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Life table of the entomophagous ladybird *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) by feeding on *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) as prey at two different temperatures and plant species

Biologische Eigenschaften des entomophagen Marienkäfers *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) mit *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) als Beute bei zwei unterschiedlichen Temperaturen und Pflanzenarten

C. Sengonca*, F. Al-Zyoud, P. Blaeser
Department of Entomology and Plant Protection, Institute of Phytopathology, University of Bonn, Nussallee 9, D-53115 Bonn, Germany
* Corresponding author, e-mail: C.Sengonca@uni-bonn.de

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Summary

Serangium parcesetosum Sicard (Col., Coccinellidae) seems to be a specialist predator of whiteflies. However, the knowledge about its life table parameters with the cotton whitefly, *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) as prey was insufficient on the influence of temperature, prey species and plant species on its biology in the literature. Therefore, in the present work, development, mortality, sex ratio, longevity and reproduction of *S. parcesetosum* were studied in the laboratory at 18 ± 1 °C and 30 ± 1 °C on cotton and cucumber leaves.

S. parcesetosum was able to develop and reach adult stage at both temperatures and plant species tested. Temperature, prey's host plant species and sex of the predator had influenced the mean developmental duration of all stages of the predator. Total developmental duration at 18 °C was a mean of 43.4 (♀♀) and 42.4 (♂♂) days as well as 45.2 (♀♀) and 43.4 (♂♂) days, while at 30 °C, it valued a mean of 17.2 (♀♀) and 16.2 (♂♂) days as well as 15.9 (♀♀) and 15.1 (♂♂) days on cotton and cucumber, respectively. Total mortality percentage of *S. parcesetosum* during development from egg to adult was also affected by temperature and plant species, where it was higher at 18 °C than 30 °C on both plant species, and it was higher on cotton than on cucumber at both temperatures.

The sex ratio (♂♂ : ♀♀) of *S. parcesetosum* was 1 : 0.9 and 1 : 0.8 at 18 °C, while at 30 °C, it valued 1 : 1.1 on cotton and cucumber, respectively.

Longevity of *S. parcesetosum* varied significantly according to temperature, prey's host plant species and sex of the adults, and it was significantly longer at 18 °C than 30 °C for both sexes on both plant species and it was for females significantly longer than males.

Temperature and plant species had significantly influenced pre-oviposition, oviposition and post-oviposition periods of *S. parcesetosum*. At 18 °C, adult females began oviposition 13 and 17 days after emergence with a mean total fecundity of 52.4 and 24.7 eggs/♀ on cotton and cucumber, respectively, while at 30 °C, they began oviposition after 6 and 7 days, where the mean total fecundity was on cotton not expected with only 31.0 and on cucumber 97.7 eggs/♀.

Key words: *Serangium parcesetosum; Bemisia tabaci;* life table; development; longevity; reproduction; biological control

Zusammenfassung

Der entomophage Marienkäfer, *Serangium parcesetosum* Sicard (Col., Coccinellidae) scheint ein spezialisierter Prädator der Weißen Fliege zu sein. Dennoch sind die Erkenntnisse über die Biologie dieses Prädators bei Fütterung mit der Baumwoll-Weißen Fliege *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) sowie über den Einfluss von Temperatur, Beute- und Pflanzenart sehr lückenhaft und unvollständig. In der vorliegenden Arbeit wurde daher die Entwicklung, Mortalität, das Geschlechterverhältnis, die Lebensdauer und Reproduktion von *S. parcesetosum* bei 18 ± 1 °C und 30 ± 1 °C auf Baumwoll- und Gurkenblättern untersucht.

S. parcesetosum konnte sich bei beiden Temperaturen und Pflanzenarten erfolgreich zum Adult entwickeln. Die Temperatur, Wirtspflanzenart der Beute sowie das Geschlecht des Prädators hatten einen Einfluss auf die Entwicklungsdauer der einzelnen Stadien des Räubers. Die vollständige Entwicklungsdauer bei 18 °C dauerte im Durchschnitt 43,4 (♀♀) und 42,4 (♂♂) Tage bzw. 45,2 (♀♀) und 43,4 (♂♂) Tage und bei 30 °C 17,2 (♀♀) und 16,2 (♂♂) Tage bzw. 15,9 (♀♀) und 15,1 (♂♂) Tage auf Baumwoll- bzw. Gurkenblättern. Die prozentuale Mortalität von *S. parcesetosum* während der Entwicklung vom Ei zum Adult wurde ebenfalls von der Temperatur und der Wirtspflanzenart der Beute beeinflusst. So war die Mortalität bei 18 °C höher als bei 30 °C. Ebenso konnte auf den Baumwollblättern eine höhere Mortalität als auf den Gurkenblättern beobachtet werden.

Das Geschlechterverhältnis (♂♂ : ♀♀) von *S. parcesetosum* wurde mit 1 : 0,9 bzw. 1 : 0,8 bei 18 °C und 1 : 1,1 bei 30 °C sowohl auf Baumwoll- als auch auf Gurkenblättern ermittelt.

Die Temperatur, Wirtspflanzenart der Beute sowie das Geschlecht der Adulten wirkten deutlich auf die Lebensdauer von *S. parcesetosum*. Die signifikant längste Lebensdauer konnte bei 18 °C im Gegensatz zu 30 °C bei beiden Geschlechtern auf beiden Pflanzenarten beobachtet werden, wobei sie für die Weibchen signifikant länger als für die Männchen war.

Auch auf die Präoviposition-, Oviposition- and Postovipositionsperiode von *S. parcesetosum* zeigte die Temperatur und Pflanzenart einen signifikanten Einfluss. Bei der Temperatur von 18 °C begannen die adulten Weibchen 13 bzw. 17 Tage nach dem Schlupf mit der Oviposition und erreichten eine durchschnittliche Gesamteiablage von 52,4 bzw. 24,7 Eier/♀. Bei der Temperatur von 30 °C begann die Ovipositionsperiode der Weibchen bereits nach 6 bzw. 7 Tagen mit einer durchschnittlichen Gesamteiablage von 31,0 bzw. 97,7 Eier/♀ sowohl bei Baumwoll- als auch bei Gurkenblättern.

Stichwörter: *Serangium parcesetosum; Bemisia tabaci;* Biologie; Entwicklung; Lebensdauer; Reproduktion; biologische Bekämpfung

1 Introduction

The cotton whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) was formerly confined to tropical and subtropical regions of the world (Hilje et al. 2001). It has since the late 1980s become increasingly important as a pest of greenhouse crops in temperate regions world-wide (Wagner 1995). *B. tabaci* has been known as a severe pest of numerous field and vegetable crops in many countries (Gerling et al. 2001). In Germany, this pest was recorded for the first time in 1987 on many cultivated ornamental plants (Burghause 1987). Afterwards, it has spread to many greenhouse ornamentals, but to few vegetable fields (Albert 1990). Fransen (1994) reported that *B. tabaci* is a permanent pest in many European countries. Nowadays, it has spread over most of the European countries (Martin et al. 2000).

Because of the massive spraying, *B. tabaci* has become resistant to many insecticides and its population continues to increase in various locations world-wide. Beside development of resistance to insecticides, its natural enemies were severely reduced in number or completely eliminated, which further complicated the problem (Lacey and Kirk 1993).

Serangium parcesetosum Sicard (Coleoptera: Coccinellidae) is considered an oligophag important predator of whiteflies (Kapadia and Puri 1992; Yigit 1992b). It has been recorded as a predator on *B. tabaci* in India (Kapadia and Puri 1992) and *Aleurolobus barodensis* Mask (Patel et al. 1996). It was imported to control *Dialeurodes citri* (Ashmead) in Georgia (Timofeyeva and Nhuan 1979), France and Corsica (Malausa et al. 1988) and Turkey (Yigit 1992a; Uygun et al. 1997; Yigit et al. 2003).

Also, it is used against *Bemisia argentifolii* Bellows and Perring in the USA (Legaspi et al. 1996, 2001). In Israel, it is reported on *Aleurothrixus floccosus* Mask. (Argov 1994) and in Syria on *D. citri* and *B. tabaci* (Abboud and Ahmad 1998).

In contrast, the little information that exists on the life table parameters of *S. parcesetosum* demonstrated some differences. Kapadia and Puri (1992) reported three instars for its larval development, while Patel et al. (1996) and Abboud and Ahmad (1998) found four larval instars. The longevity of *S. parcesetosum* varied greatly, for instance, it lasted a mean of 79.2 days at 20 °C and 27.6 days at 20–23 °C with *B. argentifolii* as prey (Legaspi et al. 1996). Also, Timofeyeva and Nhuan (1979) recorded a fecundity of *S. parcesetosum* of 135–185 eggs at 20–23 °C with *D. citri* as prey, while Ahmad and Abboud (2001) stated a mean of 443.9 eggs/♀ at 27 °C with *B. tabaci*.

Lacking of knowledge in the literature and variations in the previous results make it necessary to study the influence of temperature, prey species and plant species on the life table parameters of *S. parcesetosum*. Thus, we will provide basic information for further investigations to evaluate this predator as a biological control agent of *B. tabaci*.

Therefore, the present work was aimed to study the development, mortality, sex ratio, longevity and reproduction of *S. parcesetosum* at two different temperatures on two host plant species of *B. tabaci* in the laboratory.

2 Materials and methods

For establishing the colony, approximately 10 individuals of *S. parcesetosum* were sent by courtesy of Plant Protection Research Institute, Adana, Turkey. They were reared on cotton, *Gossypium hirsutum* L. cv. 'Caroline Queen' infested with *B. tabaci* in meshed cylindrical Plexiglas cages (19 cm in diameter and 40 cm in height) held in a climatically controlled chamber at 25 ± 2 °C temperature, 60 ± 10 % relative humidity and a photoperiod of 16 : 8 (L : D) h at a light intensity of about 4000 lx. *B. tabaci* was obtained from Bayer AG, Leverkusen, Germany, and reared on cotton plants in meshed cages (80 × 50 × 65 cm) in the above mentioned chamber. To maintain adequate prey supply, cotton plants infested with *B. tabaci* were frequently replaced.

Round Plexiglas cages (11 cm diameter × 3 cm height) were used in all of the experiments. The cages were partially filled with a 0.5 cm thick layer of wetted cotton pad. The lid of each cage had three meshed holes to provide ventilation. Cotton or cucumber (*Cucumis sativus* L. cv. 'Tanja') leaves infested with more than 300 eggs, nymphs and puparia of *B. tabaci* were placed upside down onto the cotton pads for *S. parcesetosum* to feed on. For the different experiments, 5–6 mated adult females of *S. parcesetosum* were transferred to each of the round Plexiglas cages and kept in an incubator under the same conditions used for rearing the desired stage of the predator. All the experiments were carried out at a low (18 ± 1 °C) and a high temperature (30 ± 1 °C), representing temperature regimes frequently encountered under summer (approximately field conditions) and winter (greenhouse conditions), respectively, with relative humidity and photoperiod described before on leaves of cotton and cucumber plants.

In order to determine the duration of the development of *S. parcesetosum*, the adult females were removed after 24 h from the round Plexiglas cages mentioned above and the laid eggs were incubated at the desired temperatures and investigated daily. The duration of embryonic development was recorded after hatching the larvae from eggs. The newly hatched L_1 instars were singly transferred using a Camel hairbrush into other similar Plexiglas cages containing cotton or cucumber leaves infested with *B. tabaci*. The cages were checked daily for moulting of the successive larval instars until the day the L_4 instar left the leaf and was observed to be attached to the surface of the Plexiglas cages. The larval instars were transferred at intervals of 1–3 days to new cages. The pupation period was determined from the day the L_4 instar was found attached to the plastic surface to the day when the adult started emerging. A minimum of 44 replicates was set up in the experiments with each sex of the predator at each temperature and plant species.

During the developmental duration experiment, the mortality of *S. parcesetosum* eggs, different larval instars and pupae was recorded daily. In the 18 °C experiment, the mortality of eggs and pupae was determined after 20 and 60 days of egg laying, while at 30 °C, it was after 10 and 30 days, respectively.

The experiments were begun with at least 144 replicates for each temperature and plant species.

To establish the sex ratio of *S. parcesetosum*, the emerged adults from the same experiment on development were sexed under a binocular microscope. The percentage of males and females were calculated. Minimums of 98 emerged adults were used for each plant species and temperature.

For recording *S. parcesetosum* longevity, newly emerged adult females and males were transferred to other round Plexiglas cages as described above and kept on cotton or cucumber leaves. The individuals in the cages were incubated at the low or high experimental temperature until they died. The females and males were transferred within a period of 3 days to new cages. The longevity of both sexes was recorded after the individuals died. During the longevity experiment, the first and last egg-laying days were also recorded for the pre-oviposition, oviposition and post-oviposition periods of *S. parcesetosum* females. There were at least twelve replicates of each sex at each temperature and plant species.

For establishing fecundity of *S. parcesetosum* females during their oviposition period, the number of laid eggs was recorded daily and removed directly from the cages during the experiment on longevity. Daily and total fecundity were determined.

The data from the laboratory studies on development and longevity of *S. parcesetosum* were analyzed statistically using a three-way (ANOVA) to test if these two parameters were affected by temperature, *B. tabaci* host plant species and sex of the predator. A two-way (ANOVA) was conducted to determine the effect of temperature and prey's host plant species on oviposition and fecundity of the predator.

3 Results

3.1 Development

S. parcesetosum was able to develop with *B. tabaci* as prey and reach the adult stage at both temperatures of 18 °C and 30 °C. Both plant species used were also found to be suitable for *S. parcesetosum* to develop on (Table 1). Mean developmental duration of egg stage on cotton and cucumber for both sexes was significantly longer at 18 °C than 30 °C. Host plant species of *B. tabaci* had significantly no effect on mean develop-

Table 1. Mean developmental duration of immature stages of *Serangium parcesetosum* by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at two different temperatures

Temp. (°C)	Plant species	n	Sex	Duration of egg stage (days) mean ± SE	Duration of larval instars (days)				Duration of pupal stage (days) mean ± SE	Total duration (egg-adult) (days) mean ± SE
					L_1 mean ± SE	L_2 mean ± SE	L_3 mean ± SE	L_4 mean ± SE		
18 ± 1	Cotton	47	♀♀	11.4 ± 2.0 aA	4.4 ± 1.4 bA	4.4 ± 1.2 bA	3.5 ± 1.1 aA	7.5 ± 1.9 aA	12.2 ± 2.1 aA	43.4 ± 4.2 aA
		51	♂♂	11.2 ± 1.7 aA	3.7 ± 1.2 aA	4.2 ± 1.4 bA	3.2 ± 1.4 aA	7.6 ± 1.9 aA	12.5 ± 2.8 aA	42.4 ± 3.0 aA
	Cucumber	44	♀♀	11.3 ± 1.7 aA	3.6 ± 1.0 aA	3.4 ± 0.6 aA	4.0 ± 1.1 bA	9.9 ± 1.7 bA	13.0 ± 2.4 bA	45.2 ± 4.0 aA
		56	♂♂	11.3 ± 1.3 aA	3.7 ± 0.9 aA	3.4 ± 0.7 aA	3.6 ± 0.9 aA	9.1 ± 2.6 bA	12.3 ± 2.2 aA	43.4 ± 3.6 aA
30 ± 1	Cotton	58	♀♀	3.9 ± 1.0 aB	1.9 ± 0.6 bB	1.8 ± 1.4 bB	1.6 ± 0.6 aB	3.4 ± 1.2 bB	4.6 ± 1.4 aB	17.2 ± 2.9 bB
		52	♂♂	3.8 ± 1.0 aB	1.8 ± 0.5 bB	1.7 ± 0.5 aB	1.7 ± 0.6 aB	3.1 ± 1.3 aB	4.1 ± 1.5 aB	16.2 ± 1.9 bB
	Cucumber	66	♀♀	4.1 ± 1.0 aB	1.3 ± 0.5 aB	1.3 ± 0.5 aB	1.6 ± 0.5 aB	2.5 ± 1.2 aB	5.1 ± 1.3 aB	15.9 ± 1.9 bB
		58	♂♂	3.9 ± 0.9 aB	1.2 ± 0.4 aB	1.5 ± 0.7 aB	1.4 ± 0.5 aB	2.6 ± 1.1 aB	4.5 ± 1.2 aB	15.1 ± 2.2 bB

Means in columns followed by different small letters indicate significant differences between the different plant species within the same sex and temperature. Means in columns followed by different capital letters indicate significant differences between the different temperatures within the same plant species and sex at $p \leq 5$ % (ANOVA) mental duration, in which it was about 11 days at 18 °C and 4 days at 30 °C. There were significant differences in the mean developmental duration of the four different larval instars of both sexes on both plant species between the two different temperatures. Host plant species exhibited some significant differences for both sexes within the same temperature. Mean developmental duration of pupal stage was the longest versus all the other developmental stages of both sexes at both temperatures and plant species tested. Pupal stage of both sexes developed significantly faster at 30 °C than 18 °C on both plant species. The pupal stage of both sexes was developed significantly similar within the same temperature on the different plant species, but there were significant differences in the mean developmental duration of pupal stage of females at 18 °C. Mean total developmental duration from egg to adult emergence of both sexes on both plant species was significantly longer at 18 °C than 30 °C. At 18 °C, it was a mean of 43.4 (♀♀) and 42.4 (♂♂) days as well as 45.2 (♀♀) and 43.4 (♂♂) days, while at 30 °C, it lasted 17.2 (♀♀) and 16.2 (♂♂) days as well as 15.9 (♀♀) and 15.1 (♂♂) days on cotton and cucumber leaves, respectively. Within the same temperature and predatory sex, there were no significant differences in the mean total developmental duration on cotton and cucumber. The three-way analysis of variance showed that the sex of the predator had influenced the duration of development in L_1, L_3 and pupal stage as well as total duration of *S. parcesetosum*.

3.2 Mortality

Mortality in the same experiment occurred during all the developmental stages of *S. parcesetosum* at both temperatures and host plant species of *B. tabaci* tested (Table 2). During egg stage, it was higher at the low temperature of 18 °C than the high temperature of 30 °C on both plant species. According to the larval instars, mortality in L_1 instar was the highest at both temperatures and plant species tested. Whereas in the pupal stage, it was the highest among all the other immature stages and it was higher at 18 °C than 30 °C on both plant species. Total mortality during development from egg to adult emergence was higher at 18 °C than 30 °C on both plant species, and it was higher on cotton than cucumber leaves at both temperatures. At 18 °C, it valued 32.9 % and 30.5 %, while at 30 °C it was 23.8 % and 20.6 % on cotton and cucumber leaves, respectively.

3.3 Sex ratio

The percentage of males and females at 18 °C was 52.0 (♂♂) and 48.0 (♀♀) as well as 56.0 (♂♂) and 44.0 (♀♀), while at 30 °C it valued 47.3 (♂♂) and 52.7 (♀♀) as well as 46.8 (♂♂) and 53.2 (♀♀) on cotton and cucumber leaves, respectively (Fig. 1). So that the sex ratio (♂♂ : ♀♀) of *S. parcesetosum* with *B. tabaci* as prey was 1 : 0.9 and 1 : 0.8 at 18 °C, while at 30 °C, it was 1 : 1.1 on cotton and cucumber leaves, respectively.

3.4 Longevity

The longevity of *S. parcesetosum* adult females and males at both temperatures and host plant species of *B. tabaci* is summarized in Table 3. The longevity of *S. parcesetosum* varied significantly according to

Table 2. Mean percentage mortality of egg and immature stages of *Serangium parcesetosum* by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at two different temperatures

Temp. (°C)	Plant species	n	Mortality during egg stage (%)	Mortality during immature stages (%)					Mortality (%)
				L_1	L_2	L_3	L_4	Pupal stage	Total
18 ± 1	Cotton	146	5.5	8.2	2.7	1.4	4.1	11.0	32.9
	Cucumber	144	6.9	6.9	4.2	1.4	2.8	8.3	30.5
30 ± 1	Cotton	144	2.8	5.6	2.8	2.8	4.2	5.6	23.8
	Cucumber	156	2.6	5.1	1.3	3.9	1.3	6.4	20.6

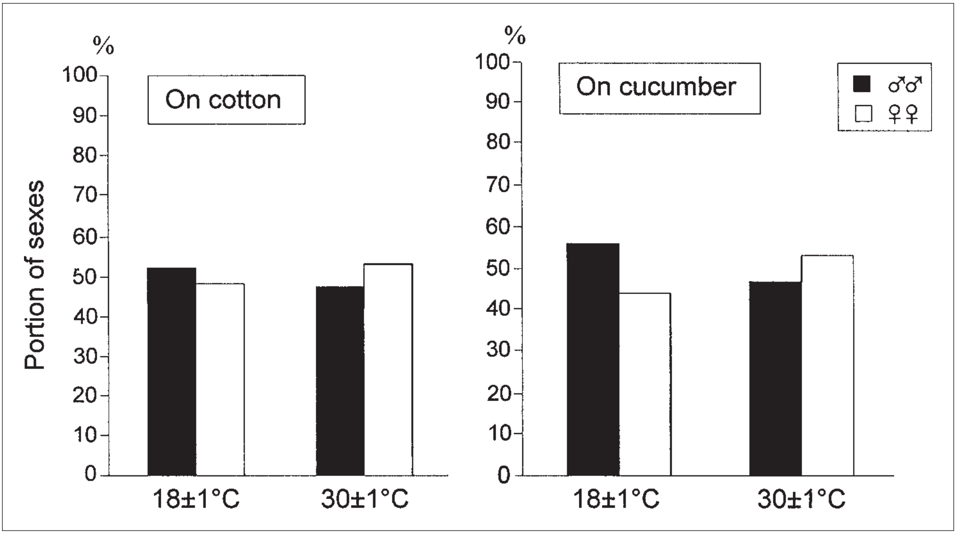

Fig. 1. Percentage portion of sexes of *Serangium parcesetosum* by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at two different temperatures.

temperature, prey's host plant species and predatory sex. Mean longevity of both sexes was significantly longer at 18 °C than 30 °C on both plant species, where it valued at 18 °C a mean of 175.4 (♀♀) and 144.5 (♂♂) days as well as 122.2 (♀♀) and 94.3 (♂♂) days, while at 30 °C, it was a mean of 92.4 (♀♀) and 52.5 (♂♂) days as well as 63.4 (♀♀) and 50.3 (♂♂) days on cotton and cucumber leaves, respectively. Host plant species of the prey had influenced significantly the longevity of *S. parcesetosum* adults, where both females and males had lived significantly longer on cotton than on cucumber, except males at 30 °C. At both temperatures and plant species, females had lived significantly longer than males.

The periods of pre-oviposition, oviposition and post-oviposition were affected significantly by temperature and *B. tabaci* host plant species. Mean period of pre-oviposition was significantly longer at 18 °C with 18.8 and 26.3 days than at 30 °C with 7.7 and 12.1 days on cotton and cucumber leaves,

Table 3. Mean longevity of *Serangium parcesetosum* females and males by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at two different temperatures

Temp. (°C)	Plant species	n	Sex	Longevity (days) mean ± SE	min.	max.
18 ± 1	Cotton	12	♀♀	175.4 ± 35.7 bA	119	238
		12	♂♂	144.5 ± 25.9 bA	89	183
	Cucumber	12	♀♀	122.2 ± 38.8 aA	58	184
		12	♂♂	94.3 ± 17.9 aA	66	123
30 ± 1	Cotton	17	♀♀	92.4 ± 42.3 bB	38	179
		17	♂♂	52.5 ± 13.9 aB	32	78
	Cucumber	15	♀♀	63.4 ± 20.6 aB	33	97
		15	♂♂	50.3 ± 13.1 aB	27	74

Means with different small letters indicate significant differences between the different plant species within the same sex and temperature. Means with different capital letters indicate significant differences between the different temperatures within the same plant species and sex at p ≤ 5 % (ANOVA)

Table 4. Mean pre-oviposition, oviposition and post-oviposition of *Serangium parcesetosum* by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at two different temperatures

Temp. (°C)	Plant species	n	Duration of (days)								
			Pre-oviposition			Oviposition			Post-oviposition		
			mean ± SE	min.	max.	mean ± SE	min.	max.	mean ± SE	min.	max.
18 ± 1	Cotton	12	18.8 ± 4.8 aB	13	29	121.1 ± 38.6 bB	59	180	35.5 ± 15.4 aA	16	71
	Cucumber	12	26.3 ± 6.9 bB	16	42	36.2 ± 13.1 aA	14	56	59.7 ± 32.1 bB	14	110
30 ± 1	Cotton	17	7.7 ± 1.5 aA	5	10	28.0 ± 12.2 aA	11	69	56.7 ± 39.9 bB	12	145
	Cucumber	15	12.1 ± 4.7 bA	6	20	40.6 ± 20.8 bA	12	81	10.7 ± 5.2 aA	2	21

Means in columns followed by different small letters indicate significant differences between the different plant species within the same temperature. Means in columns followed by different capital letters indicate significant differences between the different temperatures within the same plant species at p ≤ 5 % (ANOVA)

respectively (Table 4). Mean period of oviposition was significantly longer at 18 °C with 121.1 days than at 30 °C with 28.0 days on cotton leaves, while on cucumber leaves with 36.2 days at 18 °C and with 40.6 days at 30 °C, it was not significantly different. Mean period of post-oviposition was significantly shorter at 18 °C with 35.5 days than at 30 °C with 56.7 days on cotton leaves, while on cucumber leaves it was significantly longer at 18 °C with 59.7 days than at 30 °C with 10.7 days.

3.5 Fecundity

Mean number of eggs laid daily by *S. parcesetosum* females was different according to host plant species of *B. tabaci* at 18 °C (Fig. 2). On cotton, adult females began oviposition 13 days after emergence, where the daily fecundity was a mean of 0.2 eggs/♀ on the 13th day. It fluctuated afterwards and then increased to a maximum mean no. of 1.3 eggs/♀ on the 60th day. After that, the mean daily number of eggs laid began to decrease and fluctuated again until no eggs were laid after the 197th day. During the experiment on cotton leaves, the first female died on the 119th day, while the last one on the 238th day after adult emergence. On cucumber, the females started laying eggs on the 17th day after emergence, where they laid a mean of 0.1 eggs/♀. The mean daily fecundity increased and fluctuated hereafter and reached a maximum of 1.3 eggs/♀ on the 33rd and 43rd days, respectively. After the 43rd day, the number of daily laid eggs began to decrease gradually and fluctuated until no eggs were laid after the 88th day. On cucumber leaves, the first female died on the 58th day, the last one on the 184th day. At 30 °C on cotton leaves, the females began oviposition 6 days after emergence, where the daily fecundity was a mean of 0.1/♀ on the 6th day and it increased afterwards and reached a maximum mean of 2.0 eggs/♀ on the 12th day (Fig. 3). After that, the mean daily number of laid eggs began to decrease, fluctuate and then decreased again gradually till it approached zero on the 43rd day. Then the females laid eggs occasionally after this time till no eggs were laid after the 77th day. During the experiment on cotton leaves, the first female died on the 38th day, while the last one on the 179th day after adult emergence. On cucumber, the females started laying eggs on the 7th day after their emergence, where they laid a mean of 0.3 eggs/♀. The mean daily fecundity increased and then fluctuated hereafter and reached a maximum of 4.7 eggs/♀ on the 21st day. Starting from the 21st day, the number of daily laid eggs began to fluctuate, decreased gradually and fluctuated again till no eggs were laid after the 88th day. The first female died on cucumber leaves on the 33rd day, while the last one on the 97th day.

Both temperature and host plant species of *B. tabaci* had influenced significantly the total number of eggs laid by *S. parcesetosum* females (Fig. 4). Mean total number of eggs laid by females at 18 °C was significantly higher on cotton leaves with 52.4 eggs/♀ than on cucumber leaves with 24.7 eggs/♀, while at 30 °C, it was significantly higher on cucumber leaves with 97.7 eggs/♀ than on cotton leaves with 31.0 eggs/♀.

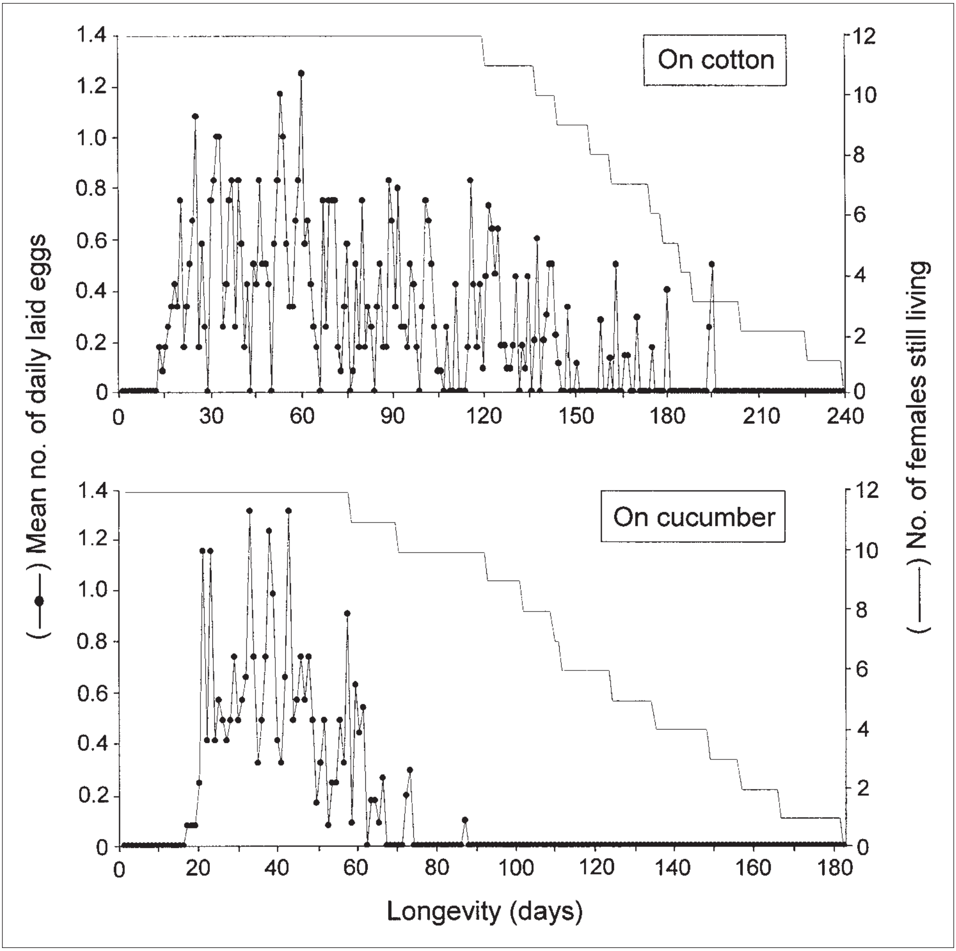

Fig. 2. Mean number of daily laid eggs by *Serangium parcesetosum* females during the oviposition period by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at 18 ± 1 °C.

4 Discussion

The current results indicated that temperature had influenced significantly the mean developmental duration of all stages of *S. parcesetosum*, while prey's host plant species and sex of the predator had exhibited some significant differences. *S. parcesetosum* was able to develop with *B. tabaci* as prey and reach the adult stage at both low and high temperatures of 18 °C and 30 °C on cotton and cucumber. It was found that development of *S. parcesetosum* consisted of an egg stage, four larval instars and a pupal stage. Similar results were obtained by Patel et al. (1996) and Abboud and Ahmad (1998). While Kapadia and Puri (1992) reported that the larval development of *S. parcesetosum* consisted of only three larval instars. The present study showed that mean total developmental duration of both sexes was significantly longer at 18 °C than at 30 °C on cotton and cucumber. According to Abboud and Ahmad (1998), *S. parcesetosum* required 23.8, 15.7, 14.3 and 12.9 days, when fed with *B. tabaci* as prey on cabbage leaves, at 21, 27, 32 °C and 27–32 °C, respectively. They found also in the same study a mean developmental duration of 15.8, 17.3 and 17.9 days, when *S. parcesetosum* was fed with

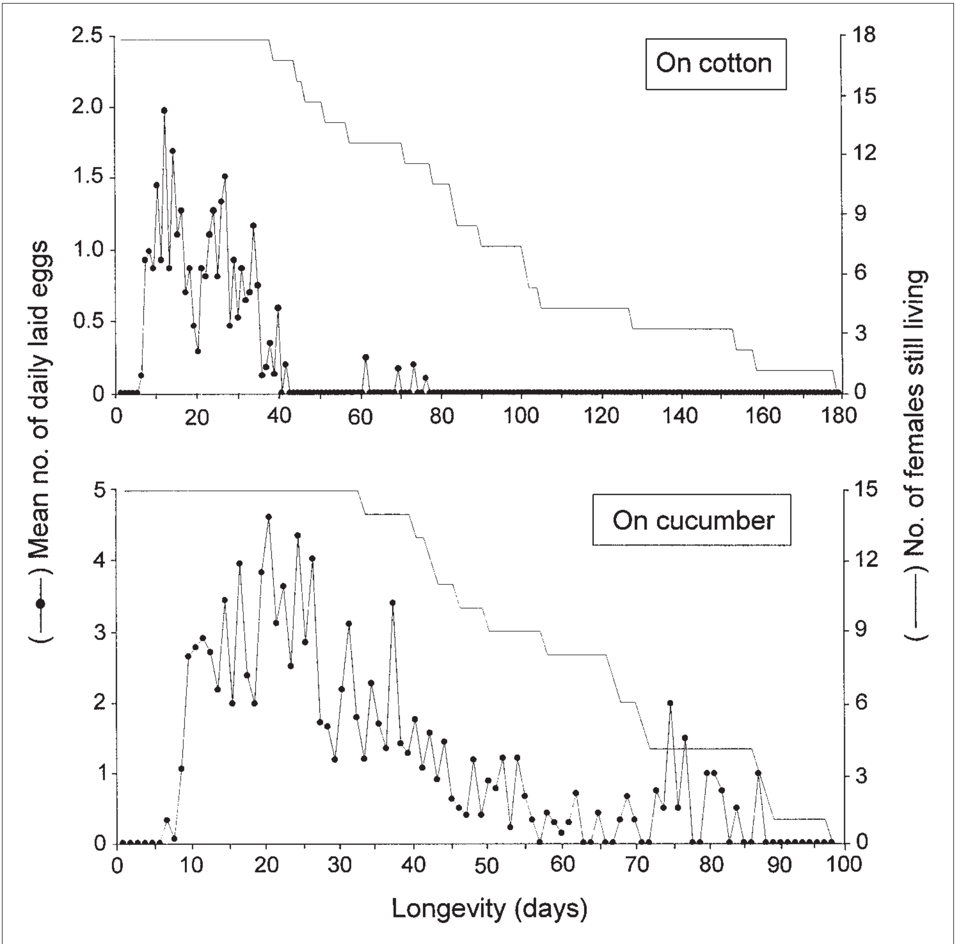

Fig. 3. Mean number of daily laid eggs by *Serangium parcesetosum* females during the oviposition period by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at 30 ± 1 °C.

B. tabaci, *A. floccosus* and *D. citri* at 25 °C, respectively. *S. parcesetosum* took a mean duration of 13.2 days to complete its development at 27 °C, with *A. barodensis* as prey (Patel et al. 1996). Concerning developmental duration, the present results are in the same trend of the earlier results taken into consideration the difference in temperatures, prey species and prey's host plant species.

Both temperature and plant species had influenced the total mortality percentage of *S. parcesetosum* during development from egg to adult emergence, where it was higher at 18 °C than 30 °C on both plant species, and it was also higher on cotton than cucumber leaves at both low and high temperatures. Abboud and Ahmad (1998) stated that mortality of *S. parcesetosum*, fed with *B. tabaci*, was 40, 22, 20 and 10 % at 32, 27, 21 °C and 27–32 °C on cabbage leaves, respectively. According to Ahmad and Abboud (2001), the mortality was 100, 30.4, 18 and 4.5 %, when *S. parcesetosum* fed with *B. tabaci* as prey, on bean, cabbage, eggplant and okra at 27 °C, respectively. They further mentioned that hair density on okra leaves helped positively in decreasing the mortality. This phenomenon was also observed in the present study, where the mortality on cucumber leaves was lower than on cotton leaves at both temperatures, which might be due to fact that hair density on cucumber leaves is more than on

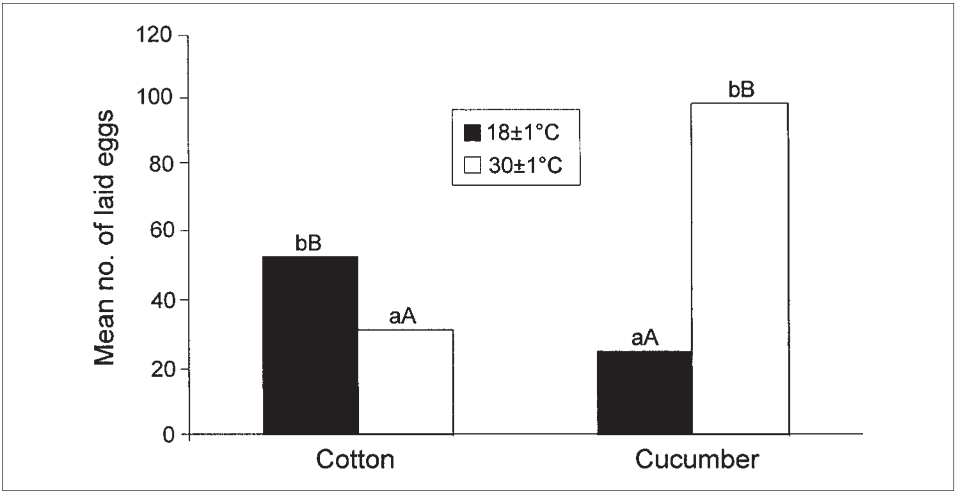

Fig. 4. Mean total number of laid eggs by *Serangium parcesetosum* females during the oviposition period by feeding on *Bemisia tabaci* as prey on cotton and cucumber leaves at two different temperatures. [Different small letters above bars indicate significant differences between the different plant species within the same temperature. Different capital letters above bars indicate significant differences between the different temperatures within the same plant species at p ≤ 5 % (ANOVA)].

cotton leaves. Also, the mortality of the predator might be affected by the combination of prey's host plant species and temperature as well as plant-whitefly-predator (tritrophic) interaction.

The sex ratio (♂♂ : ♀♀) of *S. parcesetosum* was affected also by temperature and plant species, where it was (1 : 0.9) and (1 : 0.8) at 18 °C, while at 30 °C, it was (1 : 1.1) on cotton and cucumber leaves, respectively. Kapadia and Puri (1992) reported a sex ratio (♂♂ : ♀♀) of (1 : 0.8) in the field and (1 : 1) in the laboratory at 23.7 °C.

The statistical analysis of the data indicated that longevity of *S. parcesetosum* varied significantly according to temperature, prey's host plant species and sex of the predator. The longevity was for both sexes significantly longer at 18 °C than 30 °C on both plant species. On cotton, females and males had lived significantly longer than on cucumber, except males at 30 °C. Also, females had lived significantly longer than males at both temperatures and plant species tested. In a study of Kapadia and Puri (1992), *S. parcesetosum* females lived for a mean of 50.5 days and males for 22.6 days, with *B. tabaci* as prey, on eggplant at 23.7 °C. Legaspi et al. (1996) observed a mean longevity of *S. parcesetosum* with *B. argentifolii* as prey of 79.2, 26.9 and 1.4 days at 20 °C, 30 °C and 40 °C on cantaloupe, respectively. A mean longevity of 29.8 days was obtained at 27 °C with *A. barodensis* as prey (Patel et al. 1996). In the present study, it seems that the longevity of *S. parcesetosum* was very long at 18 °C on both plant species tested, and especially on cotton. This might be due to several reasons, in which the 18 °C is a low temperature and the longevity is expected to be long. Also, the extreme longevity on cotton may be partly explained by that *S. parcesetosum* was reared on *B. tabaci* using cotton as the host plant. Therefore, it might be that the predator has adapted itself on cotton plants and lived much more on this plant species. A similar trend was obtained by Legaspi et al. (1996), where the mean longevity on hibiscus with 44.2 days was longer comparing to that on cucumber, cantaloupe and tomato with only 24.5, 27.6 and 27.8 days at 20–23 °C, respectively, when *S. parcesetosum* was reared on hibiscus infested with *B. argentifolii* as prey. Additionally, the morphological characteristics of the plant as well as the interaction of the plant-whitefly-predator (tritrophic) can have a major *influence* on the longevity of the predator, suggesting a high degree of specialization of *S. parcesetosum* on cotton. In general, the different prey species or even strains, temperatures, plant species and plant species cultivars used in the different experiments might explain such a variation in the present and prior results.

Temperature and plant species had affected significantly mean periods of pre-oviposition, oviposition and post-oviposition as well as mean daily and total fecundity of *S. parcesetosum* females. Females started laying eggs on the 13th and 17th days after adult emergence at 18 °C on cotton and cucumber, respectively, which lasted longer compared to that at 30 °C, where the females laid their eggs after the 6th and 7th days of longevity. The oviposition period at 18 °C on cotton with 121.1 days was too long comparing to that on cucumber with only 36.2 days. As mentioned above, it might be due to the fact that longevity on cotton with 175.4 days was also very long comparing to that on cucumber with only 122.2 days as well as the influence of plant species. Kapadia and Puri (1992) found a mean of 16.3, 24.3 and 8.6 days for pre-oviposition, oviposition and post-oviposition periods at 23.7 °C on eggplant, respectively.

Mean fecundity of *S. parcesetosum* females was significantly affected by temperature and host plant species of *B. tabaci*. At 30 °C, it was significantly higher on cucumber than on cotton, while at 18 °C, it was significantly higher on cotton than on cucumber. It might be explained by that at 18 °C, the oviposition period was very long on cotton, so that the predatory females laid more eggs during this long period of time. Timofeyeva and Nhuan (1979) reported that *S. parcesetosum* females laid 135–185 eggs at 20–23 °C, fed with *D. citri* as prey on citrus. *S. parcesetosum* laid a mean of 22.7 eggs/♀ on eggplant at 23.7 °C with *B. tabaci* as prey (Kapadia and Puri 1992). While according to Ahmad and Abboud (2001), *S. parcesetosum* females laid a mean of 443.9 eggs/♀ on cabbage leaves infested with *B. tabaci* at 27 °C, which was much higher than that of Kapadia and Puri (1992) as well as the present study. Variations between the present and prior studies might be due, in addition, to the different temperatures used in the different studies, to the prey's host plant species. In this regard, Al-Zyoud et al. (2004) recorded that the host plant species of *B. tabaci* has significantly influenced the number of eggs laid by *S. parcesetosum* females from the 8th till the 15th days of longevity, in which among five plant species used, a total of 115 eggs was laid on cucumber, while only 3 eggs were laid on sweet pepper. In a similar fashion, Rü and Mitsipa (2000) mentioned that fecundity of the coccinellid predator, *Exochomus flaviventris* Mader was significantly affected by host plant species of the mealybug, *Phenacoccus manihoti* Matile-Ferrero used. Additionally, among three host plant species of *Myzus persicae* (Sulzer), oilseed rape enhanced larger egg production of the predator, *Adalia bipunctata* (L.), whereas white mustard induced lower fecundity of the beetles (Francis et al. 2001). Also, the variation in the fecundity, especially when the prey species was the same, might be due to different *B. tabaci* strains used in the different studies.

The results of the present study showed that *S. parcesetosum* preys successfully upon *B. tabaci* and can complete its full development with exclusively this prey. The current results also provided a knowledge about the biological parameters of this predator, which might be considered as basic information for further investigations leading to the use of this ladybird to suppress *B. tabaci* population on cotton and cucumber plants.

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