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Improving the Mass Rearing Possibilities of *Serangium montazerii* Fürsch (Coleoptera: Coccinellidae) on Different Host Plants of *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae)

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Abstract: The objectives of this study were to identify suitable plant species for mass rearing and to determine some biological characteristics of the predator *Serangium montazerii* Fürsch (Coleoptera: Coccinellidae) used in the biological control of *Dialeurodes citri* (Ashmead) (Homoptera: Aleyrodidae). The development time, mortality rate, preoviposition, oviposition and postoviposition periods and fecundity of *S. montazerii* were studied on various host plants using *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae). Two cotton (Çukurova-1518 and Deltapine) and two eggplant (Pala and Çukurova topağı) cultivars were used at 25 °C and 65 ± 5% RH in growth chambers. Additionally, life tables were constructed from the data obtained to compare the effects of different diets. The development time of *S. montazerii* was shortest on Çukurova-1518 (22.9 days) and longest on Çukurova topağı (28.0 days). The total mortality of the immature stages was lowest on Çukurova-1518 (20.8%) and highest on Pala (48.9%). The highest Ro and T levels were found on Deltapine 90. According to the results, cotton varieties constituted more suitable plant species for mass rearing due to the short development time, low mortality rate and high fecundity of *S. montazerii*.

Key Words: *Serangium montazerii*, *Bemisia tabaci*, biology, life table

Bemisia tabaci (Genn.) (Homoptera: Aleyrodidae)'nın Farklı Konukçuları Üzerinde *Serangium montazerii* Fürsch (Coleoptera: Coccinellidae)'nın Kitle Üretim Olanaklarının Geliştirilmesi

Özet: Bu çalışma, *Dialeurodes citri* (Ashmead) (Homoptera: Aleyrodidae)'nin biyolojik mücadelesinde kullanılan *Serangium montazerii* Fürsch (Coleoptera: Coccinellidae)'nin kitle üretiminde temel oluşturacak bazı biyolojik veriler ile uygun konukçu bitkiyi belirlemek amacıyla yapılmıştır. *S. montazerii*'nin gelişme süresi, ölüm oranı, preovipozisyon, ovipozisyon ve postovipozisyon periodu ve doğurganlığı, konukçu olarak *Bemisia tabaci* (Genn.) kullanılarak çalışılmıştır. Çalışmada; iki pamuk (Çukurova 1518 ve Deltapine 90) ve iki patlıcan (Pala ve Çukurova topağı) çeşidi kullanılmış ve denemeler 25 °C sıcaklık ve % 65 ± 5 orantılı neme ayarlı iklim dolaplarında yürütülmüştür. Buna ek olarak farklı besinlerin etkisini karşılaştırmak amacıyla elde edilen verilerden yaşam tabloları oluşturulmuştur. *S. montazerii*'nin en kısa gelişme süresi Çukurova 1518'de (22.9 gün) ve en uzun Çukurova topağında (28.0 gün) belirlenmiştir. Ergin öncesi dönemlerin en düşük ölüm oranı Çukurova 1518'de (% 20.8) en yüksek ise Pala'da (% 48.9) bulunmuştur. En yüksek Ro ve T ise Deltapine 90 üzerinde bulunmuştur. Elde edilen sonuçlara göre, gelişme süresinin daha kısa, ölüm oranının daha az ve doğurganlığının daha fazla olması dolayısıyla *S. montazerii*'nin kitle üretiminde pamuk çeşitlerinin daha uygun olduğu kanısına varılmıştır.

Anahtar Sözcükler: *Serangium montazerii*, *Bemisia tabaci*, bioloji, yaşam tablosu

Introduction

Numerous pest species have been determined in the citrus growing areas of Turkey. Of these pests, "whiteflies" constitute one of the most important groups. Six species of whitefly have been identified in citrus plantations in Turkey, although the major problem is caused by the citrus whitefly, *Dialeurodes citri* (Ashmead) (Homoptera: Aleyrodidae) (Uygun et al., 1997).

The citrus whitefly is preyed on by 20 indigenous or introduced predators, two parasitoids and one pathogen. Although *D. citri* has various natural enemies, *Serangium montazerii* Fürsch (Coleoptera: Coccinellidae), which was

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formerly known as *S. parcesetosum*, is one of the most efficient predators in suppressing pest populations under field conditions. *S. montazerii* was orginally introduced from the Eastern Black Sea region to the Eastern Mediterranean region. According to field studies carried out in the Eastern and Western Mediterranean regions (Antalya) and in the Aegean region (İzmir) of Turkey, it has successfully adapted in citrus growing areas (Ulusoy et al., 1996 a; Uygun et al., 1997). It also plays an effective role in the biological control of *D. citri* in Georgia (Antadze and Timofeyeva, 1975; Antadze and Timofeyeva, 1976; Shenderovskaya, 1976; Timofeyeva and Hoang, 1978; Shutova et al., 1985). In addition, *S. montazerii* has successfully adapted to citrus growing regions infested with *D. citri* in France (Malausa et al., 1988).

Although *D. citri* is an important prey for *S. montazerii* it is difficult to rear under controlled conditions (Malausa and Franco, 1986; Argov et al., 1999). On the other hand, *Bemisia tabaci* is an insect that is easily reared laboratory conditions (Kaygısız, 1976) and is suitable for rearing *S. montazerii* (Yiğit, 1992). For the laboratory culture of *B. tabaci* among the numerous host plant species, eggplant (18.6 days) and cotton (22.0 days) were found to give the highest reproduction rates (Ulusoy et al., 1996 b).

Host plants as well as prey species have many impacts on natural enemies by influencing their searching success and the quality of their dietary resources, and consequently their biologies (Dixon and Russell, 1972; Price et al., 1980; Carter et al., 1984; Coll and Ridgeway, 1995). It was known that hairy–leaf cotton cultivars generally enhanced whitefly populations compared to smooth-leaf cotton cultivars (Flint and Parks, 1990; Norman and Sparks, 1997). Eggplants are also known for their large, hairy leaf structure.

The objective of the study was to reveal the biology of *S. montazerii* with regard to to mass rearing possibilities on the two different host plants, cotton and eggplant, each consisting of two different varieties.

Materials and Methods

Rearing of host plants, prey and predators

Two cotton and two eggplant varieties were chosen as host plants due to their high *B. tabaci* production potential according to Ulusoy et al., (1996 b). The cotton varieties, Çukurova-1518 and Deltapine 90, have semi-smooth and smooth leaf structures respectively. The eggplant varieties, Pala and Çukurova Topağı both have a large, hairy leaf structures.

Both the cotton and the eggplant varieties were grown under laboratory conditions by sowing the cotton seeds in pots 10 x 15 cm in size and the eggplant seeds on seedling trays. After the eggplants had reached 5 cm in height, they were transplanted into pots of the same size as those used for cotton. When these plants had grown to 15 cm in height they were transferred to another climatic chamber infested with *B. tabaci* from an ongoing laboratory culture. New plants were placed in the rearing chamber twice a week to maintain the *B. tabaci* culture.

Infested host plants (cotton and eggplant) were transferred to the third rearing room containing growth cages 70 x 70 x 90 cm in size where *S. montazerii* adults were released to obtain eggs to maintain the culture (Yiğit, 1992).

All three cultures; the host plant, *B. tabaci* and *S. montazerii* were kept at 25 ± 1°C, 65 ± 5% R. H. and 16 h artificial light conditions.

Development and mortality rates of immature stages

The biology of *S. montazerii* was examined in second-generation adults from the rearing cages. Cotton and eggplant leaves bearing *B. tabaci* eggs and nymphs were placed in petri dishes (12 cm in diameter and 3 cm high), onto a damp tissue, and a group of *S. montazerii* adults were left on the top of the infested leaves to obtain their eggs. These petri dishes were checked more than three times during the day to observe the eggs laid. Every day, eggs (24 h old) were transferred to other petri dishes (9 cm in diameter and 1.5 cm high) that had a cotton mesh on the lid for ventilation. *B. tabaci* - infested leaves were renewed during the daily checks. Therefore, all the immature stages of *S. montazerii* had more than enough prey to complete their development. The duration of the egg, larvae and pupae stages and their mortality rates were determined by daily checks of the petri dishes. This study was repeated for each variety of cotton and eggplant by using 50 individuals for each immature stage under a completely randomized plot design.

Longevity and fecundity

To study the preoviposition, oviposition and postoviposition periods, and the longevity and fecundity of *S. montazerii*, adults emerging on the same day were paired and released into the same petri dish and provided with unlimited prey. These petri dishes were checked two or three times a day for mating pairs and these were transferred to another petri dish after mating. Males and females were kept with unlimited prey in these dishes. This study was repeated for each variety of cotton and eggplant by using 15 pairs of adults per replication under completely a randomized plot design.

The experiments on the development and mortality rates of the immature stages and on longevity and fecundity were conducted at 25 ± 1 °C, 65 ± 5% RH and 16 h artificial light conditions.

Statistical Analysis

Differences in development time, longevity and fecundity were calculated by analysis of variance (ANOVA). Multiple comparisons were made using LSD (α: 0.05). All data collected from these experiments were used to draw up life tables of *S. montazerii* on both the cotton and eggplant varieties. The life tables were drawn up according to Andrewartha and Birch (1970) and Southwood (1976), using the formula:

$$\Sigma l_x m_x . e^{-r_m x} = 1$$

where x: age in days, r: intrinsic rate of increase, l_x: age-specific survival, m_x: age-specific number of female offspring.

Results and Discussion

The results regarding the differences of the immature stages, development time are presented in Table 1. No differences were found in the egg stages due to the different host plants of *B. tabaci*. The mean hatching period of *S. montazerii* was 5.5 days. In all the immature stages there were no differences between the cotton varieties. Of the eggplant varieties the *S. montazerii* development stages were usually longer on Çukurova topağı. From a comparison between the total developing stages durations no differences occurred in the cotton varieties. The eggplant varieties exhibited differences regarding the longer development period on Çukurova topağı. However, the shortest total development time was that of the cotton variety Çukurova-1518 (22.9 days) and the longest that on the eggplant variety Çukurova topağı (28.0 days). Yiğit (1992) also recorded a 28.8 day total development period on cotton, which was similar to the eggplant variety result in this study. The differences between the two studies may be that the mixed immature stages provided in Yiğit (1992) affect the duration of the development period. When *S. montazerii* preyed on *D. citri* on citrus leaves, this period was relatively shorter at 20- 21 days (Timofeyeva and Nhûan, 1979; Yiğit et al., 1996).

The differences between the varieties were probably connected to the leaf structures, effected on the predator larvae development. Hairless varieties of cotton could offer a shorter development time for *S. montazerii* than hairy leaf eggplant varieties. The hairy structure makes it difficult to search for prey and the predator needs to expend more energy and/or catch more prey to complete its development. *S. montazerii* was able to prey on *B. tabaci* much more easily on cotton leaves since these are without hairs, but not as easily on eggplant leaves since these have hairs and it was not therefore possible for them to complete their development in as short a time on eggplants. Several researchers have stated that plant architecture and surface texture influence the search

Table 1. Development time of egg and immature stages of *Serangium montazerii* on different host plants (day).

	Host Plants	n	egg stage mean ± SE	Immature stages mean ± SE							TOTAL mean ± SE
				1st stage	2nd stage	3th stage	4th stage	prepupae	pupae		
Cotton	Çukurova-1518	50	5.5 ± 0.08a	2.6 ± 0.10a	2.0 ± 0.13a	2.0 ± 0.10a	4.5 ± 0.17a	1.6 ± 0.11a	4.6 ± 0.11a		22.9 ± 0.20a
	Deltapine 90	50	5.5 ± 0.10a	2.7 ± 0.10a	1.9 ± 0.08a	2.1 ± 0.16a	5.0 ± 0.25ab	1.5 ± 0.11a	4.8 ± 0.08b		23.4 ± 0.42a
Eggplant	Pala	50	5.4 ± 0.13a	2.9 ± 0.15a	2.3 ± 0.16b	2.4 ± 0.20ab	5.5 ± 0.30b	2.1 ± 0.17b	5.3 ± 0.11b		25.9 ± 0.54b
	Çukurova topağı	50	5.5 ± 0.10a	3.5 ± 0.20b	2.2 ± 0.14ab	2.8 ± 0.18b	6.5 ± 0.35b	2.3 ± 0.18b	5.3 ± 0.09b		28.0 ± 0.44b

Means withina column followed by the same letterare not significantly different by LSD (P < 0.05) behaviour of coccinellid predators (Lauenstein, 1980; Kajita, 1986; Kareiva and Sahakian, 1990). On the other hand, Carter et al., (1984) suggested that overly smooth leaf surfaces may have a negative effect on larval performance. The larvae of *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) attacked their prey with less efficiency and ate fewer *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) from the smooth leaves of peas than from the more pubescent leaves of broad beans. On peas, they fell off the plants more often and took longer to find the aphid colonies again. In addition, Yiğit (1992) found similar results on a *B. tabaci* culture that contained mixed stages. F1 adults were observed after 28.8 days after mass rearing on cotton.

The mortality rates of the egg and immature stages of *S. montazerii* on the same host plants were recorded (Table 2). Almost the same mortality rates were found on both cotton varieties for the egg (4.0%) and total immature stages (20.8% and 22.9% on Çukurova-1518 and Deltapine 90, respectively). In the case of the eggplant varieties, egg mortality was different: 2.0% on Pala and 8.0% on Çukurova topağı, whereas the difference in the mortality of the immature stages was not significant (48.9% and 45.8% on Pala and Çukurova topağı, respectively). The most interesting point about these mortality rates is the high mortality of first stage larvae on the eggplant varieties (28.6% and 25.0%) compared to the other immature stages of *S. montazerii*. This high mortality rate could again be related to the hairy nature of the eggplant leaves. In particular, the small early stage larvae may have difficulties in moving, and reaching their prey on the hairy surface. The larvae were able to move and forage easily on the smooth leaves of the cotton varieties. Various studies have highlighted the effects of plant structure on predators. Putman (1955) stated that the hooked trichomes on the foliage of the scarlet runner bean tore the integument of *Stethorus punctillum* Weise (Coleoptera: Coccinellidae): the larvae died quickly and the longevity of the adults was shortened. Furthermore, Plaut (1965) found that *S. punctillum,* a predator of *Tetranychus cinnabarinus* in Israel, reproduced in several habitats, but that adults could only be found on bush beans.

In Table 3, the preoviposition, oviposition, postoviposition, longevity and fecundity of *S. montazerii* on host plants of *B. tabaci* are given. The shortest preoviposition period was 16.7 days on cotton (Çukurova-1518) and the longest 21.9 days on eggplant (Pala). All the data showed statistical differences. According to one study on the mass rearing of *S. montazerii,* the preoviposition period was 9.8 days after the release of adults from the cages (Yiğit, 1992). On citrus, preoviposition was 10.82 days when the adults of *S. montazerii* preyed on *D. citri* (Yiğit et al., 1996).

The oviposition period also showed statistical differences: 99.8 days on cotton (Deltapine) and 58.4 days on eggplant (Pala). Yiğit et al., (1996) observed a 77.2-day oviposition period on cotton in their study. The differences between the previous study and this one may be related to the preying potential, and therefore the accumulation of energy for laying eggs. This figure was lower than the results from the cotton varieties, but higher than those from the eggplant varieties. The postoviposition periods, did not show any statistical differences.

The longevity of *S. montazerii* female adults was also statistically different. Yiğit et al., (1996) also determined 97.2 days as the longevity of *S. montazerii* on citrus bearing *D. citri* as prey. Legaspi et al., (1996) observed the longevity as 24.5 days on cucumber and 44.2 days on okra with *Bemisia argentifolii* Bellows and Perring as

Table 2. Mortality rates of egg and immature stages of *Serangium montazerii* on different host plants (%).

	Host Plants	Mortality during egg stage		Mortality of immature stages (%)						Total mortality	
		n	%	1sh stage	2nd stage	3rd stage	4th stage	prepupae	pupae	n	%
Cotton	Çukurova-1518	50	4.0	4.2	2.1	4.2	4.2	6.3	0.0	48	20.8
	Deltapine 90	50	4.0	6.3	4.2	4.2	4.2	4.2	0.0	48	22.9
Eggplant	Pala	50	2.0	28.6	12.2	2.0	2.0	4.1	0.0	49	48.9
	Çukurova topağı	50	8.0	25.0	4.2	8.3	8.3	0.0	0.0	46	45.8

Table 3. The preoviposition, oviposition and postoviposition periods (day), longevity (day) and fecundity of *Serangium montazerii* on different host plants.

	Host Plants	n	Preoviposition mean±SE	Oviposition mean±SE	Postoviposition mean±SE	Longevity mean±SE	Fecundity mean±SE
Cotton	Çukurova-1518	15	16.7 ± 1.51 b	92.9 ± 12.61 ac	19.4 ± 3.56 a	120.2 ± 13.92 a	309.3 ± 70.46 a
	Deltapine 90	15	17.7 ± 1.00 ab	99.8 ± 11.98 a	13.6 ± 3.30 a	131.1 ± 13.82 a	354.7 ± 101.51 a
Eggplant	Pala	13	21.9 ± 2.71 a	58.4 ± 9.76 b	15.7 ± 3.70 a	91.9 ± 11.47 b	135.2 ± 35.74 b
	Çukurova topağı	12	19.8 ± 1.80 ab	61.7 ± 9.10 bc	13.8 ± 2.80 a	95.3 ± 11.41 ab	118.8 ± 26.33 c

Means within a column followed by the same letter are not significantly different by LSD (P < 0.05)

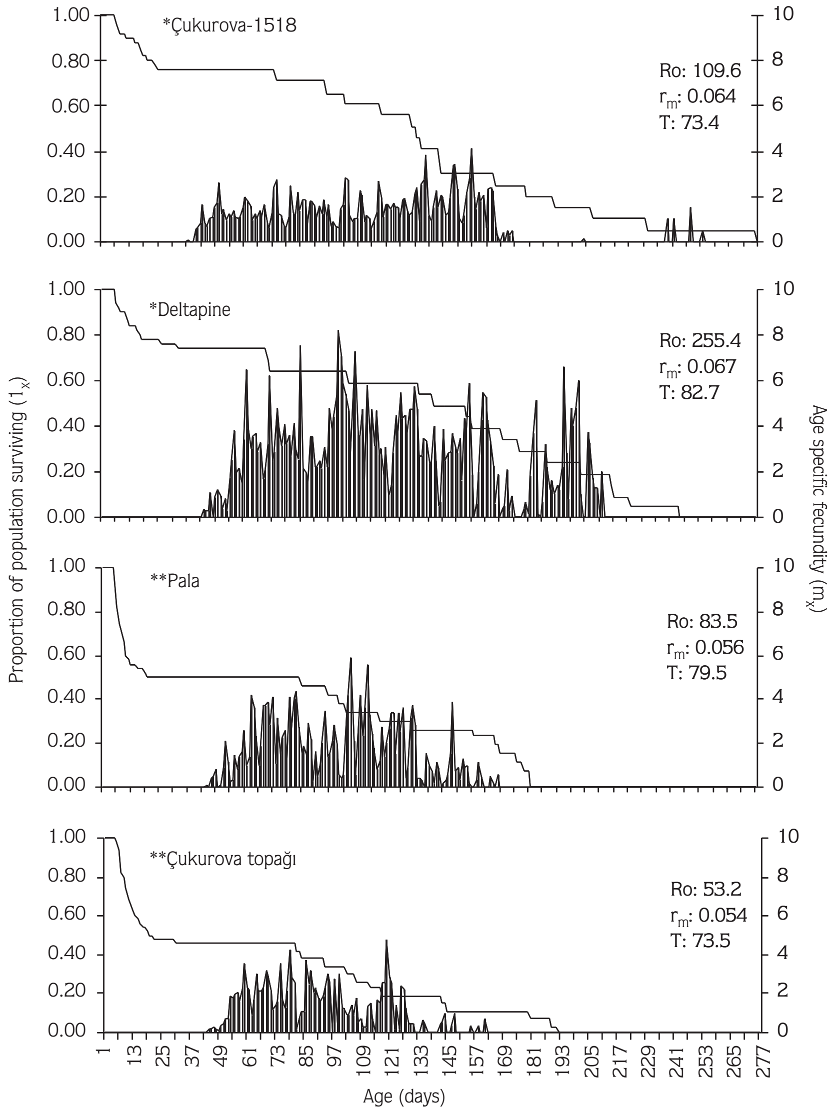

Figure 1. Survivorship curve (l_x) and age specific fecundity rate (m_x) of *Serangium montazerii* on different host plants (* cotton, ** eggplant).

prey. The differences in these results show that both prey and their host plants could affect the biological features of natural enemies.

The fecundity of *S. montazerii* varied on the different host plants (Table 3). On the cotton varieties, Çukurova-1518 and Deltapine, the mean numbers of eggs laid per female were 309.3 and 354.7, respectively. However, the mean numbers of eggs laid on the eggplant varieties (135.2 and 118.8 eggs on the Pala and Çukurova topağı varieties, respectively) were less than half of those laid on the cotton varieties. Yiğit et al., (1996) found 232.1 eggs per female on cotton. According to Timofeyeva and Hoang (1978), fecundity ranged between 135 and 185 eggs. Yasnosh and Chaidze (1986) observed 200 eggs laid per female on citrus. These data indicate that the low predation rate on eggplant leaves was the result of low preference, low searching efficiency and high predator mortality. A complex search surface structure, interference by trichomes with predator searching and the availability of more shelter, which protect whitefly from predator attacks might account for the negative effect of eggplant on the searching ability of *S. montazerii*.

The life tables of *S. montazerii* are presented in Figure 1. The highest reproductive rate (R_o) was found on the cotton variety Deltapine 90, and both Ro and generation time (T) were also higher than on the other varieties. Of the eggplant varieties, Pala gave better results than Çukurova topağı. However, both Ro and the intrinsic rate of increase (r_m) on the Pala variety were lower than those of the cotton varieties, which means that cotton, especially Deltapine 90, is a more suitable host for the mass production of *S. montazerii* than the other varieties.

The data showed that the interactions between *S. montazerii* and its prey were influenced not only by prey abundance and predator searching ability but also by the suitability of the food plants used by the prey that served as food for the predator. Consequently, we concluded that the cotton varieties, especially Deltapine 90, were more suitable host plants than the eggplant varieties for the mass rearing of *S. montazerii*, a predator of *D. citri*.

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