

# The effect of season on the levels of predation by the ladybird *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) on the cotton whitefly *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae), a serious pest of eggplants

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**Abstract** The whitefly *Bemisia tabaci* is a serious pest of eggplants, especially those grown undercover in polytunnels and greenhouses. Due to increasing levels of resistance of *B. tabaci* to a wide range of insecticides, there is now an urgent need to explore other non-chemical methods of control. In this study, *Serangium parcesetosum*, a ladybird, was evaluated as a possible biological control agent of *B. tabaci*'s winter and spring populations which infests eggplants grown undercover in Turkey. It was found that in winter, *S. parcesetosum* failed to control *B. tabaci*, even when the ladybird population was augmented six times over the course of the experiment. This contrasted with that observed in spring when, with only one introduction of the ladybird, control of the pest was gained within 3 weeks after release. In spring, the *B. tabaci* population in the cages receiving two and four *S. parcesetosum* adult per plant showed 56 and 53% reduction, respectively. The percent reduction in *B. tabaci* population rose to 98.6 and 98.3% in both cages, respectively, by the end of experiment. It is suggested that release of *S. parcesetosum* against *B. tabaci* during spring months may be offered as an alternative

solution to increase implementation of biologically based *B. tabaci* management. In winter other biological control agents are needed and these need to be further explored.

**Keywords** Aubergine · Biological control · Greenhouses · Polytunnels · Spring · Turkish horticulture · Winter

## Introduction

Eggplant, cucumber, pepper and tomato are the major greenhouse crops grown in late summer or late winter on the Mediterranean coast of Turkey (Anonymous 2003). The whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) is one of the most serious pest species for greenhouse crops, particularly the above-mentioned. A key pest, *B. tabaci* causes direct damage to all crops due to a reduction in plant vigor and production of honeydew on foliage with subsequent development of sooty molds. It also transmits plant-pathogenic viruses, particularly in tomato (Lodos 1982; Brown et al. 1995; Perring 2001). Whiteflies take off in large numbers when the vegetable grown in outdoor are harvested (September–October) and disperse to search new host plants. During this dispersal flight, they invade plastic greenhouses and attack the newly planted crops, such as tomato, cucumber, eggplant and, pepper.

The whitefly can be controlled by chemical means, spraying 10–12 times during growing season in Turkey (Ulubilir and Yabas 1996; Ulubilir et al. 1999). There is growing interest in finding alternative control methods for *B. tabaci* apart from the use of insecticides. Producers in Turkey are unwilling to use large amounts of pesticides, biological control of other pests is disrupted, and there has been rapid evolution of insecticide resistance in the pest (Ulubilir et al. 1997, 1998; Yucel et al. 1995; Yoldas et al.

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1996; Karut 2007). In Turkey, the biological control agent of *B. tabaci* has already been identified (Ulusoy 2001). Adult and larval stages of *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) is active whitefly predators throughout their long life; both larva and adults exhibit high prey consumption (Legaspi et al. 1996; Ellis et al. 2001; Vatansever et al. 2003; Sengonca et al. 2004, 2005; Al-Zyoud and Sengonca 2004; Al-Zyoud et al. 2005a, b, c). Moreover, this ladybird is well adapted to environmental conditions of Mediterranean Region of Turkey (Yigit and Canhilal 2005). These traits suggest that *S. parcesetosum* may be a viable candidate for biological control in greenhouses with high *B. tabaci* densities.

Plastic greenhouses mostly have a high humid climate, large diurnal temperature variation and are poorly ventilated. These conditions favor pests and diseases; insect and mites as well as diseases have an optimum temperature for their development and dispersal. Generally, greenhouse pests perform best within 20–30°C night–day ambient temperatures. Unfavorable temperatures not only affect pests but also their natural enemies which may perform poorly during summer and winter in the Mediterranean Region (Berlinger et al. 1999).

Because of this large diurnal temperature variation in plastic green houses, the present work aimed to evaluate the efficiency of this predator as a biological control agent of *B. tabaci* during winter and spring months under plastic green house conditions. The dynamics of *B. tabaci* and *S. parcesetosum* were monitored on eggplants. The study is expected to help characterize some basis and provide information in order to facilitate the release of *S. parcesetosum* in large scale in greenhouses to suppress *B. tabaci* population.

## Materials and methods

We conducted studies on potted eggplants covered with cages in plastic greenhouses during winter and spring at Agricultural Machinery Training Center and the Adana Plant Protection Research Institute, in 2005, and 2006, respectively.

### Winter experiment

The study was conducted on eggplants in three separate exclusion cages (2 × 1 × 1.7 m), the sides of which were covered with cheese-cloth in a plastic greenhouse of the Agricultural Machinery Education Center in Adana, Turkey. Eggplant seedlings were planted in soil in plastic pots; the pots were maintained in a climate controlled chamber until the seedlings reached a height of 40–50 cm. They were then transferred to a constant temperature room at 25°C under 16-h illumination and 70% R. H. and placed

next to the plants infested with *B. tabaci*. These plants were kept in this room for 3 weeks to obtain a sufficient *B. tabaci* density.

Four potted eggplants (40–50 cm height), infested with *B. tabaci* were placed in each cage on 15 November 2005. *Serangium parcesetosum* adults were reared in the laboratory according to the methods of Yigit (1992) and released by gently shaking them from the bottles onto caged plants. Releases were made prior to 9 am at a rate of 8 adults (2 adults per eggplant) in cage I, 16 adults (4 adults per eggplant) in cage II on 15 November 2005. The remaining third cage acted as the control and did not receive any *S. parcesetosum*. The ladybirds were released again into the first and second cages on 25 November, 6 December, 10 December, 30 December 2005 and, 5 January 2006, a total of six times throughout the course of the experiment.

To assess the levels of pest infestation, plants were monitored weekly for 8 weeks, beginning 15 November. Two leaves (eight leaves per cage) were sampled from each plant. Larval and pupal stages of whitefly were recorded on 10 cm<sup>2</sup> section of each leaf using a 10× hand lens.

*Serangium parcesetosum* populations were monitored throughout study to assess its survival, development, and reproduction. The abundance of *S. parcesetosum* larvae and adults were estimated by visual inspections lasting 10 min per cage (2.5 min per plant) before counting the *B. tabaci*.

Sooty mold growth on honeydew excreted by the *B. tabaci* on eggplants was scored according to the scale developed by Ulu (1984) as an indirect measure of the predator's success.

### Spring experiment

Five potted egg plants (40–50 cm height), heavily infested with *B. tabaci* were placed in each cage on 17 March 2006. *S. parcesetosum* adults were released only once using the same experimental design method mentioned above. Thereafter, *B. tabaci* and ladybird populations were monitored weekly for 8 weeks beginning 17 March thereafter following the protocol outlined in the winter study.

### Statistical analyses

All data were analyzed using the SPSS (vs. 11.0) statistical package. First, treatment variation in *B. tabaci* densities among cage means was analyzed using a repeated-measure analysis of variance (ANOVA) with sample date as the repeated measure. In the repeated-measure analysis of variance, the Mauchly sphericity test was violated ( $P \leq 0.05$ ) in both experiments, then the effect of treatment was compared with multivariate analysis of variance (MANOVA) on the square root ( $X + 0.5$ ) transformed data, with each

sample date as dependent variables and treatments as the independent variable (factor). For this analysis, treatments were classified cage I (two adult per plant), cage II (four adult per plant) and cage III (control). Significance of the model was assessed on the basis of Wilks’ Lambda statistic. Individual ANOVAs were compared for *B. tabaci* densities at each sampling date to determine the significant differences among *B. tabaci* densities ( $P \leq 0.05$ ) using the Duncan multiple significant difference test, if the overall MANOVA was significant. The sooty mold growth differences among treatment were analyzed using a nonparametric statistical test (Kruskal–Wallis) (Yigit et al. 2003). The percentage reduction of *B. tabaci* obtained with predator release was calculated as  $100 \times [1 - (\text{density of } B. \text{ tabaci in treated cage/density of } B. \text{ tabaci in control cage})]$ .

**Results**

In the both studies, temperature and relative humidity were monitored hourly in one cage with HOBO 4-Channel External RH/Temp Loggers (Onset Computer Corporation, Bourne, MA, USA). The mean temperature and relative humidity were 16°C (min. 1.6; max. 34°C) and 45.94% R.H. (min. 23 and max. 73% R.H.), respectively, in cages during winter months. However, the mean temperature and relative humidity were 24°C (min. 5.4; max. 45°C) and 42% R.H. (min. 22 and max. 71% R.H.), respectively, in cages during spring months.

**Table 1** Mean ( $\pm$  SE) winter numbers of *Bemisia tabaci* per 10 cm<sup>2</sup> section of leaf and mean numbers of *Serangium parcesetosum* per plant observed in 2.5-min visual search at different sampling dates and

**Winter experiment**

Numbers of *B. tabaci* were insignificantly different among three treatments until the study ended (MANOVA Wilk’s Lambda = 0.609). Plants receiving low (cage I) and high rate (cage II) of ladybird were not free of sooty mold damage and exhibited sign of feeding damage. Untreated plants (cage III) also were covered with sooty mold (Table 1).

During the experiment, no larvae of *S. parcesetosum* per plant were recognized in cage II receiving four adults per plant. However, in cage I receiving two adults per plant, there were less than 3.0 larvae of *S. parcesetosum* per plant 49 days after release (30 December) (Table 1).

**Spring experiment**

Numbers of *B. tabaci* were significantly different among three treatments (MANOVA Wilk’s Lambda = 0.003). Whitefly densities were higher in both release cages than that of control cages until 3 weeks after ladybird release. After 3 weeks, densities of *B. tabaci* were reduced by 56.5 and 53.1%, respectively, in cage I and cage II. The reduction in whitefly population corresponded to an increase in *S. parcesetosum* populations in the release cages beginning 1 April and remained significant to the last sampling date (Table 2). At the end of experiment, reduction in the *B. tabaci* population rose to 98.6 and 98.3%, respectively, in cage I and cage II.

sooty mold levels on eggplant leaves at the end of experiment under plastic greenhouse conditions

Treatments	Sampling date							
	15 November 2005 <sup>a</sup>		25 November 2005 <sup>a</sup>		6 December 2005 <sup>a</sup>		15 December 05	
	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)
Cage I	3.00 $\pm$ 0.23	2 + 0	4.93 $\pm$ 0.21	2 + 0	7.65 $\pm$ 0.86	2 + 0	9.35 $\pm$ 0.87	1.5 + 0
Cage II	3.12 $\pm$ 0.11	4 + 0	5.06 $\pm$ 0.16	4 + 0	8.33 $\pm$ 1.61	4 + 0	10.82 $\pm$ 1.60	1.25 + 0
Cage III	3.17 $\pm$ 0.21	0	4.68 $\pm$ 0.32	0	6.43 $\pm$ 0.94	0	8.03 $\pm$ 1.22	0

  

Treatments	23 December 2005		30 December 2005 <sup>a</sup>		5 January 2006 <sup>a</sup>		17 January 2006		Sooty mold growth	
	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Sooty mold index	Mean rank <sup>*</sup>
Cage I	14.90 $\pm$ 1.19	1.25 + 0	18.99 $\pm$ 1.06	2 + 1.5	21.43 $\pm$ 0.91	2 + 2.75	22.84 $\pm$ 1.19	0.5 + 2.75	3.75	7.5 a
Cage II	14.90 $\pm$ 1.04	1.00 + 0	16.52 $\pm$ 0.84	4 + 0	20.52 $\pm$ 1.47	4 + 0	22.36 $\pm$ 1.55	1.5 + 0	3.5	6.0 a
Cage III	15.63 $\pm$ 2.01	0	17.93 $\pm$ 2.01	0	18.42 $\pm$ 1.50	0	19.35 $\pm$ 1.54	0	3.5	6.0 a

10 December 2005 (date not shown) ladybird released again, MANOVA Wilk’s Lambda = 0.609  $df = 16, 28$   $F = 0.492, P$  value = 0.930

<sup>a</sup> Ladybird released

\* Means within a column followed different letters are significantly different  $P \leq 0.05$  (Mann–Whitney  $U$  test)

**Table 2** Mean ( $\pm$  SE) spring numbers of *Bemisia tabaci* per 10 cm<sup>2</sup> section of leaf and mean numbers of *Serangium parcesetosum* per plant observed in 2.5-min visual search at different sampling dates and sooty mold levels on eggplant leaves at the end of experiment under plastic greenhouse conditions

Treatments	Sampling date									
	17 March 2006 <sup>a</sup>		23 March 2006		1 April 2006		9 April 2006			
	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)								
Cage I	18.72 $\pm$ 0.99b	2 + 0	19.55 $\pm$ 0.89b	2 + 0	17.77 $\pm$ 0.84b	0.2 + 9.6	10.45 $\pm$ 0.35a	0.4 + 75.2		
Cage II	20.41 $\pm$ 1.14b	4 + 0	21.92 $\pm$ 0.80b	4 + 0	19.34 $\pm$ 0.93b	1.6 + 11.2	10.77 $\pm$ 0.53a	0.6 + 91.2		
Cage III	13.66 $\pm$ 0.82a	0	14.68 $\pm$ 0.78a	0	15.09 $\pm$ 0.77a	0	15.53 $\pm$ 0.77b	0		
ANOVA										
df	2, 25		2, 25		2, 25		2, 25			
F	10.829		18.104		5.740		24.573			
P	0.000		0.000		0.009		0.000			
Treatments	16 April 2006		24 April 2006		1 May 2006		8 May 2006		Sooty mold growth	
	Whitefly (mean $\pm$ SE)	Ladybird (adult + larvae)	Sooty mold index	Mean rank <sup>*</sup>						
Cage I	4.89 $\pm$ 0.21a	0 + 34.2	4.31 $\pm$ 0.12a	1.2 + 0	2.87 $\pm$ 0.17a	3 + 0.6	2.77 $\pm$ 0.12a	0.8 + 0.6	0.20	5.0 a
Cage II	4.73 $\pm$ 0.13a	0 + 43.2	4.67 $\pm$ 0.21a	2.4 + 0	3.12 $\pm$ 0.21a	3.2 + 0	3.05 $\pm$ 0.09a	1.2 + 0.8	0.40	6.0 a
Cage III	17.23 $\pm$ 0.69b	0	18.15 $\pm$ 0.64b	0	19.44 $\pm$ 0.62b	0	20.49 $\pm$ 0.46b	0	3.80	13.0 b
ANOVA										
df	2, 25		2, 25		2, 25		2, 25			
F	333.429		467.968		680.356		1556.078			
P	0.000		0.000		0.000		0.000			

MANOVA Wilk's Lambda = 0.003 df = 16, 36,  $F = 37.076$ ,  $P$  value = 0.000

<sup>a</sup> Ladybird released

\* Means within a column followed different letters are significantly different  $P \leq 0.05$  (Mann–Whitney  $U$  test)

In cages receiving ladybird release, *S. parcesetosum* larvae were detected as early as 1 April (2 weeks after release) and peaked 3 weeks after release on 9 April at more than 70 and 90 ladybird larvae per plant, respectively, in cage I and cage II. Pupae and teneral adults were first observed 35 days after release on 24 April. Very little sooty mold was observed on plants receiving low and high rate of ladybird; whereas, the plants with no ladybird control were covered by sooty mold (Table 2). Copulating adults and ladybird larvae, and pupae were observed in cages during sampling, revealing that *S. parcesetosum* can survive, develop, and reproduce in plastic greenhouses condition during spring months in Turkey.

## Discussion

The results of winter study indicated that *S. parcesetosum* failed to control *B. tabaci* population and to build up its population on eggplants with this prey, even when the ladybird population was augmented six times over the

course of the experiment (Table 1). The low air temperatures in the cages should be taken into consideration when utilizing this species, because coccinellids show a high tendency to disperse upon the availability of prey and temperature (Ives 1981). In this study, averaged air temperature was under 20°C and temperature dropped as low as 3–4°C. Ponsonby and Copland (1996) suggested that the survival rates of *Chilocorus nigritus* (F.), another coccinellid predator were 9% in the winter months and 20% throughout the remainder of the year, but the species was considered to be a suitable biocontrol agent when mean daily temperatures were maintained above 20°C under glasshouse conditions. Yigit et al. (1996) found that preimaginal development of *S. parcesetosum* was completed within 511 degree-days above a lower thermal threshold of 8.95°C. On the other hand, Zalom et al. (1985) suggested that *B. tabaci* produced one generation within 306 degree-days above a lower thermal threshold of 10°C. It was seen that *B. tabaci* produced 1.33 generations during the study. However, degree-days was not enough to produce a generation for *S. parcesetosum*.

The results of spring study indicated that *S. parcesetosum* has successfully built up its population with *B. tabaci* as prey under plastic houses conditions (Table 2). Total generation time was approximately 35 days from release onto eggplants to adult emergence. Yigit et al. (1996), Vatansever et al. (2003) and Sengonca et al. (2004), determined 21, 28 and 16 or 17 days as adult emergence (from egg to adult) of *S. parcesetosum* on citrus leaves infested with *D. citri* at 25°C constant temperature, on eggplants leaves infested with *B. tabaci* at 25°C and, on cotton leaves at 30°C, respectively.

The suppression of *B. tabaci* density in cages receiving two or four ladybird per plant was more effective than control. In particular, the larvae of *S. parcesetosum* decreased the density of *B. tabaci* population (Table 2). Legaspi et al. (1996) suggested that both immature and adult stages of *S. parcesetosum* are voracious feeders of *B. argentifolii* (= *B. tabaci* biotype B). Ellis et al. (2001) reported that a single release of two or four *S. parcesetosum* per plant onto greenhouse poinsettia in cages was extremely effective at stopping the growth of *B. argentifolii* populations and within 2 weeks of *S. parcesetosum* release. *B. argentifolii* mortality increased and for ensuing 10 weeks *B. tabaci* levels remained at or near those observed at time of predator release. Al-Zyoud et al. (2007) found that the release of a pair of *S. parcesetosum* adults per plant caused a reduction in the population of *B. tabaci* up to 90.7% on cotton under greenhouse conditions.

The number of the larvae of *S. parcesetosum* decreased rapidly 2 weeks after reaching to peak point (Table 2). Escape from the cages, lacking prey, natural mortality of larvae, cannibalism and other factors such as low prey population may be the reasons for this decrease.

It was seen that the sooty mold growth halted by the predator in release cages during spring months (Table 2). However, they failed to prevent sooty mold growth during winter months (Table 1). Yigit et al. (2003) reported that there were no noticeable sooty mold growth on citrus leaves, where *S. parcesetosum* released orchards.

In conclusion, under the conditions of the present experiments, release of *S. parcesetosum* adults was more effective to suppress the *B. tabaci* population during spring months, however, the release of the ladybird failed to control *B. tabaci* population during winter months. *S. parcesetosum* may be offered as an alternative solution to increase implementation of biologically based *B. tabaci* management in plastic greenhouse eggplant culture during spring months.

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