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ORIGINAL ARTICLE

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Influence of host plant species of *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) on some of the biological and ecological characteristics of the entomophagous *Serangium parcesetosum* Sicard (Col., Coccinellidae)

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Abstract The entomophagous *Serangium parcesetosum* Sicard (Col., Coccinellidae) is an effective predator of some whitefly species. However, information on the influence of the prey's host plant species on its biological and ecological characteristics is still lacking in the literature. Therefore, the current study focuses on the possible influence of three greenhouse and two field host plant species of *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) on the number of eggs laid by *S. parcesetosum*. In addition, because of the economic importance and widespread planting of cucumber in greenhouses and cotton in the field, these plants were selected for further investigation into the development, mortality, longevity and reproduction of *S. parcesetosum* at a high temperature in the laboratory. Results showed that *S. parcesetosum* was able to lay eggs on all five host plant species of *B. tabaci*, whether greenhouse or field plants. However, among the three greenhouse plant species studied, *S. parcesetosum* females laid the highest number of eggs on cucumber followed by tomato and then sweet pepper. Of the two field plant species, significantly higher numbers of eggs were laid on tobacco than on cotton. *S. parcesetosum* could develop either on cucumber or on cotton as preferable host plant species for *B. tabaci*. There were significant differences in mean developmental duration of larval instars of the same sex between both host plant species; the duration was significantly shorter on cucumber than on cotton. There were no significant differences for mean total developmental duration from egg to adult emergence between both host plant species within the same sex; females showed a mean of 15.9 days and males of 15.1 days on cucumber, while on cotton the means were 17.2 days for females and 16.2 days for males. Total mortality percentage of *S. parcesetosum* during development from egg to adult stage was lower on cucumber than on cotton, 20.6 and 23.8%, respectively. Longevity of *S. parcesetosum* varied according to host plant species and sex with a mean of 63.4 days for females and 50.3 days for males on cucumber, and 92.4 days for females and 52.5 days for males on cotton. On cucumber, mean period of oviposition of *S. parcesetosum* was significantly longer than on cotton. Mean total fecundity was significantly higher on cucumber than on cotton, with means of 97.7 and 31.0 eggs/female, respectively.

Keywords *Serangium parcesetosum* · *Bemisia tabaci* · Host plant species · Biological control

Introduction

Plant species can directly influence the herbivorous insects that feed on them. The prey's host plant species can also have a major influence on the potential of a biological control agent of a pest species. Some researchers have studied the influence of host plant species of the prey on different biological and ecological characteristics of coccinellid predators. Copland et al. (1993) found that among six host plant species of the two mealybugs, *Planococcus citri* (Rossi) and *Pseudococcus affinis* (Maskell), the predator *Nephus reunioni* (Fürsch) was most active on citrus and least active on passiflora. On lemon, coffee and passionflower as host plant species of the mealybug, *Pseudococcus viburni* (Signoret), *N. reunioni* were more effective than on cape primrose and tomato (Heidari 1999). Furthermore, among two cassava varieties (incoza and zanaga), faux-caoutchouc, and talinum infested with *Phenacoccus manihoti*

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Matile-Ferrero, the predator *Exochomus flaviventris* Mader developed significantly faster on incoza and talinum, and laid more eggs on zanaga (Rü and Mitsipa 2000). The authors further reported a higher mortality and shorter oviposition period of the predator on incoza and faux-caoutchouc. According to Rott and Ponsonby (2000), on pepper and tomato infested with *Tetranychus urticae* Koch, the predator *Stethorus punctillum* Weise was more active than on aubergine. Among *Myzus persicae* (Sulzer) host plants used, namely broad bean, oilseed rape and white mustard, both rape and mustard shortened developmental duration of the predator *Adalia bipunctata* (L.), whereas white mustard induced lower fecundity (Francis et al. 2001).

In recent years the entomophagous *Serangium parcesetosum* Sicard (Col., Coccinellidae) has become known as an effective predator of some whitefly species. It was first reported on cotton and eggplant as host plants of *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) in India (Kapadia and Puri 1992). On sugarcane, the predator was observed to be highly specific to the whitefly, *Aleurolobus barodensis* Mask. (Patel et al. 1996), and to feed on its eggs and puparia (Shah et al. 1986). On citrus, *S. parcesetosum* has been used to control the whitefly *Dialeurodes citri* (Ashmead) in Georgia (Timofeyeva and Nhuan 1979), France (Malausa et al. 1988) and Turkey (Yigit 1992a, 1992b; Uygun et al. 1997; Yigit et al. 2003). Hibiscus, infested with *Bemisia argentifolii* Bellows and Perring, has increased the predator's longevity compared to cucumber, cantaloupe and tomato with the predator showing a greater preference for *B. argentifolii* on cantaloupe and cucumber than on poinsettia in the United States (Legaspi et al. 1996). A release of *S. parcesetosum* was evaluated in a grapefruit orchard to control *Aleurocanthus woglumi* Ashby (Legaspi et al. 2001), on poinsettia to control *B. argentifolii* (Ellis et al. 2001) and on citrus to control the whitefly *Aleurothrixus floccosus* Maskell in Israel (Argov 1994). On cotton, Cohen et al. (1995) mentioned that this coccinellid is a whitefly specialist. Cabbage, infested with *B. tabaci,* and citrus, infested with *D. citri* and *A. floccosus*, were found to be suitable for *S. parcesetosum* development (Abboud and Ahmad 1998). In Germany, Al-Zyoud and Sengonca (2004) reported that, on cotton, *S. parcesetosum* showed a significant preference for *B. tabaci* and *Trialeurodes vaporariorum* Westwood.

Information on the influence of a prey's host plant species on the biological and ecological characteristics of *S. parcesetosum* is still lacking in the literature. Therefore, the current study focuses on the possible influence of three greenhouse and two field host plant species of *B. tabaci* on the number of eggs laid by *S. parcesetosum*. In addition, because of the economic importance and widespread use of cucumber (greenhouse plant) and cotton (field plant), these plants were selected for further investigation of the development, mortality, longevity and reproduction of *S. parcesetosum* at a high temperature in the laboratory.

Materials and methods

A few individuals of the ladybird, *S. parcesetosum*, from the Plant Protection Research Institute, Adana, Turkey, were used to initiate the colony on cotton plants. The cotton plants, which were infested with *B. tabaci,* were placed inside meshed cylindrical Plexiglas cages that measured 19 cm in diameter and 40 cm in height, and the plants were renewed when necessary with fresh ones. In order to colonize whitefly as prey, a few cotton plants infested with individuals of *B. tabaci* were obtained from Bayer AG, Leverkusen, Germany, and kept after that together with fresh plants in mesh cages (80×50×60 cm). The colonies of the predator and the prey were incubated in climatically controlled chambers at a temperature of 25 ± 2 °C, relative humidity of 60 ± 10% and a photoperiod of 16:8 h (L:D) with an artificial light of about 4,000 lx as well as daylight. The required stages of *S. parcesetosum* for the experiments were obtained from round Plexiglas cages 11 cm in diameter and 3 cm in height, filled partially with a 0.5-cm layer of wetted cotton pad, prepared for this purpose. A number of adult females were taken from the cylindrical Plexiglas cages and then maintained in the round Plexiglas cages on cucumber or cotton leaves which had been infested with an excess number of different stages of *B. tabaci*. After 24 h the females were moved to other round Plexiglas cages and the laid eggs were used immediately or reared further until they reached the required stages. All experiments were carried out at a high temperature of 30 ± 1 °C and the relative humidity and photoperiod mentioned above.

To determine the influence of *B. tabaci* host plant species on the number of eggs laid by *S. parcesetosum* females, three greenhouse plant species, cucumber (*Cucumis sativus*), tomato (*Lycopersicon esculentum*) and sweet pepper (*Capsicum annuum*), as well as two field plant species, cotton (*Gossypium hirsutum*) and tobacco (*Nicotiana tabacum*), were selected. Newly emerged adult females and males of *S. parcesetosum* were obtained from the previously described round Plexiglas cages and transferred for 7 days into mesh cages (30×25×50 cm) containing the five different potted plant species. This step was necessary in order to reduce the possibility that *S. parcesetosum* might get adapted to a certain plant species and to give the adult females and males the chance to mate. Thereafter, on the 8th day, 20 adult females were transferred into another meshed cage, similar to the one described above, containing the five different potted host plants. For this purpose, all the plants were used after two weeks of infestation with *B. tabaci* as prey. After that, the females were transferred to another mesh cage containing new plants every 24 h. The five plants in the old mesh cage were taken to the laboratory and checked under a microscope for eggs. The experiment was continued for 8 days.

For further experiments, the greenhouse plant cucumber and the field plant cotton were selected to study the influence of host plant species of *B. tabaci* on development, mortality, longevity, and reproduction of *S. parcesetosum*. The experiments took place in round Plexiglas cages similar to those used to obtain the required stages of *S. parcesetosum*. Cucumber or cotton leaves, infested with an excess number of eggs, nymphs and puparia of *B. tabaci*, were placed upside down onto cotton pads in the round Plexiglas cages.

For estimating embryonic developmental duration of *S. parcesetosum*, freshly laid eggs no more than 12-h old were transferred into the round Plexiglas cages described above. Immediately after hatching of the larvae, the duration of embryonic development was recorded, and the hatching larvae at their first instars were transferred individually into similar cages containing a sufficient number of *B. tabaci* eggs, nymphs, and puparia on cucumber or cotton leaves. The cages were checked daily, and the progress in larval development and moulting till the end of the fourth larval instar was recorded. The larval instars were transferred, whenever needed, to new cages containing an excess number of prey on cucumber or cotton leaves. The pupation period was estimated to be the time from the end of the fourth larval instar to adult emergence. There were at least 52 replicates in the experiment for each host plant and sex.

The mortality of *S. parcesetosum* eggs, larval instars and pupae during developmental duration was also estimated daily. In order to differentiate between live and dead individuals, many criteria were used, e.g., dark to black color in all the different developmental stages, no larvae hatched from dead eggs, and failure to moult to the next instar during larval development, as well as no adult hatching from dead pupae. The experiments began with 156 and 144 eggs of *S. parcesetosum* on cucumber and cotton, respectively.

Freshly emerged females and males, no more than 24-h old, were used to determine the longevity of *S. parcesetosum* adults. One couple was kept in each round Plexiglas cage and provided with an excess number of *B. tabaci* eggs, nymphs and puparia on cucumber or cotton leaves and incubated until the individuals died. The females and males were provided with fresh prey as needed. Mean longevity of both sexes on the two host plant species was determined. The experiments were replicated at least fifteen times for each sex on each host plant.

For recording oviposition period and fecundity of *S. parcesetosum* females, the days of the first and last laid eggs as well as total number of laid eggs were recorded from the longevity experiment. Mean oviposition period and mean total fecundity were recorded.

The data from the laboratory studies were analyzed statistically using ANOVA (one/two-way) to test if the different host plant species affected the number of eggs laid by *S. parcesetosum* and to analyze the data for the influence of cucumber and cotton plants on the biological characteristics of the predator. Significant differences among several means were determined utilizing LSD test at $P < 0.05$. *T*-tests were conducted for comparisons between only two means (Winstat 1996).

Results

Influence of host plant species of *Bemisia tabaci* on eggs laid by *Serangium parcesetosum*

Daily and total numbers of eggs laid by twenty *S. parcesetosum* females from the 8th–15th days of adult life on different host plant species of *B. tabaci* at 30 ± 1 °C are summarized in Table 1. Results show that *S. parcesetosum* was able to lay eggs on all plant species whether greenhouse or field plants. However, among the three greenhouse plant species used, cucumber, with a total of 115 eggs, showed the significantly highest number of *S. parcesetosum* eggs. This was followed by tomato with 30 eggs, which was also significantly higher than sweet pepper with only 3 eggs. Of the two field plant species, the predator laid a significantly higher number of eggs on tobacco with 42 eggs than on cotton with 33 eggs.

Development

Cucumber and cotton as host plant species of *B. tabaci* were found to be suitable for the development of *S. parsecetosum* at a high temperature of 30 ± 1 °C (Fig. 1). Mean developmental duration of egg stage was 4.1 days (females) and 3.9 days (males) on cucumber and 3.9 days (females) and 3.8 days (males) on cotton. There were no significant differences between the different sexes within the same plant species or the different host plant species within the same sex. Mean duration of larval instar development was 6.7 days (females) and 6.7 days (males) on cucumber and 8.7 days (females) and 8.3 days (males) on cotton. Significant differences were found between cucumber and cotton within the same sex, but both females and males had the same developmental duration within the same host plant species. Development of pupal stage lasted a mean of 5.1 days (females) and 4.5 days (males) on cucumber and 4.6 days (females) and 4.1 days (males) on cotton. On cucumber, the pupal stage of females lasted significantly longer than males, but on cotton both sexes had

Table 1 Daily and total number of eggs laid by 20 *Serangium parcesetosum* females on different host plant species of *Bemisia tabaci* from the 8th–15th days of adult life in a combined experiment at 30 ± 1 °C

Host plant	Number of eggs laid each day								
	8th	9th	10th	11th	12th	13th	14th	15th	Total[a]
Cucumber	5	4	13	12	18	24	19	20	115d
Tomato	0	2	1	0	7	9	5	6	30b
Sweet pepper	1	0	1	0	1	0	0	0	3a
Cotton	2	1	3	5	5	2	8	7	33b
Tobacco	3	2	1	1	6	8	12	9	42c

[a] *Different letters* indicate significant differences among the different host plant species at $P < 0.05$ (one-factor analysis of variance)

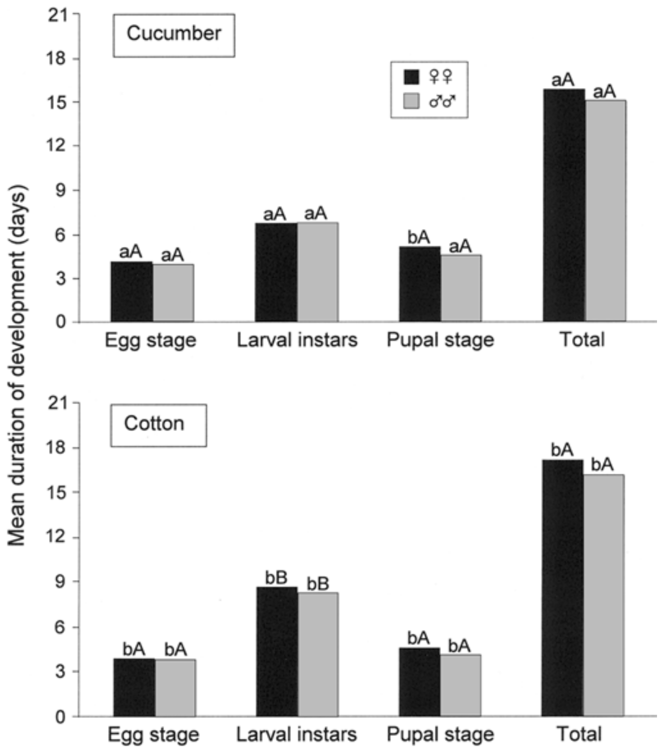

Fig. 1 Mean developmental duration of immature stages of *Serangium parcesetosum* on leaves of two host plant species of *Bemisia tabaci* at 30 ± 1 °C. *Bars with different small letters* indicate significant differences between the different sexes within the same host plant species and *S. parcesetosum* stage. *Bars with different capital letters* indicate significant differences between the different host plant species within the same *S. parcesetosum* stage and sex at $P < 0.05$ (two-factor analysis of variance)

the same duration of development. There were no significant differences in the mean total developmental duration from egg to adult emergence between females and males on both plant species tested or within the same sex on both host plant species; the mean durations were 15.9 days (females) and 15.1 days (males) on cucumber and 17.2 days (females) and 16.2 days (males) on cotton.

Mortality

Both host plant species of *B. tabaci* used in the experiments influenced the mortality of immature stages of *S. parcesetosum* during development (Fig. 2). Death occurred during all of the developmental stages of *S. parcesetosum* on cucumber and cotton. In the egg stage, the mortality rate was 2.6% on cucumber, while on cotton it was 2.8%. The mortality rate in the larval instars was higher than in egg and pupal stages together; for larval instars it was lower on cucumber at 11.6% than on cotton at 15.4%. In contrast, during the pupal stage, the mortality rate was higher on cucumber (6.4%) than on cotton (5.6%). Total mortality during development from egg to adult emergence was lower on cucumber at 20.6% than on cotton at 23.8%.

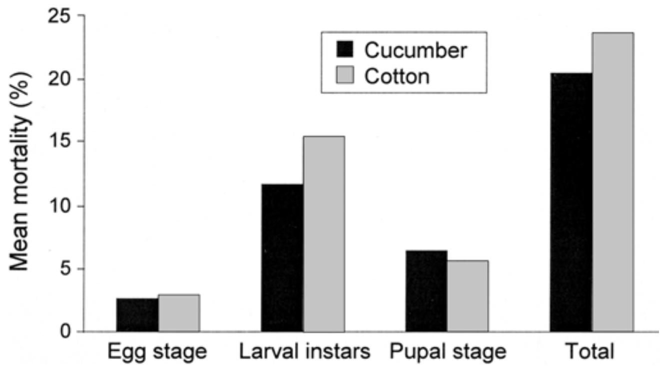

Fig. 2 Mean percentage mortality of immature stages of *Serangium parcesetosum* on leaves of two host plant species of *Bemisia tabaci* at 30 ± 1 °C

Longevity

Longevity of *S. parcesetosum* varied greatly according to sex on both cucumber and cotton at 30 ± 1 °C (Fig. 3). The longevity period lasted a mean of 63.4 days (females) and 50.3 days (males) on cucumber, while on cotton the means were 92.4 days (females) and 52.5 days (males). Host plant species influenced the longevity of *S. parcesetosum*; there were significant differences in the mean longevity of females between cucumber and cotton. Females lived significantly longer on cotton than on cucumber, while males had the same mean longevity period on both host plant species. Within the same host plant species, there were significant differences in the mean longevity of females and males, with females living significantly longer than males on both cucumber and cotton.

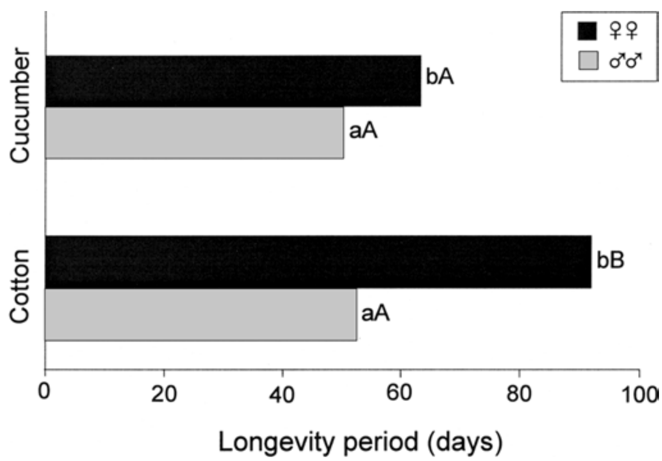

Fig. 3 Mean longevity of *Serangium parcesetosum* females and males on leaves of two host plant species of *Bemisia tabaci* at 30 ± 1 °C. *Bars with different small letters* indicate significant differences between the different sexes within the same host plant species. *Bars with different capital letters* indicate significant differences between the different host plant species within the same sex at $P < 0.05$ (two-factor analysis of variance)

Reproduction

Mean period of oviposition and mean total fecundity of *S. parcesetosum* on cucumber and cotton leaves as two host plant species of *B. tabaci* are presented in Table 2. The prey's host plant species had an important influence on oviposition period and total fecundity of the predatory females; the mean period of oviposition was significantly longer on cucumber at 40.6 days than on cotton at 28.0 days. Mean total number of eggs laid by *S. parcesetosum* females was approximately three times higher on cucumber (97.7 eggs/female) than on cotton (31 eggs/female).

Discussion

All host plant species used, whether greenhouse or field plants, were found to be suitable for *S. parcesetosum* oviposition. However, among the three greenhouse plant species, cucumber had significantly more *S. parcesetosum* eggs than tomato and sweet pepper. It should be mentioned that cucumber leaves are very hairy (high hair density) and sweet pepper leaves are nearly hairless (no or very low hair density). Therefore, it may be that leaf pubescence positively affected the number of eggs laid by *S. parcesetosum*. The same phenomenon of hair density was noticed in the two field plant species, where *S. parcesetosum* laid a significantly higher number of eggs on tobacco than cotton. Regardless of whether the host plant species was a greenhouse or a field plant, cucumber was the most preferred plant for *S. parcesetosum* oviposition among the five plant species. There are no earlier studies on the influence of prey's host plant species on the number of eggs laid by *S. parcesetosum*. However, Rü and Mitsipa (2000) similarly recorded that fecundity of the coccinellid predator *E. flaviventris* was significantly affected by which host plant species of the mealybug *P. manihoti* was used. Aphid's host plant species displayed mixed influences on the performance of the predator *A. bipunctata*. Among the broad bean, oilseed rape and white mustard used as host plants for the prey, oilseed rape encouraged larger egg production, whereas white mustard induced lower fecundity in the beetles (Francis et al. 2001).

In the current study, *S. parcesetosum* developed successfully on cucumber and cotton, two host plant species of *B. tabaci*, at a high temperature of 30 °C. There were no significant differences in the mean total developmental duration either between the different sexes on the same plant species or the different host plant species within the same sex. Mean developmental duration of larval instars, however, was influenced by the prey's host plant species; it was significantly longer on cotton than cucumber. According to Patel et al. (1996), *S. parcesetosum* took a mean duration of 13.2 days to complete its development on sugarcane with *A. barodensis* as prey at 27 °C. On cabbage, mean total developmental durations of 23.8, 15.7, 14.3, and 12.9 days were recorded at 21, 27, 32, and 27–32 °C, respectively, for *S. parcesetosum* fed with *B. tabaci* as prey (Ahmad and Abboud 2001). Sengonca et al. (2004) found, on cucumber and cotton with *B. tabaci* as prey, that *S. parsecetosum* developed successfully at a low temperature of 18 °C; the mean total developmental durations were 43.4 days (females) and 42.4 days (males) on cotton and 45.2 days (females) and 43.4 days (males) on cucumber. Also, Rü and Mitsipa (2000) simliarly recorded that developmental duration of the predator *E. flaviventris* was significantly affected by the mealybug's host plant. Among broad bean, oilseed rape and white mustard used as host plant species of aphid, both rape and mustard shortened the developmental duration of the predator *A. bipunctata* (Francis et al. 2001). The present results are in accordance with previous results, in which the prey's host plant species influenced the developmental duration of the predator.

Total mortality of *S. parcesetosum* during development was lower on cucumber than on cotton. Ahmad and Abboud (2001) described mortality rates of *S. parcesetosum* from egg to adult stage of 100, 30.4, 18, and 4.5% on bean, cabbage, eggplant and okra, respectively, for *S. parcesetosum* fed with *B. tabaci* as prey. Also, according to these authors, the reduction in mortality was closely linked to hair density on okra leaves. This phenomenon was also observed in the present study, where the mortality on cucumber leaves was lower than on cotton leaves, which might be due to fact that hair density on cucumber leaves is greater than on cotton leaves. Also, Rü and Mitsipa (2000) stated that the mealybug's host plant species significantly influenced the mortality of the predator *E. flaviventris*.

Mean longevity of *S. parcesetosum* varied according to the prey's host plant species and the predator's sex. Mean longevity of females was significantly greater on cucumber than on cotton. In a study conducted by Kapadia and Puri (1992) on eggplant, *S. parcesetosum* females lived for a mean of 50.5 days and males for 22.6 days with *B. tabaci* as prey at 23.7 °C. Mean longevities of 24.5, 27.6, 27.8, and 44.2 days on cucumber, cantaloupe, tomato, and hibiscus were observed, respectively, at 20–23 °C when *S. parcesetosum* was fed with *B. argentifolii* (Legaspi et al. 1996). Patel et al. (1996) found a mean longevity of 29.8 days for *S. parcesetosum* adults at 27 °C on sugarcane infested with *A. barodensis*. The current results are consistent with the earlier results, which indicate that, in addition

Table 2 Means ± SD[a] of oviposition period and total fecundity of *Serangium parcesetosum* on leaves of two host plant species of *Bemisia tabaci* at 30 ± 1 °C

Plant species	*n*	Period of oviposition (days)	Total number of eggs laid
Cucumber	15	40.6 ± 20.8b	97.7 ± 55.4b
Cotton	17	28.0 ± 12.2a	31.0 ± 14.1a

[a] *Different letters* indicate significant differences within a column between the different host plant species at $P < 0.05$ (one-factor analysis of variance)

to the difference in prey species and temperatures, the variations in predator longevity might be due to the different prey's host plant species used in the experiments.

Mean period of oviposition and mean total fecundity of *S. parcesetosum* females were significantly affected by the prey's host plant species. Kapadia and Puri (1992) determined a mean oviposition period of 24.3 days on eggplant with *B. tabaci* as prey at 23.7 °C. *S. parcesetosum* females laid 135–185 eggs on citrus at 20–23 °C when fed with *D. citri* as prey (Timofeyeva and Nhuan 1979). According to Ahmad and Abboud (2001), *S. parcesetosum* females laid a mean of 443.9 eggs/female at 27 °C on cabbage infested with *B. tabaci*. In addition, Rü and Mitsipa (2000) recorded that oviposition period of the predator *E. flaviventris* was significantly affected by the mealybug's host plant species. The results suggest a close relationship between host plant species of *B. tabaci* and both oviposition period and total fecundity of the predator.

In conclusion, the results of the present study showed that *S. parcesetosum* seems to occupy a number of *B. tabaci* host plant species for oviposition and can complete its full development successfully on cucumber and cotton. Also, the biological and ecological characteristics of *S. parcesetosum* varied greatly among *B. tabaci* host plant species used, suggesting a high degree of specialization of the predator on the host plant. Additionally, the current study on the influence of a prey's host plant species offered opportunities for better understanding the interactions of the plant–whitefly–predator (tritrophic) relationship and demonstrated that successful biological control of pests should integrate the environmental aspects of each trophic level.

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