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Orijinal araştırma (Original article)

Parasitism status of *Bemisia tabaci* (Gennadius 1889) (Hemiptera: Aleyrodidae) on different host-plants in the Çukurova region of Turkey[1]

Çukurova Bölgesi'nde *Bemisia tabaci* (Gennadius 1889) (Hemiptera: Aleyrodidae)'nin farklı kültür bitkilerinde parazitlenme durumu

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Summary

Populations changes of *Bemisia tabaci* (Gennadius 1889) (Hemiptera: Aleyrodidae) and its parasitism status were monitored on different host-plants in the Çukurova Region (Yüreğir and Karataş districts) in 2008 and 2009. Samples were taken from cotton, cucumber, eggplant and soybean and pest numbers were counted in the laboratory. Each year, lower numbers of *B. tabaci* occurred in early July and increased to higher densities in August and September. Likewise, low parasitism rates by *Eretmocerus mundus* Mercet 1931 and *Encarsia lutea* (Masi 1909) (Hymenoptera: Aphelinidae) occurred in July and peaked in August and September. *Er. mundus* was observed to be more efficient on cotton, eggplant and soybean, but less on cucumber. The parasitism rates by *Er. mundus* on all host-plants were higher than those of *En. lutea*. While the highest parasitism rate of *Er. mundus* was found on soybean (73.94%) in the Yüreğir district, that of *En. lutea* was on eggplant (24.3%) in the Karataş district in 2008. In 2009, while the highest parasitism rate by *Er. mundus* was on cotton (50.0%) in the Yüreğir district, that of *En. lutea* was found on eggplant (20.0%) in the same district. These parasitism levels confirmed that *Er. mundus* and *En. lutea* are important parasitoids of *B. tabaci* in the Çukurova Region.

Key words: *Bemisia tabaci*, *Eretmocerus mundus*, *Encarsia lutea*, host plant, parasitism

Özet

Bemisia tabaci (Gennadius 1889) (Hemiptera: Aleyrodidae)'nin populasyon gelişimi ile parazitlenme durumu, Çukurova Bölgesinde (Karataş ve Yüreğir ilçelerinde) 2008 ve 2009 yıllarında farklı kültür bitkilerinde ortaya çıkarılmıştır. Yaprak örnekleri hıyar, pamuk, patlıcan ve soya bitkilerinden alınarak laboratuvarda sayılmıştır. Her iki yılda da Temmuz başında düşük olan *B. tabaci* yoğunluğu, Ağustos ve Eylül aylarında artmıştır. Benzer şekilde Temmuz ayında düşük olan, *Eretmocerus mundus* Mercet 1931 ve *Encarsia lutea* (Masi 1909) (Hymenoptera: Aphelinidae)'ya ait parazitleme oranları, Ağustos ve Eylül aylarında yükselmiştir. *Er. mundus* pamuk, patlıcan ve soya bitkilerinde hıyar bitkisinden daha etkili bulunmuştur. *Er. mundus*'a ait parazitleme oranı tüm kültür bitkilerinde *En. lutea*'ya ait parazitleme oranından daha yüksek bulunmuştur. 2008 yılında *Er. mundus*'a ait en yüksek parazitleme oranı Yüreğir ilçesindeki soya tarlasında (% 73.94) elde edilirken, *En. lutea* için bu değer % 24.3 ile Karataş ilçesindeki patlıcan tarlasından elde edilmiştir. İkibin dokuz yılında *Er. mundus*'a ait en yüksek parazitleme oranı Yüreğir ilçesindeki pamuk tarlasında (% 50) elde edilirken, *En. lutea* için bu değer % 20 ile aynı ilçedeki patlıcan tarlasından elde edilmiştir. Elde edilen parazitlenme oranları Çukurova Bölgesi'nde *Er. mundus* ve *En. lutea*'nın *B. tabaci*'nin önemli parazitoitleri olduğunu göstermiştir.

Anahtar sözcükler: *Bemisia tabaci*, *Eretmocerus mundus*, *Encarsia lutea*, kültür bitkisi, parazitlenme

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Introduction

Various species of whiteflies have been reported in association with annual crops, but none of them is as cosmopolitan as *Bemisia tabaci* (Gennadius 1889) (Hemiptera: Aleyrodidae) which is commonly associated with cotton, tobacco and sweet potato. *Bemisia tabaci* has a range of around 506 plant species within 74 families (Stansly & Naranjo 2010), but is often found on crop species belonging to the following plant families: Convolvulaceae, Cucurbitaceae, Leguminosae, Malvaceae, and Solanaceae (Byrne et al. 1990). In Turkey, *B. tabaci* was reported to be a problem on different cultural plants as early as 1928 (Arık et al.1976). Although its populations differ annually, it is still considered the key pest in the Çukurova Region, causing yield reduction and economic losses (Özgür & Şekeroğlu 1986; Şekeroğlu et al. 2000; Karut & Akdağcık 2006). Ever since an outbreak in 1974, it has been the most important pest of cotton under irrigated conditions and research has increased over the years to develop solutions (Şengonca 1975; Şekeroğlu et al., 2002).

The high populations of *B. tabaci* have resulted in a large increase in the use of insecticides in the Çukurova Region. The number of applications per season has reached as high as ten and yet these costly applications of insecticides have hardly prevented economic losses. Insecticides often become ineffective against *B. tabaci* due to the development of resistance in its populations (Özgür & Şekeroğlu 1986). Currently, the most common management approach is with pesticides; however, more efficient and environmentally sound methods are needed. Biological control through augmentation of natural enemies would be a more suitable approach if it was more consistent and effective. However, the success of parasitoids in biological control is highly variable, depending on host-plant interaction, climate, the presence of competing natural enemies, use of non-selective insecticides and a number of other environmental factors (Butler & Henneberry 1984; Hoelmer 1995).

Studies have shown that host plant species can affect the abundance of whiteflies, as well as parasitoid abundance and rate of parasitism. Simmons et al. (2002) reported that two *Brassica* species and *Vigna anguiculata* (L.) were more conducive to parasitism of *B. tabaci* than *Cucumis sativus* L. and *Lycopersicon esculentum* Miller. Qiu et al. (2005) demonstrated that *Eretmocerus* sp. nr. *furuhashii* Rose and Zolnerowich was more effective on non-glabrous crop varieties than glabrous plants for biological control of *B. tabaci*. Stansly et al. (1997) found that a greater proportion of *B. argentifolii* was parasitized by *Encarsia pergandiella* Howard 1907 on tomato than on collard and eggplant in a greenhouse choice test.

Karut & Naranjo (2009) hypothesized that the key to understanding parasitism was based on graphical and regression-based comparisons of individual k-factor values to total generational mortality. The authors related this to cotton planting in the Çukurova Region where the crop is surrounded by a relatively diverse cropping landscape that may more readily facilitate higher parasitoid populations and thus contribute to higher pest mortality. However, there are no detailed studies on parasitism of *B. tabaci* on different crops surround the cotton plants in the region.

The diverse cropping landscape in the Çukurova Region includes eggplant, cotton, cucumber and soybean, all important host-crops of *B. tabaci*. Eggplant and cucumber are normally grown in a few, small areas whereas cotton and soybean are grown in much larger areas. Cotton is sometimes grown as a second crop in June, but mainly as a first crop beginning in mid April to mid May and soybean is normally grown as a second crop with planting in June.

Although studies have shown that *Eretmocerus mundus* Mercet 1931 and *Encarsia lutea* (Masi 1909) are important parasitoids and a key factor in managing the populations of *B. tabaci* on cotton in the Çukurova Region (Kaygısız 1976; Ulusoy et al. 1996; Karut 2006; Karut & Akdağcık 2006; Karut & Kazak 2007; Karut & Naranjo 2009), there are no detailed studies on other host-plants grown in the region. The present study was carried out to determine the parasitism status of *Er. mundus* and *En. lutea* on *B. tabaci* on eggplant, cucumber, soybean and cotton and to help develop effective and more sustainable pest management systems to control *B. tabaci* populations in the Çukurova Region.

Material and Methods

To determine the parasitism status of *B. tabaci* on cucumber (*Cucumis sativus* L.), eggplant (*Solanum melongena* L.), cotton (*Gossypium hirsutum* L.) and soybean (*Glycine max* (L.) Merr.), surveys were carried out in commercially sprayed fields located in the Yüreğir and Karataş districts of the Çukurova Region during the 2008 and 2009 growing seasons. In 2008, whitefly abundance and parasitism rates were evaluated in six different fields; three (cotton, eggplant and soybean) located at Karataş, and the others (cotton, cucumber and soybean) at Yüreğir district of Adana. In 2009, similar studies were conducted at seven fields; three (cotton, eggplant and soybean) located at Karataş and the others (cotton, eggplant, soybean and cucumber) were in the Yüreğir district of Adana. The average monthly temperatures for June-September in this region ranged between 25 and 29.5˚C.

A summary of the information for the fields sampled in 2008 and 2009 seasons is given in Table 1. The type of insecticides used to control *B. tabaci* varied by field and over time. The number of sprays varied between two to six per season and the more commonly used insecticides were Imidacloprid, Pyriproxyfen, Acetamiprid, Diafenthiuron, Chlorpyriphos and Cypermethrin.

Table 1. Sites used to determine the parasitism status of *Bemisia tabaci* in Çukurova Region, in 2008 and 2009

Season	Host-plant	Variety	Location	Area (hectares)
2008	Cucumber	Altay	Yüreğir	1
	Eggplant	Adana topağı	Karataş	~ 0.1
	Cotton A	SG 125	Yüreğir	2.8
	Cotton B	SG 125	Karataş	2
	Soybean A	SA 88	Yüreğir	10
	Soybean B	SA 88	Karataş	2
2009	Cucumber	Altay	Yüreğir	0.6
	Eggplant A	Adana topağı	Yüreğir	1.5
	Eggplant B	Adana topağı	Karataş	0.3
	Cotton A	SG 125	Yüreğir	20
	Cotton B	SG 125	Karataş	4.5
	Soybean A	BLAZE	Yüreğir	4
	Soybean B	SA 88	Karataş	10

Sampling commenced in June and continued for 14 weeks in both years. On each sampling date, 40 leaves from each field were randomly selected (20 from the upper half of the plant from. 3rd or 4th node leaves and 20 from the lower half of the plant from. 6th or 7th node leaves). They were covered carefully with paper, labeled, put in plastic bags, stored in a slightly cold container and brought to the laboratory where a random area of 4 cm² on the lower part of each leaf was selected for the counting of eggs, larvae, pupae and exuvia of *B. tabaci*; and pupae of *Er. mundus* and *En. lutea,* using a binocular microscope. Parasitism without meconia in the parasitized pupae was attributed to *Er. mundus*, and parasitism with meconia to *En. lutea* (Otoidobiga et al. 2002).

Percent parasitism was calculated as the quotient of the total number of parasitized whitefly and the total number of parasitized plus unparasitized whitefly. Data on percentage parasitism and *B. tabaci* stages on different host-plants were subjected to analysis of variance (ANOVA), and mean percentages were separated using the Least Significant Difference Test (LSD) following a significant F test at $P<0.05$ (Microsoft Excel, MstatC). Percentage data were arcsin transformed before analysis.

Results

B. tabaci is a species complex that includes different biotypes. Although biotypes of *B. tabaci* were not determined for this study, earlier studies show that B and Q biotypes are present together in the region (Karut, 2009). Weekly mean number of immature stages of *B. tabaci* was lower on cotton than cucumber, eggplant and soybean in 2008 (Figs. 1 and 2). While mean number of eggs never reached more than 0.45 per 4 cm^2 on cotton, it averaged 45 on cucumber plants in 2008. In general, the whitefly population in 2009 was lower than the population in 2008 on all host-plants, except for cucumber. Mean numbers of immature stages of *B. tabaci* on cotton, eggplant and soybean were lower than on cucumber plants and never reached more than 6 nymphs per 4 cm^2 in 2009 (Figs. 1, 2 and 3). The parasitoid species found in all sampled fields were the native species, *Er. mundus* and *En. lutea* (Ulusoy et al 1996; Karut 2006; Karut & Kazak 2007). In general, population fluctuations of *Er. mundus* and *En. lutea* were similar to that of *B. tabaci*. On all host-plants in the two growing seasons, low weekly mean numbers of *B. tabaci* occurred in early July, and increased to higher densities in August and September. Likewise, low weekly parasitism rates occurred in July and peaked in August and September (Figs. 1, 2 and 3).

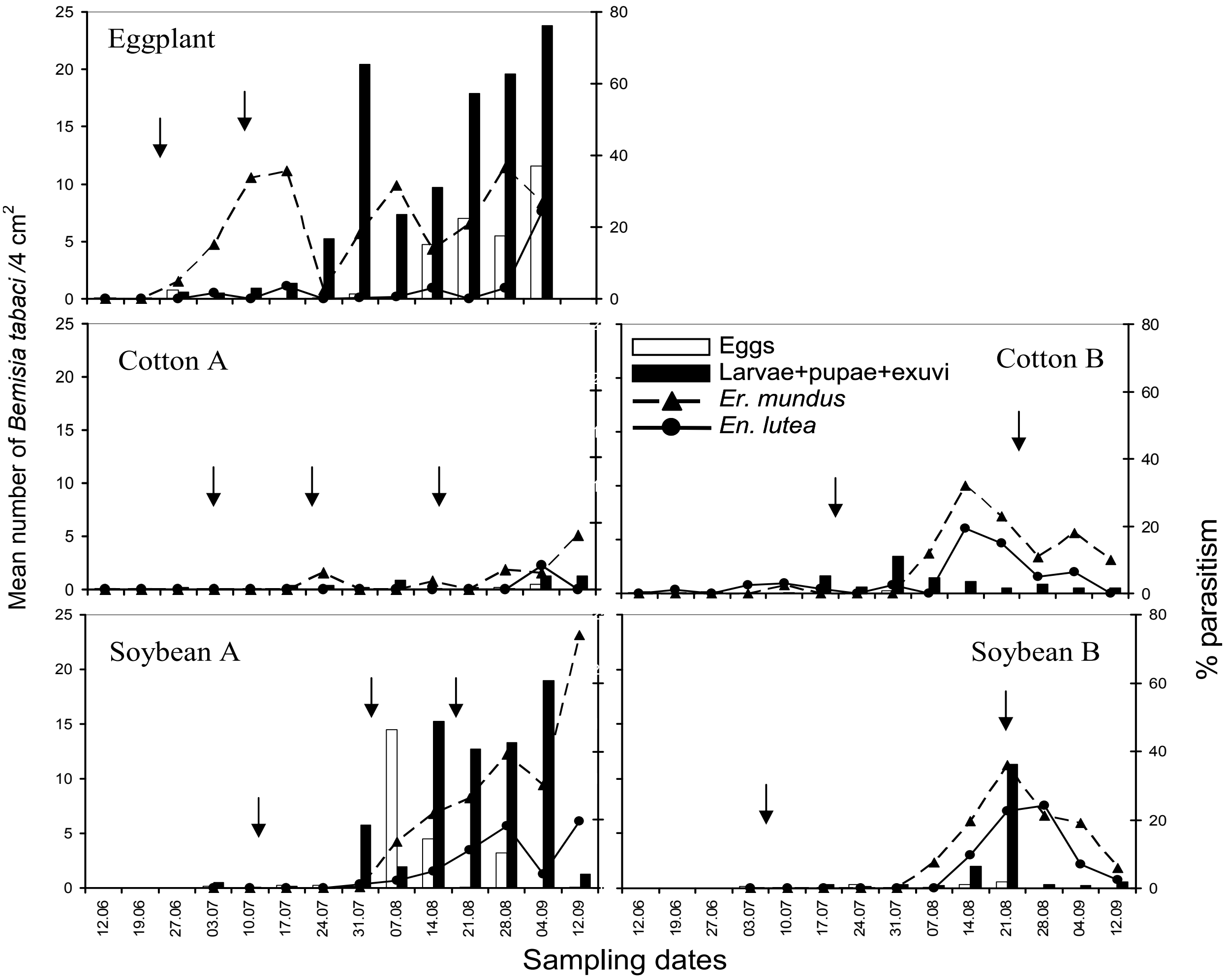

Figure 1. Weekly mean numbers of *Bemisia tabaci* and parasitism rates of *Eretmocerus mundus* and *Encarsia lutea* on eggplant, cotton and soybean during the 2008 season at the Karataş and Yüreğir districts of Adana. Arrows indicate the dates of insecticide applications for whitefly. Host-plant with A and B indicates Yüreğir or Karataş district, respectively.

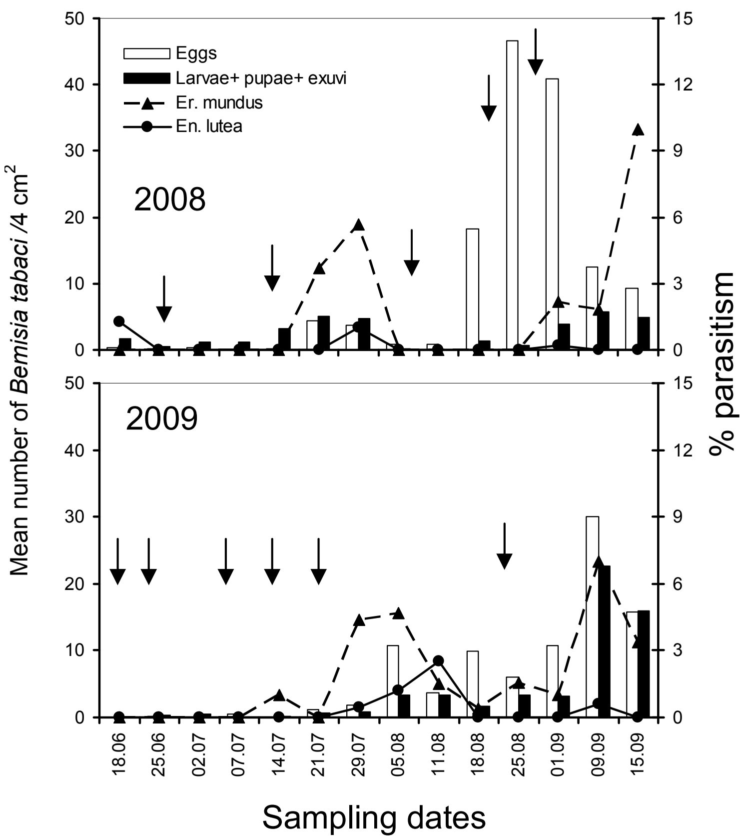

Figure 2. Weekly mean numbers of *Bemisia tabaci* and parasitism rates of *Eretmocerus mundus* and *Encarsia lutea* on cucumber during the 2008 and 2009 seasons in the Yüreğir district of Adana. Arrows indicate the dates of insecticide applications for whitefly.

In 2008, the highest parasitism rate by *Er. mundus* was obtained on soybean A (73.94%) in Yüreğir in the second week of September and that by *En. lutea* was on eggplant (24.3%) located in Karataş in the first week of September (Fig. 1). Although the populations of *B. tabaci* on cucumber were higher than on cotton, eggplant and soybean plants, the weekly parasitism rates were lower for both parasitoids. The highest weekly parasitism percentages for *Er. mundus* and *En. lutea* in 2008 were 10% in the second week of September and 1.25% in the second week of June, respectively, on cucumber (Fig. 2). In 2009, the highest parasitism rate by *Er. mundus* was on cotton A (50%) located in Yüreğir on August 18 and by *En. lutea* was on eggplant (20%) on June 21 in the same area (Fig. 3).

The seasonal mean numbers of *B. tabaci* eggs were higher on cucumber plants than on other host plants in both seasons (F = 4.11, df = 71, P = 0.0024 for 2008; F = 6.55, df = 85, P = 0.001 for 2009), in spite of the early insecticide applications. Similar to the egg stage, the seasonal mean number of larvae was higher on cucumber than on the other host plants in 2009 (F = 2.64, df = 85, P = 0.021). Seasonal parasitism rates by *Er. mundus* were highest on soybean and eggplant followed by cotton in the 2008 and 2009 growing seasons (F = 4.35, df = 71, P = 0.001 for 2008; F = 2.36, df = 85, P = 0.036 for 2009). The lowest parasitism rates by *Er. mundus* were on cucumber plants for both 2008 and 2009 (mean= 1.66 and 1.78%, F = 4.35, df = 71, P = 0.001 for 2008; F = 2.36, df = 85, P = 0.036 for 2009). In the 2008 and 2009 growing seasons, the parasitism rates by *Er. mundus* on all host plants were higher than those by *En. lutea*. Similar to *Er. mundus*, the highest parasitism rates by *En. lutea* were on soybean and the lowest were on cucumber plants (Table 2).

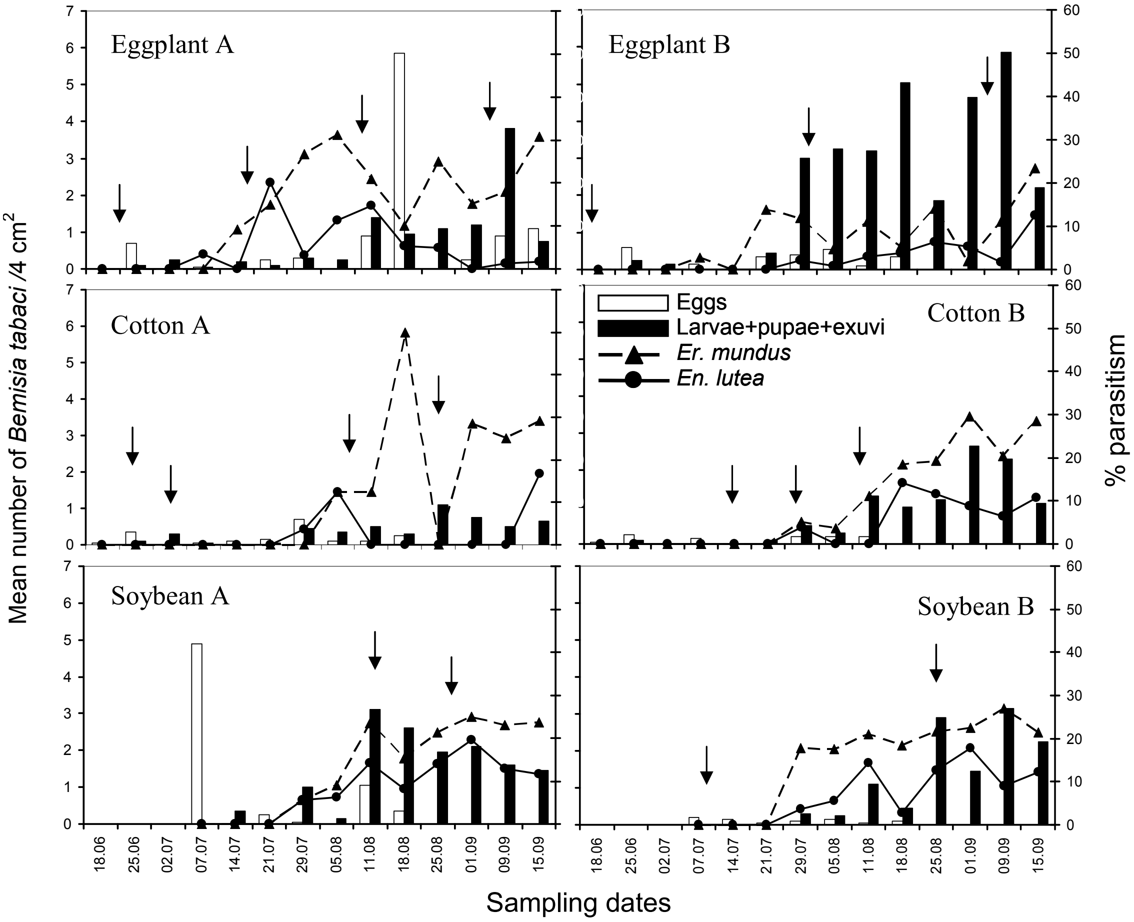

Figure 3. Weekly mean numbers of *Bemisia tabaci* and parasitism rates of *Eretmocerus mundus* and *Encarsia lutea* on eggplant, cotton and soybean during the 2009 season at the Karataş and Yüreğir districts of Adana. Arrows indicate the dates of insecticide applications for whitefly. Host plant with A or B indicates Yüreğir or Karataş district, respectively.

Table 2. Seasonal mean numbers of *Bemisia tabaci* stages and parasitism (%) on different host plants in the Çukurova Region in the 2008 and 2009 growing seasons

Seasons		*Bemisia tabaci* stages		% parasitism	
	Host-plant	Egg	Larvae	*Eretmocerus mundus*	*Encarsia lutea*
2008	Cucumber	9.90 ± 4.11 a*	2.46 ± 0.54 b	1.66 ± 0.79 c	0.17 ± 0.10 b
	Eggplant	2.32 ± 1.03 b	8.26 ± 2.50 a	18.40 ± 3.80 a	2.79 ± 1.83 ab
	Cotton A	0.05 ± 0.03 b	0.36 ± 0.11 b	2.48 ± 1.22 c	0.52 ± 0.52 b
	Cotton B	0.03 ± 0.02 b	0.80 ± 0.24 b	7.72 ± 2.77 bc	3.98 ± 1.59 a
	Soybean A	2.09 ± 1.32 b	6.36 ± 2.17 a	13.10 ± 4.77 ab	5.53 ± 2.21 a
	Soybean B	0.13 ± 0.05 b	1.42 ± 1.00 b	9.92 ± 3.68 abc	5.98 ± 2.76 a
2009	Cucumber	6.48 ± 2.27 a	4.01 ± 1.80 a	1.78 ± 0.59 b	0.34 ± 0.19 d
	Eggplant A	0.73 ± 0.40 b	0.74 ± 0.26 b	14.40 ± 3.09 a	4.70 ± 1.68 abc
	Eggplant B	0.17 ± 0.06 b	2.13 ± 0.55 ab	7.13 ± 1.91 ab	2.56 ± 0.95 bcd
	Cotton A	0.13 ± 0.05 b	0.36 ± 0.08 b	8.28 ± 3.31 ab	2.34 ± 1.42 cd
	Cotton B	0.07 ± 0.02 b	0.75 ± 0.23 b	9.72 ± 3.01 ab	3.95 ± 1.40 bcd
	Soybean A	0.60 ± 0.44 b	1.30 ± 0.32 b	13.32 ± 3.19 a	8.38 ± 2.00 a
	Soybean B	0.07 ± 0.02 b	1.07 ± 0.36 b	15.20 ± 3.04 a	7.07 ± 1.93 ab

*According to the LSD test, means in the same column in the same year followed by the same letter do not differ significantly (P< 0.05).

Discussion

We found low weekly mean numbers of *B. tabaci* in early July that increased to higher densities in August and September on all host plants in the two growing seasons. These findings are similar to those of Özgür et al. (1989) and Karut et al. (2005). Özgür et al. (1989) used yellow sticky cards to monitor *B. tabaci* in Çukurova and reported that most of the *B. tabaci* population overwintered in the foothills on *Cistus* spp. which are the main winter hosts. Dispersal into cultivated crop areas began in April. They also reported low population densities until the end of July in cotton and other crops. Thereafter, large numbers of adults occurred in August and September in the Çukurova Plain area. Similar results were reported by Karut et al. (2005) who determined the flight activities of adult *B. tabaci* by monitoring with plastic cup traps (CC trap) (Chu et al. 2001).

In spite of several insecticide applications, the whitefly population on cucumber was higher than on the other host plants. This may be due to lower parasitoid populations on this host plant or due to inadequate penetration of insecticide sprays into the canopy of the low-growing cucumber crop. Another possibility is that cucumber may be a much better host for *B. tabaci* than the other host plants, resulting in a more rapid increase of whiteflies. Lower parasitoid numbers have been recorded on cucumbers in a number of previous studies and were attributed to the negative effects of leaf hairs on the cucumber plants which constrain walking speed and searching pattern of the parasitoids (Hulspas-Jordaan & van Lenteren 1978, van Lenteren et al. 1995, Gruenhagen & Perring 2001, Qiu et al. 2005). In addition, we considered that not only were the numbers of trichomes on cucumber leaves important, but that the type of trichome may also have affected the efficiency of parasitoids. In our early trichome studies, we found that the numbers of trichomes on cucumber and eggplant were not significantly different from each other (data not presented), but that the populations of the two parasitoids had been lower on cucumber than eggplant. Sumathi et al. (2008) reported that normally the trichomes on cucumber were long, thick and non-glandular and were abundant on the leaf lamina. However, under open field conditions, both glandular and non-glandular trichomes were present on cucumber leaves. This is a finding that was also reported by Gruenhagen & Perring (2001). In addition, these authors reported that parasitism by *Er. eremicus* Rose & Zolnerowich 1997 was lower on velvetleaf than on all other hosts (camphorweed, cantaloupe melon and cotton), and partially attributed the difference to exudate from glandular trichomes of velvetleaf that entrapped parasitoids.

The results from our study showed that parasitism levels by *Er. mundus* were almost the same on soybean, eggplant and cotton plants. However, parasitism levels by *En. lutea* were higher on soybean than on the other host plants. This may be attributed to relatively fewer insecticide applications on soybean or other biotic and abiotic factors which require more detailed investigation. Relatively fewer studies have been conducted on *En. lutea* than *Er. mundus*. Goolsby et al. (1998) could not find high enough populations of this species (originating in Cyprus, Israel and Spain) to conduct laboratory and field evaluation studies in the Lower Rio Grande Valley of Texas. Rapisarda & Tropea Garzia (2002) found only *Er. mundus* on vegetables grown in the greenhouse, while under field conditions they found a more varied parasitoid complex, dominated *Er. mundus* (over 80%), followed by *En. lutea* (12%) and *En. pergandiella* (6%). These authors also reported that *En. lutea* was more effective on *Lantana camara* L. than poinsettia or *Malva*.

Parasitism by *Er. mundus* was higher than by *En. lutea* during the two growing seasons on all the host plants, especially on soybean, eggplant and cotton. These differences may be attributable to insecticide applications; *Encarsia lutea* may have been more affected by insecticide applications than *Er. mundus*. In an earlier study, Karut & Kazak (2007) showed that parasitism by *En. lutea* was higher than by *Er. mundus*, especially on cotton plants where no insecticides had been applied. While *Er. mundus* is primarily a solitary ecto-parasitoid of whitefly nymphs, *En. lutea* is an autoparasitoid, either obligate or facultative, with males occurring in low numbers (Sharaf 1982; Rose et al. 1995). In theoretical studies, Briggs & Collier (2001) stated that when male autoparasitoids are followed closely in models, mate limitation reduces the stabilizing effect of autoparasitism and leads to a further increase in host abundance. This suggests that the low numbers of *En*. *lutea* males that were observed may have been the result of insecticide applications that affected mate availability and ultimately reduced *En*. *lutea* populations on all the host-plants.

It is concluded that even after several insecticide applications, *Er*. *mundus* and *En*. *lutea* are important parasitoids of *B*. *tabaci* in the Çukurova Region. While the efficiency of *Er*. *mundus* is more promising on cotton, eggplant and soybean, *En. lutea* was also effective on soybean. A more rational use of pesticides that focuses on greater selectivity in conjunction with optimum cultural practices could lead to improved biocontrol and cleaner crop production. By improving the integration of biological and chemical controls, more effective integrated pest management strategies focused on conservation of natural enemies, particularly parasitoids, may provide for more sustainable management of *B*. *tabaci* and other pests affecting cotton, eggplant and soybean in the Çukurova Region of Turkey.

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