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ORIGINAL ARTICLE

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Prey consumption preferences of *Serangium parcesetosum* Sicard (Col., Coccinelidae) for different prey stages, species and parasitized prey

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Abstract *Serangium parcesetosum* Sicard (Col., Coccinellidae) is considered one of the important predators of whiteflies. However, knowledge about its preferences for different prey stages, species and parasitized prey is still lacking in the literature. The present work investigated the preferences of *S. parcesetosum* for different stages of *B. tabaci*, different prey species and *B. tabaci* parasitized by *Encarsia formosa* Gahan (Hym., Aphelinidae) by prey consumption at different temperatures in the laboratory. Results showed that L_2 and L_4 predatory instars of *S. parcesetosum* preferred puparia to nymphs and eggs of *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae). The mean daily prey consumption was 5.1–9.0, 4.5–6.2 and 3.6–4.3 by L_2 and 6.4–9.7, 5.5–8.5 and 2.5–7.5 by L_4 for puparia, nymphs and eggs, respectively. Adult females, however, indicated a significantly greater preference for both puparia and nymphs, consuming a daily mean of 6.4–7.5 puparia and 5.1–6.7 nymphs, but only 3.0–4.7 eggs. At 18 and 30 °C, all *S. parcesetosum* stages tested significantly preferred *B. tabaci* and *Trialeurodes vaporariorum* Westwood (Hom., Aleyrodidae) over the other three prey species offered. At both temperatures, all predatory stages preferred *B. tabaci* to *T. vaporariorum*, the L_2 instar at 18 °C, showing significantly more preference for *B. tabaci* than *T. vaporariorum*. In contrast, very few individuals were consumed from *Aphis gossypii* Glover (Hom., Aphididae), *Frankliniella occidentalis* (Pergande) (Thys., Thripidae) and *Tetranychus urticae* Koch (Acari, Tetranychidae). At 18 °C, a daily mean of 7.5–8.0, 6.6–9.0 and 6.7–8.1 *B. tabaci* as well as 5.3–6.4, 5.4–7.8 and 5.6–6.3 *T. vaporariorum* was consumed by L_2, L_4 and adult females, respectively, while at 30 °C, L_2, L_4 and adult females consumed a mean of 9.3, 8.8–9.7 and 8.3–9.7 *B. tabaci*/day as well as 8.3–9.0, 7.8–9.1 and 5.5–8.4 *T. vaporariorum*/day, respectively. *S. parcesetosum* L_2 and L_4 instars as well as adult females and males at both studied temperatures showed a significant tendency to avoid *B. tabaci* puparia after 5 days of parasitism by *E. formosa* and preferred to feed on unparasitized whiteflies. At 18 °C, the mean daily consumption was 8.7 and 0.2 (L_2), 11.1 and 0.6 (L_4), 12.1 and 1.0 (♀♀) as well as 10.5 and 0.2 (♂♂), while at 30 °C the means were 15.9 and 0.5 (L_2), 19.8 and 1.0 (L_4), 18.9 and 1.2 (♀♀) as well as 17.4 and 0.6 (♂♂) from unparasitized and parasitized *B. tabaci* puparia, respectively.

Keywords *Serangium parcesetosum* · *Bemisia tabaci* · Prey consumption · Prey preference · Biological control

This paper is gratefully dedicated to Prof. Dr. W Schwenke on his 83rd birthday, 22 March 2004

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Introduction

The cotton whitefly, *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) occurs worldwide in tropical, subtropical (Jiang et al. 1999; Hilje et al. 2001), as well as temperate regions (Wagner 1995). It is known as a severe pest of numerous field and vegetable crops in many parts of the world (Gerling et al. 2001) and attacks more than 600 plant species (Secker et al. 1998). It has also become important for greenhouse crops in temperate regions (Enkegaard 1993). In Germany, this pest was recorded for the first time in 1987 on many cultivated ornamental plants (Burghause 1987) and has now spread to many greenhouse ornamentals but to few vegetable fields (Albert 1990). Today, it has spread to most European countries (Martin et al. 2000).

Many attempts have been made to control *B. tabaci* in the past, but because of the high reproductive rate of the whitefly and their many generations per year (Byrne and Bellows 1991; Brown et al. 1995) as well as their rapidly developed resistance to many insecticides (Denholm et al. 1998; Horowitz et al. 1999; Kranthi et al. 2001), it is difficult to achieve successful chemical control. Therefore, it seems promising to develop biological control methods using predators and parasitoids for pest suppression.

Serangium parcesetosum Sicard (Col., Coccinellidae) is considered one of the important predators of whiteflies (Timofeyeva and Nhuan 1979; Kuchanwar et al. 1982; Shah et al. 1986; Yigit 1992a, 1992b; Ahmad and Abboud 2001; Legaspi et al. 2001). This predator has previously been used to control the citrus whitefly, *Dialeurodes citri* (Ashmead) in Georgia (Timofeyeva and Nhuan 1979) and Corsica, France (Malausa et al. 1988) as well as Turkey (Yigit 1992a; Uygun et al. 1997; Yigit et al. 2003). *S. parcesetosum* was first reported on *B. tabaci* in India (Kapadia and Puri 1992) and in 1994 it was found attacking *D. citri* and *B. tabaci* in Syria (Abboud and Ahmad 1998). It has also been used against the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, in the USA (Legaspi et al. 1996).

Before considering a predator for a biological control program, it is important to investigate its affinity toward a certain developmental stage of the target pest or even the pest species to be controlled and a possible interaction with other natural enemies. This is true especially when both open field and greenhouse conditions must be taken into account. There are naturally several pest species, which might serve as potential prey for the predator and also several natural enemies that can interact with it. Such knowledge of *S. parcesetosum* is still lacking in the literature.

Therefore, the purpose of the present work was to investigate the prey preferences of *S. parcesetosum* for different stages of *B. tabaci*, different prey species and *B. tabaci* parasitized by *Encarsia formosa* Gahan (Hym., Aphelinidae) at different temperatures in the laboratory.

Materials and methods

All rearings of *S. parcesetosum*, the prey, as well as the parasitoid were carried out in climatic chambers under the same controlled conditions of 25 ± 2 °C temperature, 60 ± 10% relative humidity and a photoperiod of 16:8 h (L:D).

Rearing of *S. parcesetosum* was initiated with a few individuals sent by courtesy of the Plant Protection Research Institute, Adana, Turkey. The stock culture was reared on cotton plants, infested with *B. tabaci*, in meshed cylindrical Plexiglas cages (19 cm in diameter and 40 cm in height) with an artificial light intensity of about 4,000 lx. For a regular prey supply, cotton plants were replaced with fresh ones, infested with *B. tabaci*, whenever needed.

B. tabaci as prey was obtained courtesy of Bayer AG, Leverkusen, Germany, and reared on cotton plants in meshed cages (80×50×65 cm). The greenhouse whitefly, *Trialeurodes vaporariorum* Westwood (Hom., Aleyrodidae), and the two-spotted spider mite, *Tetranychus urticae* Koch (Acari, Tetranychidae) were maintained on tobacco and bean plants, respectively. The stock culture of the western flower thrips, *Frankliniella occidentalis* (Pergande) (Thys., Thripidae), was kept on bean plants, while the melon aphid, *Aphis gossypii* Glover (Hom., Aphididae), was maintained on cotton plants. Individuals of the parasitoid, *E. formosa,* were obtained from a stock culture at the Institute of Phytopathology, University of Bonn, Germany, and maintained on tobacco plants, infested with *B. tabaci*, in a meshed cage (60×50×50 cm). For a regular prey supply, tobacco plants were replaced with fresh ones, infested with *B. tabaci*, whenever needed.

All experiments took place in an arena, a round Plexiglas cage 5.5 cm in diameter and 2 cm in height, filled with 0.5-cm-thick agar gel layer, in which cotton leaf discs were placed upside down onto the agar gel layer. In order to obtain the desired stage of *S. parcesetosum*, many mated adult females were transferred onto cotton leaves infested with eggs, nymphs and puparia of *B. tabaci*, in round Plexiglas cages (11 cm in diameter) and kept in a climatic chamber under the same conditions as above. The Plexiglas cages were checked daily, and the newly laid eggs were reared. To obtain the desired stages of *B. tabaci*, cotton plants were exposed to *B. tabaci* infestation in the stock culture cages for 12 h and then incubated under the same climatic conditions until the required stage for the experiments was reached. The desired stages from the other prey species were identified under a binocular microscope on leaves obtained from the different host plants in the different stock cultures and picked up gently, using a camel-hair brush. Ten replicates were used in the experiments.

In order to determine the preferred prey stage of *B. tabaci*, L_2, L_4 instars or 7-day-old adult females of *S. parcesetosum* were observed in a special arena. Three cotton leaf discs (2 cm in diameter) were placed separately in this arena, each with only ten individuals of eggs, nymphs or puparia of *B. tabaci,* and one *S. parcesetosum* was kept in the arena for 24 h. Afterwards, the predator individuals were transferred daily to new arenas containing fresh prey stages of *B. tabaci* and the number of each prey stage killed was determined daily. The experiments were conducted throughout the entire developmental period of L_2 and L_4 instars as well as for 3 days with 7-day-old adult females of *S. parcesetosum* in a climatic chamber at 18 ± 1 °C temperature, 60 + 10% relative humidity and 16:8 h (L:D) photoperiod.

To study the prey preference by different prey species, L_2, L_4 instars or 7-day-old adult females of *S. parcesetosum* were each kept with five different prey species together on a big cotton leaf disc (4.5 cm in diameter). The prey species were *B. tabaci* (puparia), *T. vaporariorum* (puparia), *T. urticae* (adults), *F. occidentalis* (L_1-L_2) and *A. gossypii* (1–2 days old). For each predatory stage tested, ten individuals of each prey species were used in the arenas described above. The predators were transferred daily to new arenas containing fresh prey from the five different species. The number of killed prey of each species was recorded daily. The experiments were conducted throughout the whole developmental period of the predatory larvae as well as for 3 days with the adult females at 18 ± 1 and 30 ± 1 °C, respectively, and the same relative humidity and photoperiod mentioned above.

To record preferences regarding parasitized prey, the puparia of *B. tabaci* were used after 5 days of parasitism by *E. formosa*. Fifteen parasitized and 15 unparasitized puparia at 18 ± 1 °C as well as with 20 parasitized and 20 unparasitized puparia of *B. tabaci* at 30 ± 1 °C were placed on a cotton leaf disc (4.5 cm in diameter) in the arenas with either L_2, L_4 instars or 7-day-old adult females or males of *S. parcesetosum*. The puparia were arranged in alternate rows of five, parasitized and unparasitized whiteflies one beneath the other in a uniform distribution in the arenas. Both larval instars as well as adult females and males of *S. parcesetosum* were removed after 24 h, and the number of parasitized and unparasitized puparia killed was counted. The experiments were conducted under two climatic conditions similar to the experiments on prey species preference.

For the statistical comparison among several means, one-factor analysis of variance was conducted. Significant differences were determined utilizing LSD test at $p \leq 5\%$. T-test was utilized for comparisons between only two means (Anonymous 1996).

Results

Preference of different stages of *Bemisia tabaci*

Results of the prey-stage preference by L_2, L_4 instars and 7-day-old adult females of *S. parcesetosum* with eggs, nymphs and puparia of *B. tabaci* as prey are illustrated in Fig. 1. Both predatory larval instars preferred puparia

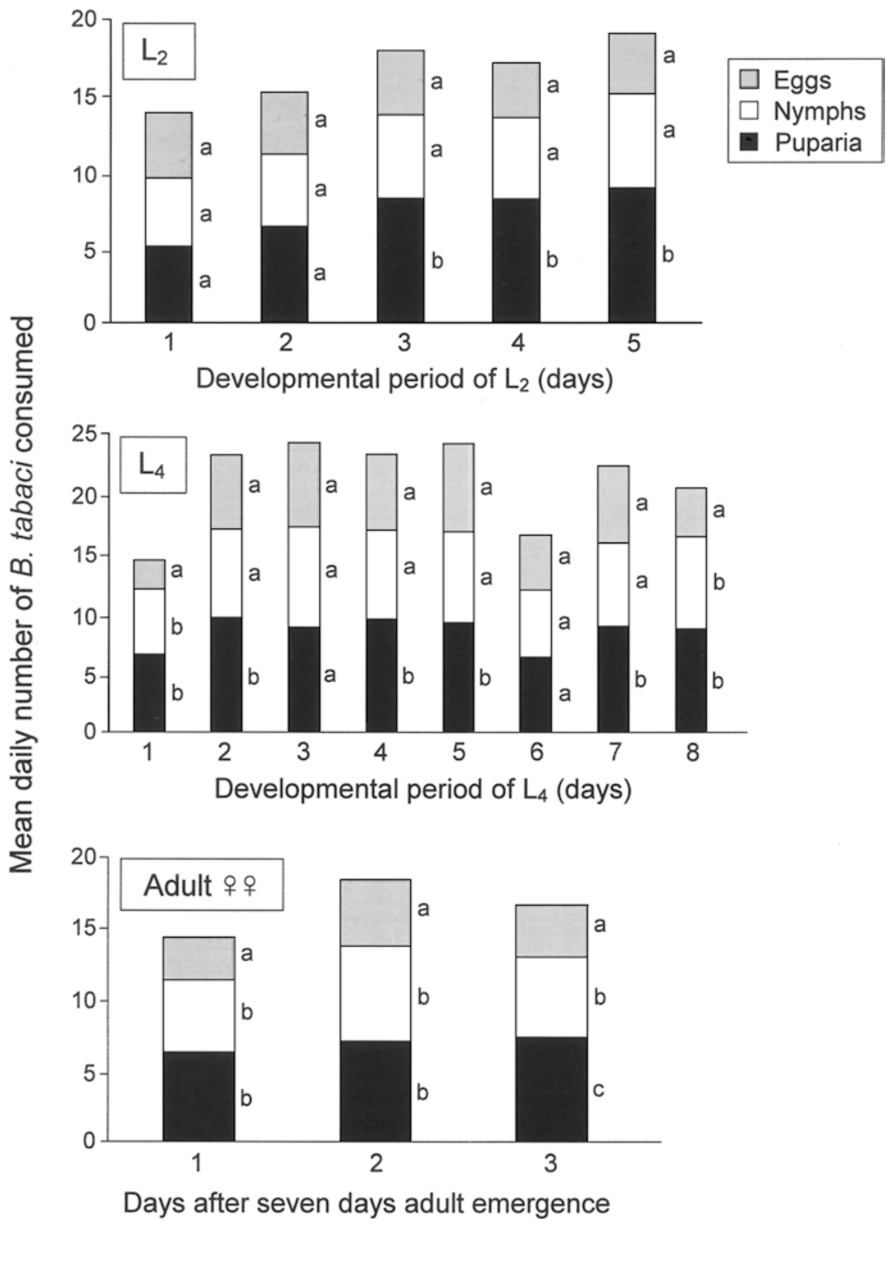

Fig. 1 Prey consumption by L_2, L_4 instars and 7-day-old adult females of *Serangium parcesetosum* on eggs, nymphs and puparia of *Bemisia tabaci* on cotton leaf discs at 18 ± 1 °C. *Different letters within the same bar* indicate significant differences in the prey consumption of the different prey stages at $p \leq 5\%$ (one-factor analysis of variance)

to nymphs and eggs of whiteflies. The L_2 instar consumed over its developmental period a mean of 5.1–9.0, 4.5–6.2 and 3.6–4.3 puparia, nymphs and eggs of *B. tabaci*/day, respectively. A mean daily consumption of 6.4–9.7 (puparia), 5.5–8.5 (nymphs) and 2.5–7.5 (eggs) was recorded for the L_4 instar over its developmental period. In contrast, predatory adult females indicated a significant preference for both puparia and nymphs of *B. tabaci*, consuming a daily mean of 6.4–7.5 puparia and 5.1–6.7 nymphs, while their mean daily consumption of eggs was 3.0–4.7.

Preference for different species of prey

All *S. parcesetosum* stages tested significantly preferred *B. tabaci* and *T. vaporariorum* to the other three prey species offered at 18 °C (Fig. 2). L_2 showed a significantly higher preference for *B. tabaci* than *T. vaporariorum*, while L_4 and adult females also showed a preference for *B. tabaci* over *T. vaporariorum*. A daily mean of 7.5–8.0, 6.6–9.0 and 6.7–8.1 *B. tabaci* as well as 5.3–6.4, 5.4–7.8 and 5.6–6.3 *T. vaporariorum* was consumed by L_2, L_4 and adult females, respectively. Only very few individuals were consumed from the other three prey species at all predatory stages tested. Means of 0.0–0.1, 0.0–0.3 and 0.0–0.5 by L_2, 0.0–0.7, 0.0–0.5 and 0.0–0.8 by L_4 as well as 0.1–0.3, 0.1–0.2 and 0.3–0.5 by females were consumed daily from *A. gossypii*, *F. occidentalis* and *T. urticae*, respectively.

At 30 °C, all predatory stages tested also showed a significant tendency in prey preference toward both whitefly species used (Fig. 3), but with greater preference for *B. tabaci* than *T. vaporariorum*. A mean of 9.3, 8.8–

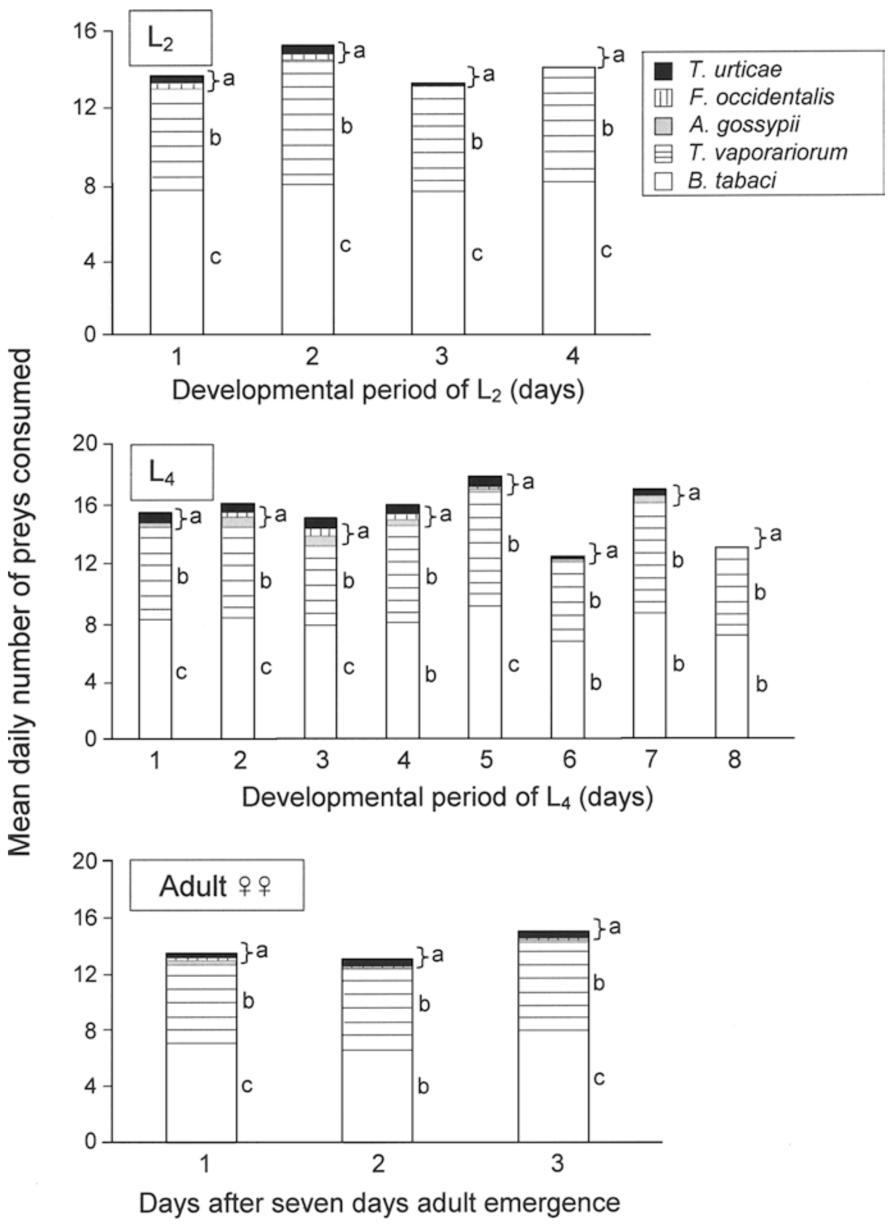

Fig. 2 Prey consumption by L_2, L_4 instars and 7-day-old adult females of *Serangium parcesetosum* feeding on five different prey species offered together on cotton leaf discs at 18 ± 1 °C. *Different letters within the same bar* indicate significant differences in the prey consumption of the different prey species at $p \leq 5\%$ (one-factor analysis of variance)

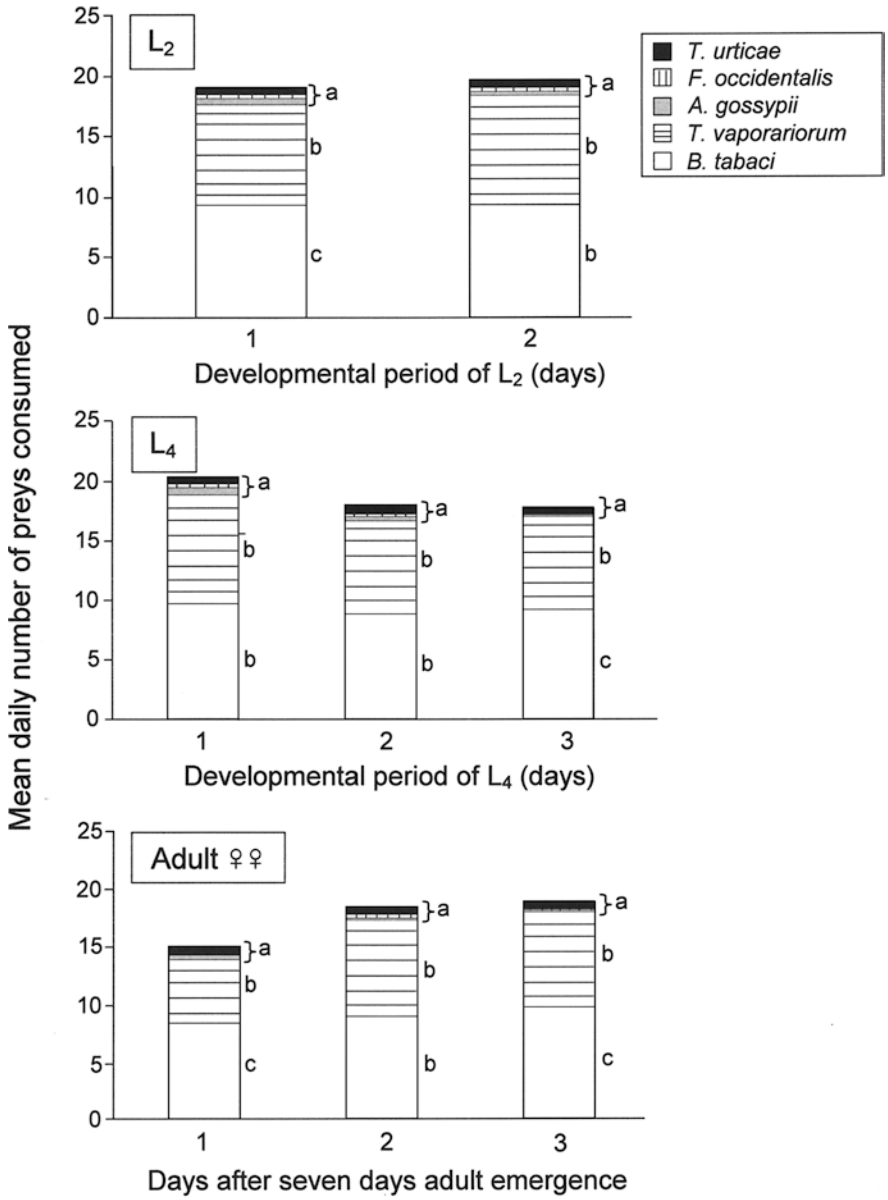

Fig. 3 Prey consumption by L_2, L_4 instars and 7-day-old adult females of *Serangium parcesetosum* feeding on five different prey species offered together on cotton leaf discs at 30 ± 1 °C. *Different letters within the same bar* indicate significant differences in the prey consumption of the different prey species at $p \leq 5\%$ (one-factor analysis of variance)

9.7 and 8.3–9.7 *B. tabaci*/day as well as 8.3–9.0, 7.8–9.1 and 5.5–8.4 *T. vaporariorum*/day was consumed by L_2, L_4 and adult females, respectively. From the other three prey species, very few individuals were consumed, and a daily mean of 0.3–0.5, 0.3 and 0.6–0.7 was consumed by L_2, 0.2–0.6, 0.0–0.3 and 0.5–0.8 by L_4, as well as 0.2–0.4, 0.0–0.3 and 0.7–0.8 by adult females from *A. gossypii*, *F. occidentalis* and *T. urticae*, respectively. No significant differences were found in the prey consumption among *A. gossypii*, *F. occidentalis* and *T. urticae*.

Preference of parasitized puparia of *Bemisia tabaci*

The mean daily number of consumed unparasitized and parasitized puparia of *B. tabaci* by *S. parcesetosum* L_2 and L_4 instars as well as 7-day-old adult females and males at two different temperatures is shown in Fig. 4. At both studied temperatures, all *S. parcesetosum* stages tested showed a significant tendency to avoid puparia after 5 days of parasitism by *E. formosa,* feeding instead on unparasitized puparia of *B. tabaci*. At 18 °C, the mean daily consumption was 8.7 and 0.2 (L_2), 11.1 and 0.6 (L_4), 12.1 and 1.0 (♀♀) as well as 10.5 and 0.2 (♂♂), unparasitized and parasitized puparia, respectively, while at 30 °C it was 15.9 and 0.5 (L_2), 19.8 and 1.0 (L_4), 18.9 and 1.2 (♀♀) as well as 17.4 and 0.6 (♂♂), respectively.

Discussion

The results of the experiments on the prey-stage preference of *S. parcesetosum* for eggs, nymphs and puparia of *B. tabaci* revealed that both predatory larval instars preferred puparia to nymphs and eggs. In contrast, adult

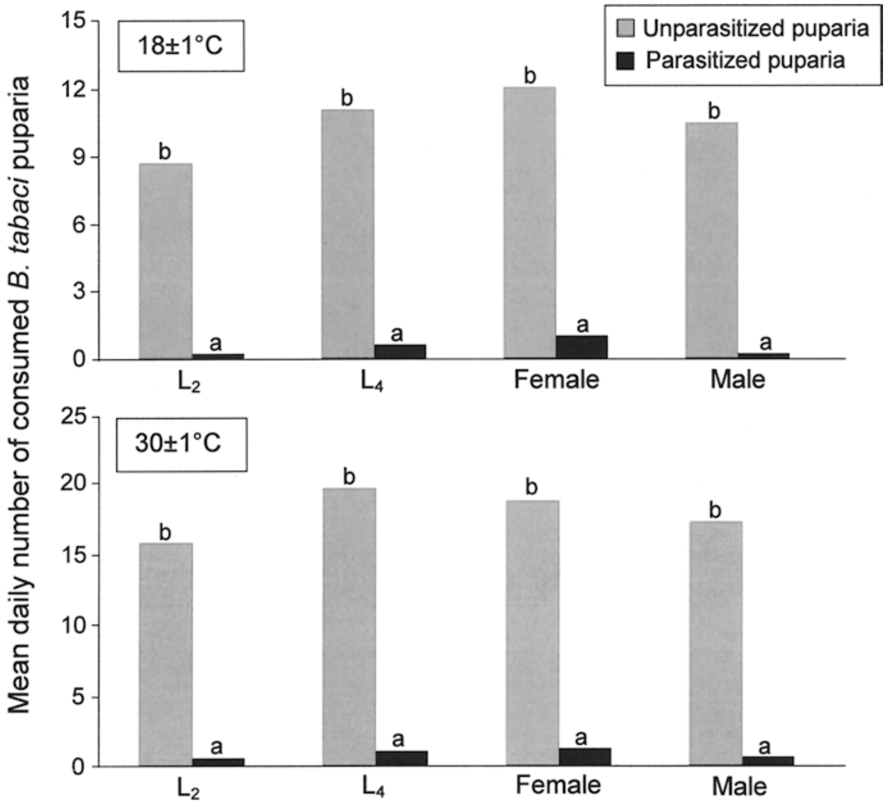

Fig. 4 Comparison of mean daily number of consumed unparasitized and 5-day puparia of *Bemisia tabaci* after parasitism by *Encarsia formosa* kept together with each *Serangium parcesetosum* L_2 and L_4 instars as well as 7-day-old adult females and males on cotton leaf discs at two different temperatures. *Bars with different letters* indicate significant differences between unparasitized and parasitized puparia of *B. tabaci* within the same stage of *S. parcesetosum* and temperature at $p \leq 5\%$ (one-factor analysis of variance)

females indicated a significant preference for both puparia and nymphs of *B. tabaci*, consuming fewer eggs. There were no previous studies on the preference of *S. parcesetosum* for different *B. tabaci* stages, however, data was found for *S. parcesetosum* predating eggs and puparia of the sugarcane whitefly, *Aleurolobus barodensis* Mask. (Shah et al. 1986). This predator is reported to be highly specific and to feed voraciously on different stages of *A. barodensis* (Patel et al. 1996). *S. parcesetosum* can feed on all *B. tabaci* developmental stages (Ahmad and Abboud 2001). Both larvae and adults of the predator are voracious feeders, capable of consuming large numbers of immature stages of *B. argentifolii* (Ellis et al. 2001). Regardless of the whitefly species used in the different studies, the results of the present study are in agreement with previous ones, in which *S. parcesetosum* could feed on the different developmental stages of whiteflies offered.

At both low and high temperatures (18 and 30 °C), all *S. parcesetosum* stages tested preferred *B. tabaci* and *T. vaporariorum* significantly over the other three prey species offered. Furthermore, at both temperatures, all predatory stages preferred *B. tabaci* to *T. vaporariorum*, except L_2 instar at 18 °C, which had a significantly higher preference for *B. tabaci* than *T. vaporariorum*. In contrast, very few individuals were consumed from *A. gossypii*, *F. occidentalis* and *T. urticae,* and no significant differences were found in the prey consumption among these species. *S. parcesetosum* is recorded to be host specific to *B. tabaci* (Kapadia and Puri 1992)- This species also seems to be a specialist predator of whiteflies (Cohen et al. 1995). When *S. parcesetosum* was offered simultaneously five prey choices, namely eggs of the corn earworm, *Helicoverpa zea* (Boddie) (Lep., Noctuidae) and eggs of the tobacco hornworm, *Manduca sexta* (L.) (Lep., Sphingidae), as well as eggs and early instars of *B. argentifolii* reared on poinsettia, cantaloupe and cucumber plants, *S. parcesetosum* adults did not feed on *H. zea* eggs and *M. sexta* eggs presented, indicating a preference for *B. argentifolii* (Legaspi et al. 1996). This author further stated that predatory adults prefer to feed on *B. argentifolii* immatures regardless of the host plant. In a study conducted on the preference of *S. parcesetosum* for different species of whiteflies, it was observed that the whitefly, *Paraleyrodes minei* Laccarino (Hom., Aleyrodidae), is not suitable for the development of *S. parcesetosum*, but *B. tabaci*, *D. citri* and *Aleurothrixus floccosus* Maskell were suitable for its development (Abboud and Ahmad 1998). These authors also found that *S. parcesetosum* developed significantly faster on *B. tabaci* than on *D. citri* and *A. floccosus*, indicating that *B. tabaci* might be preferential to the other two prey species. *S. parcesetosum* proved to be a promising biological control agent against *Bemisia* whiteflies because of its voracity and preference (Legaspi et al. 2001). *S. parcesetosum* was not as voracious on citrus blackfly, *Aleurocanthus woglumi* Ashby eggs as on silverleaf whitefly nymphs but may cause measurable suppression of citrus blackfly populations in the field (Legaspi et al. 2001). Nutrient differences between prey species could have a substantial impact on predator choice. The present results are in agreement with the previous ones, in which *S. parcesetosum* is apparently a specialist predator of whiteflies.

The results on preference for parasitized/unparasitized puparia of *B. tabaci* at both studied temperatures revealed that L_2 and L_4 instars as well as adult females and males of *S. parcesetosum* showed a significant tendency to avoid puparia parasitized by *E. formosa* and fed instead on unparasitized *B. tabaci*. There were no studies on the interaction of *S. parcesetosum* with other natural enemies. However, in similar fashion, it was observed that the vedalia beetle, *Rodolia cardinalis* (Mulsant) (Col., Coccinellidae), feeding on cottony cushion scale, *Icerya purchasi* Maskell, exhibited similar discrimination and avoidance of prey parasitized by *Cryptochaetum iceryae* (Williston) (Quezada and DeBach 1973). The fourth-instar and adult female of the whitefly predator, *Delphastus pusillus* (LeConte) (Col., Coccinellidae), exhibited a marked tendency to avoid fourth instar of *B. tabaci* parasitized by the aphelinid parasitoid, *Encarsia tranvena* (Timberlake) and *Eretmocerus* sp. nr *californicus* Howard in favor of unparasitized whitefly (Hoelmer et al. 1994). The present results enhance the options for the use of *S. parcesetosum* in pest management programs in conjunction with parasitoids. Also, the results suggest that, since the parasitized whiteflies by *E. formosa* are avoided by *S. parcesetosum*, there is feasible potential for integration of both species of natural enemies into management programs for *B. tabaci* in order to provide a greater level of pest suppression.

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