed 67.8 nymphs of *T. evansi* Baker & Pritchard daily in the oviposition period. Also, Perumalsamy *et al*., (2010) showed that *S. gilvifrons* female consumed 205.0 eggs, 92.2 larvae, 81.8 nymphs or 52.4 adult mites per day when reared on *O. coffeae*. Ali and Zaher (2007) reported that *T. swirskii* female mite consumed 120.70 and 131.00 immatures of *T. urticae* during its longevity and life span with a daily rate of 2.30 and 1.70 at 25 ^{0} C. while, Kazak (2008) indicated that *P. persimilis* female consumed a daily rate 15.41 of *T. cinnabarinus* protonymphs at 30 ^{0}C. Also, Abd el Wahed (2007) noticed that female of *N. cucumeris* consumed 78.8 and 95 moving stages during its life span.

II. Life table parameters:

Life table parameters of the predatory lady bird beetle *S .gilvifrons* and phytoseiid mites, are presented in Table (3). Fig. 1 clearly indicated that the survival curves of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* fed on *T. urticae* immatures at 28 ^{0}C followed a type I

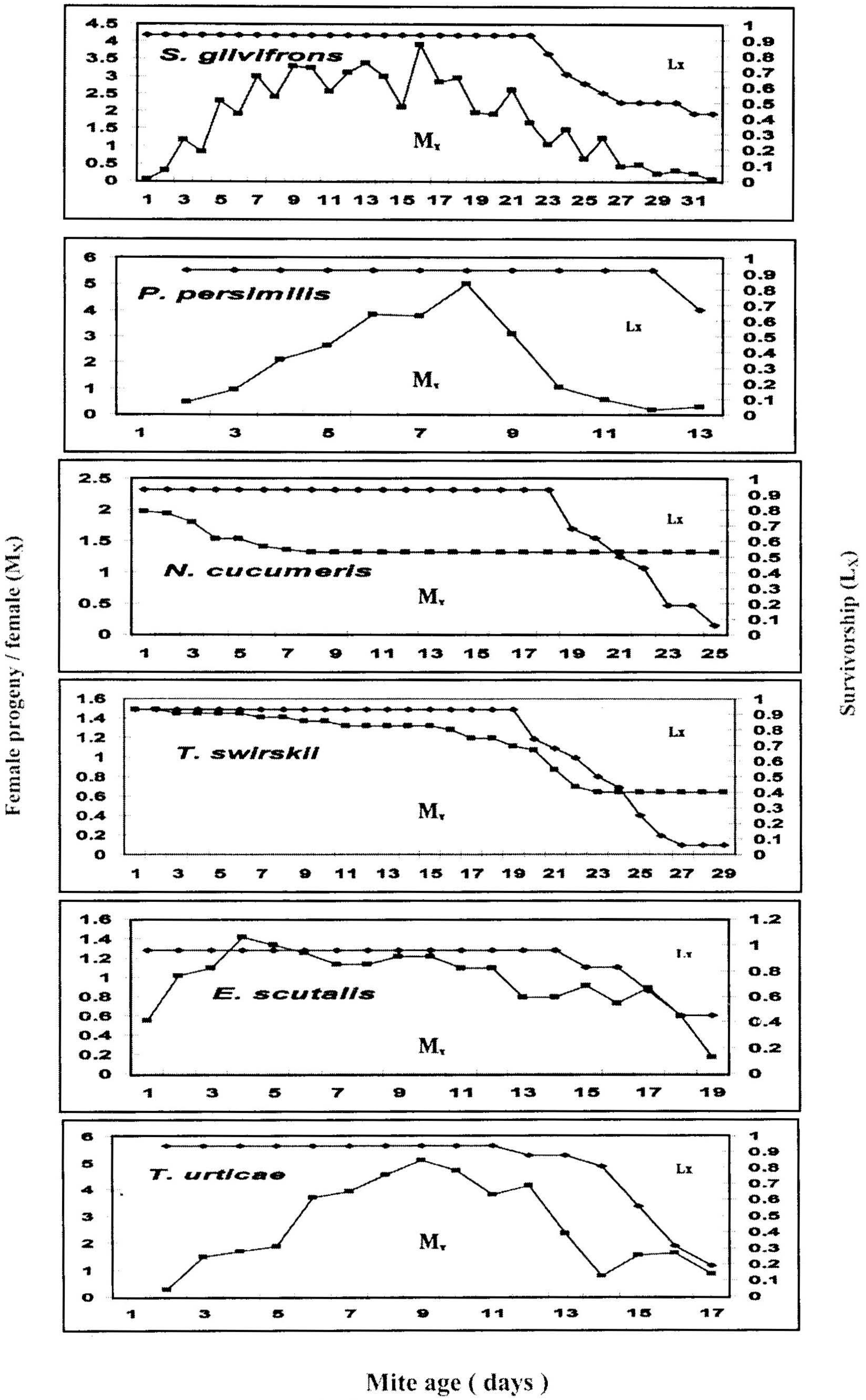

Fig.(1): Comparison between Age – specific fecundity (M_x), survivorship (L_x) of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii*, *E. scutalis* and their prey *T. urticae* at 28 ± 1 ^{0} C.

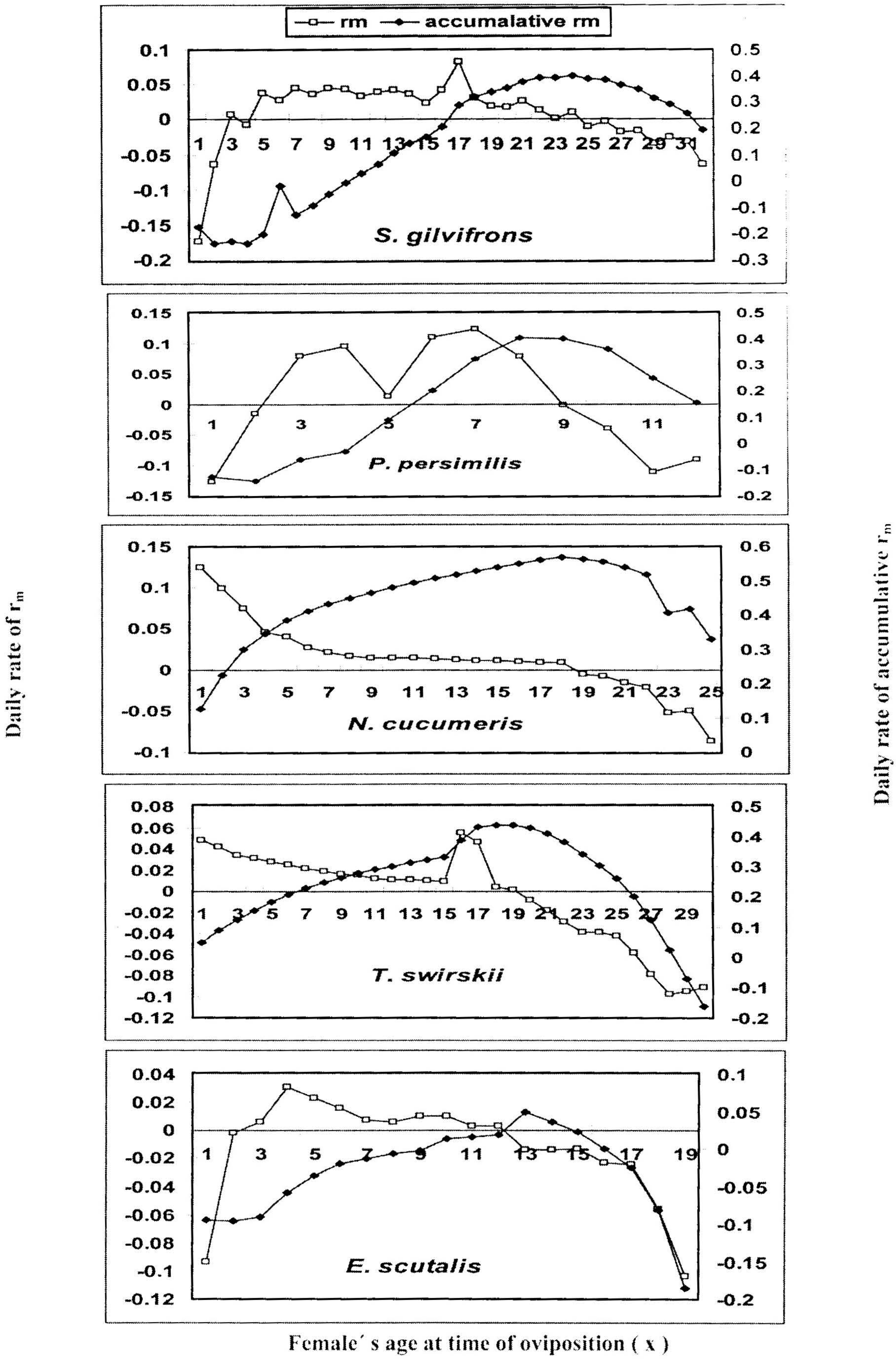

Fig. (2): Accumulative contribution to the r_m of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii*, *E. scutalis* at 28 ± 1 °C females' fecundity in successive age classes.

pattern in which most eggs developed to maturity and death occurred gradually over an extended ovipositional period (Fig. 1). These results agree with that of (Fouly and El-Laithy, 1992; Abou-setta et al., 1997; Fouly, 1997; Osman, 2000; Osman, 2005; Al-Shammery, 2010).

The net reproductive rate (R_0) was the highest for *S. gilvifrons*, 56.36 and the lowest for *E. scutalis*, 16.84. Also, the mean generation time (T) averaged 28.83, 10.51, 9.51, 12.58 and 12.28 for *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* respectively. The present results revealed that *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* could multiply 56.36, 22.02, 27.78, 26.70 and 16.84 times in a generation time 28.83 10.51 9.51 12.58 and 12.28 for the aforementioned predators respectively., whereas, *T. urticae* could multiply 36.98 times in a generation time 16.19.

Similar data obtained by Taghizadeh *et al.* (2008b) who reported that *S. gilvifrons* reared on *T. urticae* recorded R_0 and T 47.54 and 20.17 at 30 ^{0} C. Imani *et al.* (2009) showed that R_0 and T were 97.6, 154.08 and 26.76, 22.83 when *S. gilvifrons* reared on *T. turkestani* and *E. orientalis* respectively at 30 ^{0} C. 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 immatures of *T. urticae* at 25 ^{0} C. 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 ^{0} C.

However, the intrinsic rate of natural increase (r_m) is a useful parameter for predicting the population growth potential of an animal under environmental conditions, as it reflects an overall effect on development, reproduction and survival (Southwood and Handerson 2000). Data in table (3) showed that r_m values were 0.139, 0.294, 0.349, 0.261and 0.229 individuales / female / day when *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* reared on immatures of *T. urticae*, respectively, while, for *T. urticae* was 0.222 individuales / female / day. e^{rm} ranged between 1.15 and 1.41for predators and 1.24 for *T. urticae*. Osman, 2005 recorded that r_m and e^{rm} of *S. gilvifrons* were 0.12and 1.13 when reared on immatures of *T. urticae* at 25 ^{0} C. Also, Taghizadeh *et al.* (2008b) showed that r_m and e^{rm} of *S. gilvifrons* were 0.19 and 1.21 when reared on immatures of *T. urticae* at 30 ^{0}C. Imani *et al.* (2009) reported that r_m and e^{rm} were 0.17, 1.186 and 0.22, 1.24 when *S. gilvifrons* reared on *T. turkestani* and *E. orientalis* respectively at 30 ^{0}C. The biotic potential (r_m) of the main phytoseiid species constitutes 0.18–0.334; maximal values at optimal environmental conditions of *P. persimilis* are 0.219–0.334 (Laing, 1968; Popov and Kondryakov 2008). However, estimates of r_m are difficult to compare between studies, because of genetic variation, differences in rearing methods and other environmental conditions, and variable assumptions entering these estimations (Roy *et al.*, 2003). Additionally, the intrinsic rate of increase (r_m) depending on female age, showed a decline fluctuating curve for *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* (Fig. 2). Correspondingly, accumulative r_m curve for *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* followed a similar trend and declined after 17, 8, 18, 19, 16 days after emergence. This result has to be considered in future bio-control programs i.e., female of *S. gilvifrons*, *N. cucumeris*, *T. swirskii* and *E. scutalis* should be periodically released in three weeks interval and 10 days for *P. persimilis*.

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 its prey (Sabelis, 1992). In biological control practice, r_m value is increasingly used as means for selecting promising biocontrol candidates on the basis of its reproductive potential and to predict the outcome of pest-natural enemy interactions (Jervis and Copland, 1996). In the present study the r_m value of *S. gilvifrons* was lower than that of its prey *T. uricae*. A similar situation was observed by McMurtry *et al.*, (1974) on *Stethorus picipes* Casey (r_m = 0.12 day-1 at 25 ^{0}C) preying on *Oligonychus punicae* (Hirst) on avocados. Also, Muraleedharan *et al.*, (2005) recorded that the r_m value of *S. gilvifrons* was lower than that of its prey *O. coffeae*. The explanation could be that under highly favourable conditions, high predation rates by *Stethorus* spp. could eliminate prey more rapidly than they can reproduce (Roy *et al.*, 2003 and Perumalsamy *et al.*, 2010).

On the other hand, the doubling time (DT) of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* recorded 4.96, 2.35, 1.97, 2.64 and 3.01 days when reared on immatures of *T. urticae*. Also, gross reproductive rate (GRR) was 64.16, 24.02, 35.33, 32.28 and 18.84 eggs/female.

Perumalsamy *et al.*, (2010) recorded that DT and GRR of *S. gilvifrons* were 10.5 days and 82.3 eggs/female when reared on *O. coffeae* at 25 ^{0}C.

In the present study, the cohort generation time (T_c) of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* were 31.31, 11.17, 14.31, 16.62 and 14.35, while capacity of increase (r_c) recorded 0.129, 0.277, 0.232, 0.197 and 0.196. Also, annual rate of increase (ARI) of *S. gilvifrons*, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* was 1.41x 10^{22}, 5.66 x 10^{46}, 3.77 x 10^{55}, 3.58 x 10^{41}, 2.39 x 10^{36} . On the other hand, the cohort generation time (T_c), capacity of increase (r_c) and annual rate of increase (ARI) of *T. urticae* was 17.20, 0.209 and 2.13 x 10^{35}. 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 seasons, respectively.

The afro-mentioned results revealed that lady bug *S. gilvifrons* belonging to the genus *Stethorus* is obligate predator of tetranychid mites. Therefore, it is highly recommended to play an important role for supressing *T. urticae* population in open fields and in greenhouses. Also, *P. persimilis*, *N. cucumeris*, *T. swirskii* and *E. scutalis* could play effective role against the aforementioned pest.

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