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Orijinal araştırma (Original article)

Seasonal occurrence of aphids and their natural enemies in Satsuma mandarin orchards in Izmir, Turkey[1]

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Summary

Field surveys were carried to determine the seasonal occurrence of aphids and their natural enemies in four Satsuma mandarin orchards in İzmir, Turkey between January 2006 and November 2007. Aphid species determined included *Aphis craccivora* Koch, 1854; *Aphis gossypii* Glover, 1877; *Aphis spiraecola* Patch, 1914; *Myzus (Nectarosiphon) persicae* (Sulzer, 1776) and *Toxoptera aurantii* (Boyer de Fonscolombe, 1841). Predators from the following families were determined: Coccinellidae (Coleoptera), Chrysopidae (Neuroptera), Syrphidae, Cecidomyiidae, and Chamaemyiidae (Diptera). Braconidae (Hymenoptera) parasitoids were reared from field-collected mummies. Aphid numbers fluctuated from early April to the beginning of July and were highest from late April to early June. Several species natural enemies of aphid were found and, when combined with high summer temperatures, negated the need for insecticidal application. Therefore, conservation of natural enemies is an essential component of the management of aphids in Satsuma mandarins in Izmir.

Key words: Aphididae, biological control, citrus, predator, parasitoid, Satsuma mandarin

Anahtar sözcükler: Aphididae, biyolojik savaş, turunçgil, predatör, parazitoit, Satsuma mandarini

Introduction

Satsuma mandarin is one of the most important types of citrus produced in cool subtropical regions; the crop is grown in Japan, Spain, central China, Korea, Turkey, along the Black Sea in Russia, southern South Africa, and South

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America, and also on a small scale in central California and northern Florida (Ferguson, 1996). In Turkey, the most Satsuma mandarin production, for both domestic consumption and export to Europe, takes place in İzmir Province, with 90 000 tonnes of fruit produced per year (Anonymous, 2009).

Like other plants, citrus is the host for many pests. Although more than 850 species of insects and mites have been associated with citrus (Ebeling, 1959), fewer than 10% are considered to be of major importance, and the importance of individual species varies with climatic regions (Smith & Pena, 2002). Of the 30 or so citrus pests in Turkey, about 60% are aphids and other sucking insects belonging to the order Hemiptera (Uygun et al., 2001). Whiteflies, scale insects, and the citrus leafminer, *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera: Gracillariidae) are suppressed by native and introduced biological control agents (Öncüer, 1977; Önder, 1982; Yoldaş et al., 2006; Güncan et al., 2009). However, the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae) is not suppressed (Güncan et al., 2008). Although aphids are serious pests, there are few studies concerning the impact of natural enemies on aphids in Satsuma mandarin orchards in Turkey (Yumruktepe & Uygun, 1994).

Aphids are economically important pests in citrus both in Turkey (Uygun et al., 2001) and in the other countries of the world (Ebeling, 1959). Adults and nymphs attack new growth, suck phloem sap, and cause leaves to wilt and drop when population densities are high. Honeydew excreted by aphids collects dust and supports the growth of sooty mould. Large infestations blacken entire trees, reduce the market value of the fruit, and attract ants that interfere with the biological control of aphids and the other pests of citrus (Kaneko, 2007). In addition, common aphid species found on citrus, like *Aphis spiraecola* Patch, 1914*; Toxoptera aurantii* (Boyer de Fonscolombe, 1841) and especially *Aphis gossypii* Glover, 1877 are important vectors of Citrus tristeza virus in Satsuma mandarins (Marroquin et al., 2004).

The objectives of this study are 1) to determine the seasonal occurrence of aphids and their natural enemies in Satsuma mandarins in Izmir, Turkey and 2) to determine the potential impact of natural enemies associated with the aphids.

Materials and Methods

Study sites

The four mandarin orchards used in this study were located in the two main Satsuma mandarin growing areas of Izmir Province, the districts of Gümüldür and Seferihisar (Figure 1, Table 1).

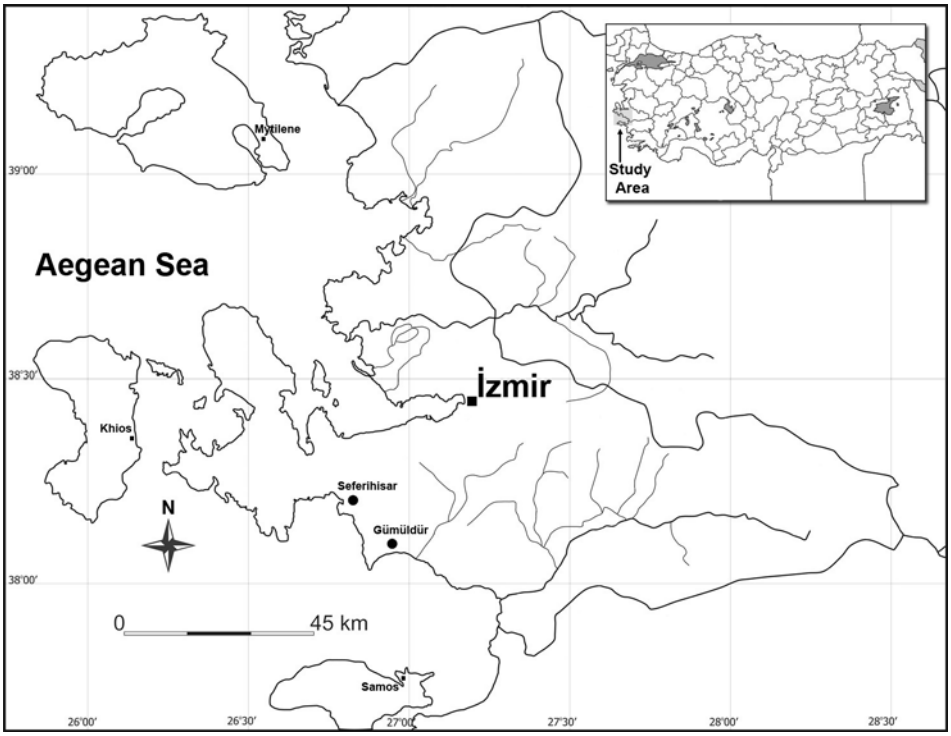

Figure 1. The locations of the four Satsuma citrus orchards in Izmir in Aegean Region of Turkey.

All orchards contained the “Owari” cultivar of Satsuma mandarin and were managed with conventional agricultural practices. The orchards were treated in autumn with malathion-based sprays to control *C. capitata*; these sprays are commonly applied and are relatively non-disruptive to natural enemies (Smith et al., 1997). In the second year of the study, orchard SEF1 was sprayed with summer oil at the end of spring to control the California red scale, *Aonidiella aurantii* (Maskell, 1879) (Hemiptera: Diaspididae). All orchards of Gümüldür were sprayed with water two times each growing season to remove honeydew excreted by aphids and thus to prevent the growth of sooty mould.

Table 1. Characteristics of the four Satsuma mandarin orchards sampled in Izmir Province

Orchard code	Location	Approximate tree age (years)	Approximate area (ha)	Number of trees	Coordinates (latitude, longitude)	Elevation (meter)
GUM1	Gümüldür	40	1.0	1000	$38^0$04’N, $27^0$01’E	16
GUM2	Gümüldür	45	1.5	600	$38^0$04’N, $27^0$00’E	14
SEF1	Seferihisar	28	0.5	400	$38^0$11’N, $26^0$48’E	9
SEF2	Seferihisar	20	1.5	1000	$38^0$15’N, $26^0$49’E	36

Sampling for aphids and their natural enemies

Sampling was scheduled according to the effect of temperature on the growth of aphid populations on citrus (Komazaki, 1982). Field counts were conducted weekly when the mean daily temperatures were between 10ºC and 30ºC and monthly when the mean daily temperatures were below 10ºC or above 30ºC from January 2006 to November 2007. Temperatures in the orchards were monitored using HOBO® data loggers (Onset Computer Corp. Bourne, Massachusetts, USA).

On each sampling date and in each orchard, all the aphids (nymphs and adults) and aphid mummies were counted on one leaf from each of one shoot on 100 randomly selected trees. Thus, totally 100 leaves were examined for each sampling date in each orchard. Because all of the aphid species in Satsuma mandarin orchards feed on newly flushed leaves, only younger leaves on younger shoots were sampled to record the aphids (nymphs and adults) and aphid mummies. Field identification of these aphids can be difficult, in part because they often occur in mixed colonies of two or more species. Total aphid numbers were recorded, regardless of species. Parasitism percentage was calculated as the ratio of the number parasitized to the total number of hosts (Van Driesche, 1983).

Samples of aphids and their mummies were placed in bags and brought to the laboratory in coolers and prepared for species identification. Adult parasitoids were reared from mummies under laboratory conditions for identification.

Individuals of the predatory families Coccinellidae and Chrysopidae were counted visually in the field as eggs, larvae, pupae and adult stages on 100 leaves, whereas individuals of dipteran predators were counted only as larvae on 100 leaves. Identification of predators was made on site in order not to influence the numbers of predators found on each sampling date. Therefore some syrphid predators (Diptera: Syrphidae) and other arthropod predators could not be identified.

Aphid species were identified by Dr. Işıl Özdemir (Ankara Plant Protection Research Institute, Ankara, Turkey) and Dr. Serdar Satar (Çukurova University, Adana, Turkey), parasitoids by RNDr. Petr Starý DrSc. (Institute of Entomology, Ceske Budejovice, Czech Republic), Chamaemyiidae family species by Dr. John Deeming (National Museum Cardiff, Cardiff UK) and Coccinellidae, Chrysopidae and Cecidomyiidae family species by authors.

Statistical analysis

Statistical analysis was done by using aphid densities obtained during study (26 sampling weeks). Missing data were placed by series mean method,

an average value across each data series (von Ende, 2001). Aphid densities were converted to aphids/leaf and log (x+1) transformation to satisfy the assumption of normality before analysis (Sokal & Rolf 1995). Data were analyzed using a repeated measures analysis of variance followed by multiple Bonferroni's comparison test to compare the numbers of aphids between orchards. All the statistical procedures were performed using SPSS version 15 (SPSS, 2006).

Results

Aphids and their natural enemies

Five species of aphids were found in the Satsuma mandarin orchards in this study (Table 2). The most common species observed were *Aphis gossypii* and *Aphis spiraecola*. *Toxoptera aurantii* was found in all orchards, but *Aphis. craccivora* and *Myzus (Nectarosiphon) persicae* were found only in GUM1 and GUM2.

Table 2. Occurrence of aphid species in the four Satsuma mandarin orchards

Aphid species	Orchards in which the indicated aphid species was detected
Aphis gossypii Glover, 1877	GUM1,GUM2,SEF1,SEF2
Aphis spiraecola Patch, 1914	GUM1,GUM2,SEF1,SEF2
Aphis craccivora Koch, 1854	GUM1,GUM2
Toxoptera aurantii (Boyer de Fonscolombe, 1841)	GUM1,GUM2,SEF1,SEF2
Myzus (Nectarosiphon) persicae (Sulzer, 1776)	GUM1,GUM2

The distribution and abundance of predators varied among the orchards. However, *Chrysoperla carnea* (Stephens, 1836) (Neuroptera: Chrysopidae) and *Coccinella septempunctata* Linnaeus, 1758 (Coleoptera: Coccinellidae) were the most abundant species of predators (Figure 2 and 3). *Coccinula quatuordecimpustulata* (Linnaeus, 1758) (Coleoptera: Coccinellidae) was found only in GUM1. *Hippodamia variegata* (Goeze, 1777) (Coleoptera: Coccinellidae) and *Aphidoletes aphidimyza* (Rondani, 1847) (Diptera: Cecidomyiidae) were abundant in SEF1 and SEF2, respectively. *Propylea quatuordecimpunctata* (Linnaeus, 1758) (Coleoptera: Coccinellidae) was found in all orchards except GUM2 while *Leucopis annulipes* Zetterstedt, 1848 (Diptera: Chamaemyiidae) was found only in GUM1 and GUM2. Other predator species were occasionally found in the four orchards (Figure 2, 3, Table 3).

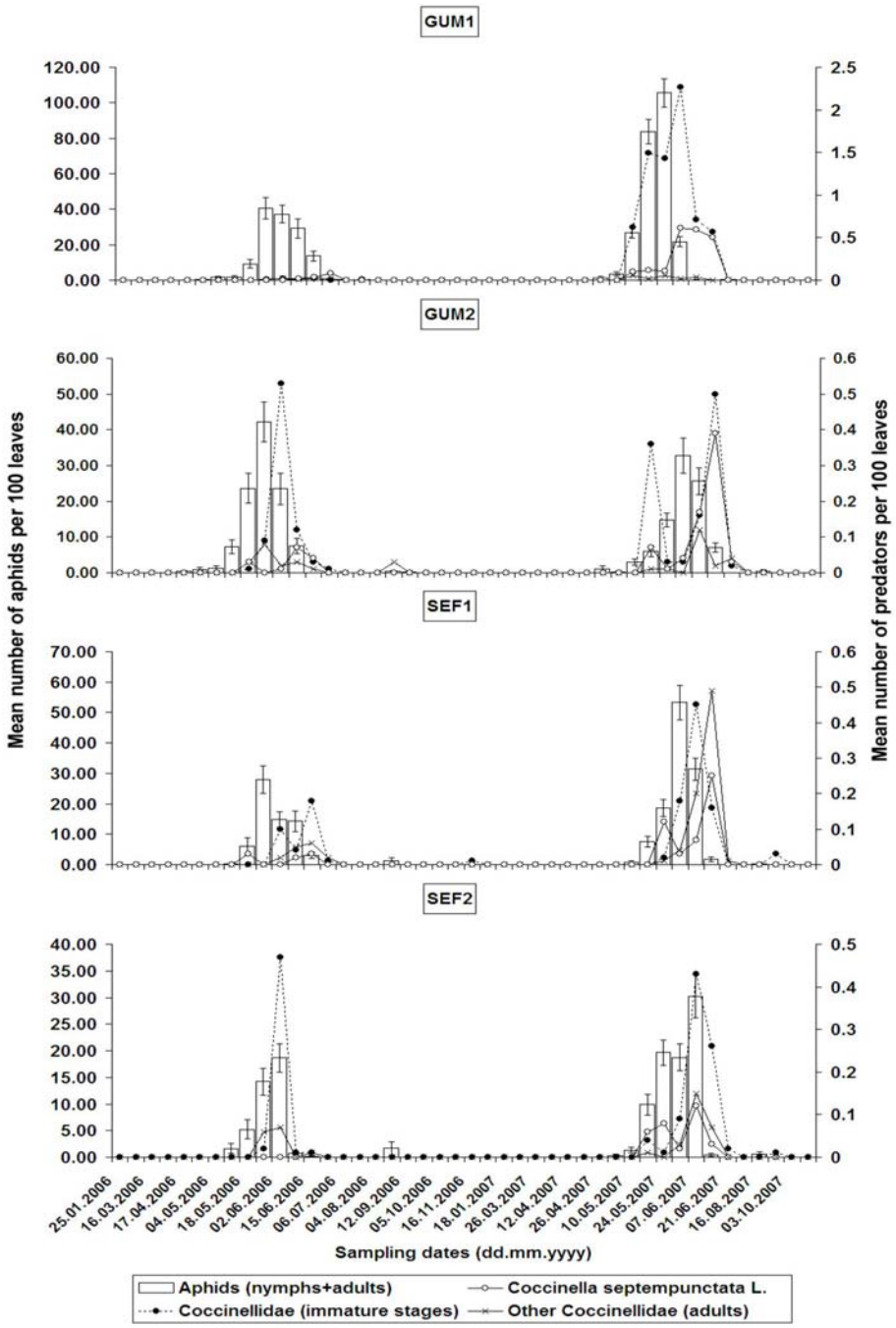

Figure 2. Seasonal abundances of aphids and predatory coccinellids in four Satsuma citrus orchards (GUM1, GUM2, SEF1, and SEF2) from January 2006 to November 2007. Values indicate mean (±SEM) number of aphids (nymphs + adults) per 100 leaves vs. mean number of coccinellid predators per 100 leaves.

Five species of parasitoids belonging to the family Braconidae (Hymenoptera) were found in the orchards (Table 3). *Aphidius colemani* Viereck, 1912, *Binodoxys angelicae* (Haliday, 1833), *Ephedrus persicae* Froggatt, 1904 and *Lysiphlebus testaceipes* (Cresson, 1880) were found in all four orchards whereas *Praon volucre* (Haliday, 1833) was found only in GUM1 (Table 3).

Table 3. Natural enemies of aphids obtained in the four Satsuma mandarin orchards (GUM1, GUM2, SEF1, and SEF2)

Natural enemy	Orchards in which the indicated natural enemy was detected
Parasitoids	
Hymenoptera (Braconidae)	
Aphidius colemani Viereck, 1912	GUM1,GUM2,SEF1,SEF2
Binodoxys angelicae (Haliday, 1833)	GUM1,GUM2,SEF1,SEF2
Ephedrus persicae Froggatt, 1904	GUM1,GUM2,SEF1,SEF2
Lysiphlebus testaceipes (Cresson, 1880)	GUM1,GUM2,SEF1,SEF2
Praon volucre (Haliday, 1833)	GUM1
Predators	
Coleoptera (Coccinellidae)	
Adalia bipunctata (Linnaeus, 1758)	GUM2,SEF1,SEF2
Coccinella septempunctata Linnaeus, 1758	GUM1,GUM2,SEF1,SEF2
Coccinula quatuordecimpustulata (Linnaeus, 1758)	GUM1
Hippodamia variegata (Goeze, 1777)	GUM1,GUM2,SEF1,SEF2
Oenopia conglobata (Linnaeus, 1758)	GUM1,GUM2,SEF1,SEF2
Propylea quatuordecimpunctata (Linnaeus, 1758)	GUM1,SEF1,SEF2
Scymnus sp.	GUM1,GUM2,SEF1,SEF2
Neuroptera (Chrysopidae)	
Chrysoperla carnea (Stephen, 1836)	GUM1,GUM2,SEF1,SEF2
Diptera (Cecidomyiidae)	
Aphidoletes aphidimyza (Rondani, 1847)	GUM1,GUM2,SEF2
Diptera (Chamaemyiidae)	
Leucopis annulipes Zetterstedt, 1848	GUM1,GUM2
Diptera (Syrphidae)	GUM1,GUM2,SEF1,SEF2

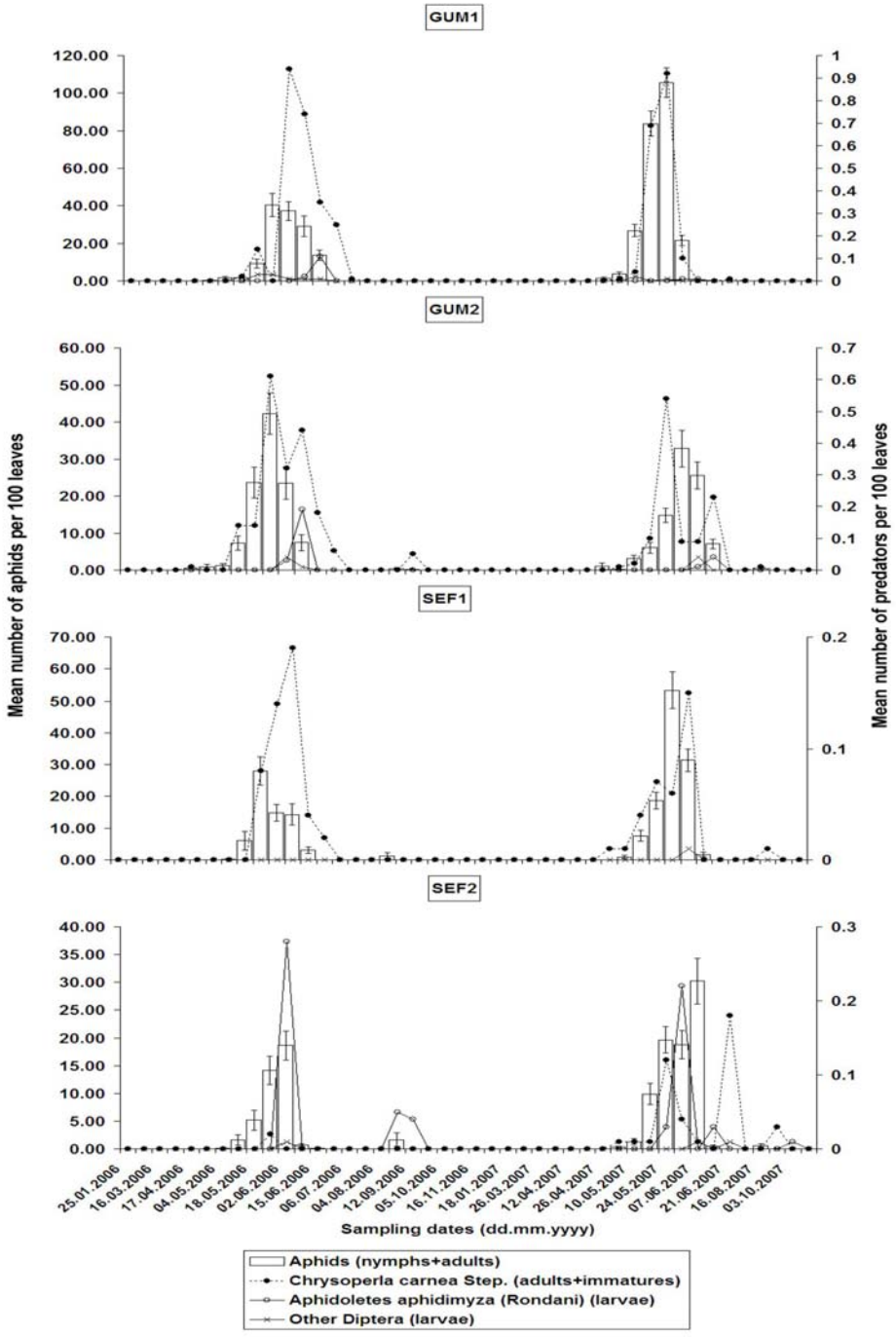

Figure 3. Seasonal abundances of aphids and noncoccinellid predators in four Satsuma citrus orchards (GUM1, GUM2, SEF1, and SEF2) from January 2006 to November 2007. Values indicate mean (±SEM) number of aphids (nymphs + adults) per 100 leaves vs. mean number of noncoccinellid predators per 100 leaves.

Seasonal changes in numbers of aphids, numbers of their predators, and parasitism percentage

Population densities of aphids, percent parasitism, and densities of coccinellids and other predators in four Satsuma orchards are presented in Figures 2-4. The mean relative humidity (%), mean air temperature (ºC), and total rainfall (mm) during sampling period are presented in Figure 5.

There were significant effects of year ($F=19.92$, df=25, 19800, $P<0.001$), orchard ($F=7.12$, df=75, 19800, $P<0.001$), and year × orchard ($F=23.17$, df=75, 19800, $P<0.001$) on densities of aphids within the sampling weeks (Table 4). The highest aphid numbers were 40.48±6.15 on 25 April 2006 and 105.60±8.02 on 24 May 2007 in GUM1. In GUM2, aphid numbers increased to 42.18±5.56 on 25 May 2006 and to 32.83±4.93 on 31 May 2007. In SEF1, the highest numbers of aphids were 28.03±4.53 on 25 May 2006 and 53.28±5.67 on 31 May 2007. In SEF2, the highest numbers of the aphids were 18.65±2.61 on 02 June 2006 and 30.24±4.12 on 07 June 2007. Aphid densities were higher in the Gümüldür orchards than those in the Seferihisar orchards throughout the study. There were significant differences in density of aphids among the orchards ($F=3.62$, df=3, 792, $P=0.013$) and between years ($F=6.28$, df=1, 792, $P=0.012$).

Table 4. Results of repeated measures analysis of variance for the effects of sampling week, year, orchard, and their interactions on the mean number of aphids

Source	Degrees of freedom	Mean square	*F*	*P*
Within-subjects effects				
WEEK	25	355.42	758.05	0.001
WEEK×YEAR	25	9.34	19.92	0.001
WEEK×ORCHARDS	75	3.34	7.12	0.001
WEEK×YEAR*ORCHARDS	75	10.86	23.17	0.001
Error (WEEK)	19800			
Between-subject effects				
Intercept	1	372.76	1581.76	0.001
YEAR	1	1.48	6.28	0.012
ORCHARDS	3	0.85	3.62	0.013
YEAR×ORCHARDS	3	5.21	22.12	0.001
Error	792	0.24		

Densities of aphids decreased to zero because of the activity of parasitoids and predators on 22 June 2006 and 14 June 2007 in both GUM1 and GUM2, and on 22 June 2006 and 21 June 2007 in both SEF1 and SEF2. Aphid mummies were present in the trees on these sampling dates, which resulted in parasitism rates of 100% on subsequent sampling dates (Figure 4).

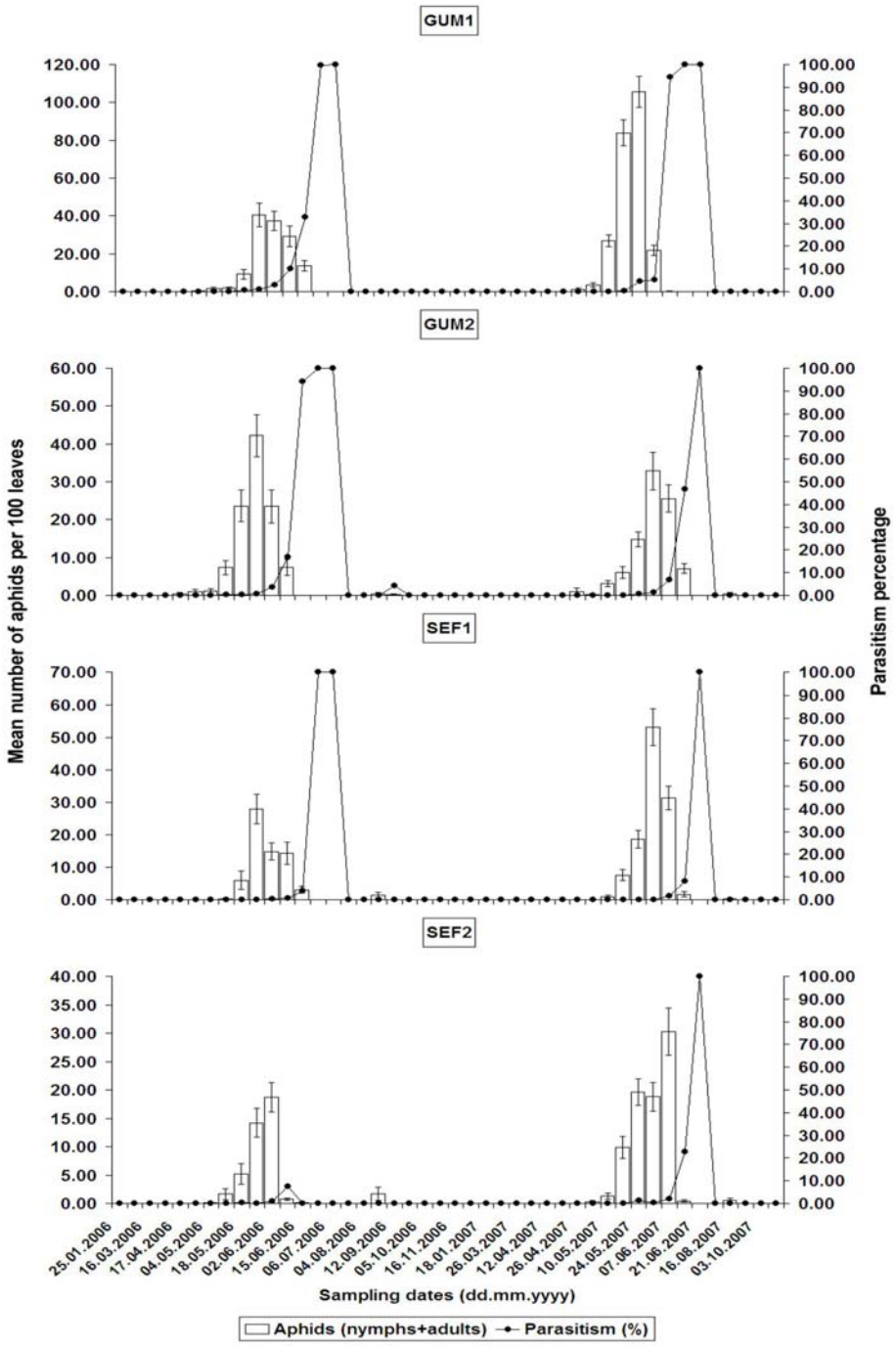

Figure 4. Seasonal aphid abundance and parasitism percentage in four Satsuma citrus orchards (GUM1, GUM2, SEF1, and SEF2) from January 2006 to November 2007. Values indicate mean (±SEM) number of aphids (nymphs + adults) per 100 leaves vs. parasitism percentage.

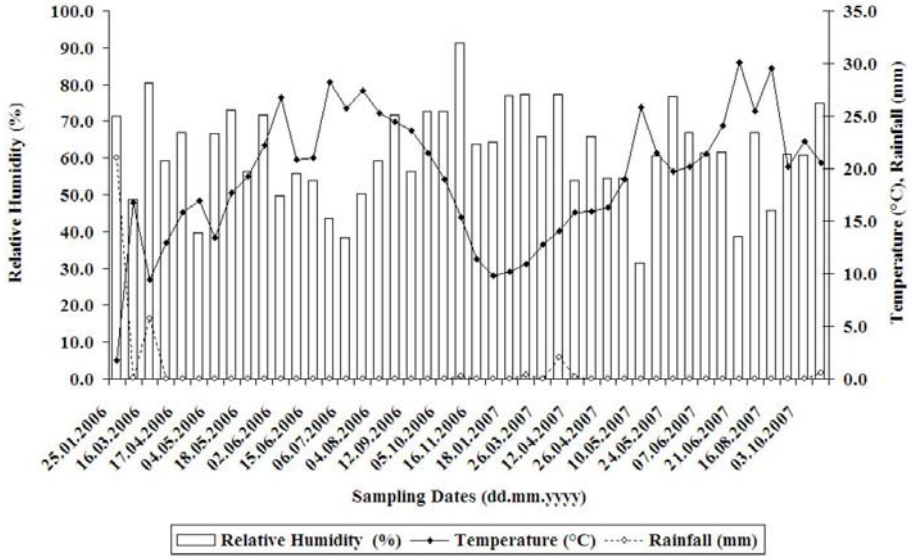

Figure 5. Mean relative humidity (%), mean air temperature (°C), and total rainfall (mm) during the sampling period in Izmir.

The most abundant predators in all four orchards were coccinellids (Figure 2). Coccinellids were seen in the orchards before aphids appeared. The species encountered most frequently was *C. septempunctata*. The highest number of immature coccinellids and *C. septempunctata* adults were found in GUM1 on 31 May 2007. *H. variegata* was the dominant species of coccinellids found in SEF1. The numbers of other adult and immature coccinellids varied among the four orchards.

Numbers of adults and immature stages of *C. carnea* ranged from 0.18 to 0.94 per leaf in the four orchards (Figure 3). *A. aphidimyza* was the most prevalent dipteran predator, and its numbers ranged from 0.11 to 0.28 per leaf and were highest in SEF2. Other species of syrphids and *L. annulipes* were found only in GUM1 and GUM2 only occasionally.

Discussion

Five aphid species were found in the four Satsuma mandarin orchards in this study and *Aphis gossypii* and *Aphis spiraecola* were the most common species in all four orchards. All aphid species, but *A. gossypii* in particular, are important vectors of Citrus tristeza virus (Marroquin et al., 2004), a disease previously detected in Satsuma orchards in Izmir (Korkmaz et al., 2008). In addition to typical damage of aphids, *A. spiraecola* often causes curling and distortion of leaves (Miles, 1989). The aphids, *Toxoptera aurantii*, *Aphis craccivora* and *Myzus (Nectarosiphon) persicae* were found occasionally in the four orchards.

Similar species of aphids were reported in the eastern Mediterranean region of Turkey (Yumruktepe & Uygun, 1994). Worldwide, 16 species of aphids are reported to feed regularly on citrus, and four more species may be occasional pests (Halbert & Brown, 1996). Of these 20 species, nine are found in southeastern Europe citrus groves, including *A. gossypii*, *A. spiraecola*, *T. aurantii*, *A. craccivora*, *M. persicae, Aulacorthum solani* (Kaltenbach, 1843), *Brachycaudus helichrysi* (Kaltenbach, 1843), *Macrosiphum euphorbiae* (Thomas, 1878), and *Rhopalosiphum maidis* (Fitch, 1856) (Kavallieratos et al., 2005). The brown citrus aphid, *Toxoptera citricida* (Kirkaldy, 1907), which is a major concern to citrus growers throughout the world because of its high efficiency in transmitting Citrus tristeza virus (Michaud, 1998), was not found in this study and has never been reported from Turkey.

In both 2006 and 2007 and in all four orchards, aphid populations were first time recorded at the beginning of April and then increased to maximum densities at the end of May or beginning of June. The activities of predators and parasitoids increased rapidly during the increase in aphid density and reached a maximum at the end of June. All aphid population densities decreased to zero by the beginning of July. In the Mediterranean climate, aphid densities peak in late spring, and reach a smaller, second peak in late summer or early autumn (Barbagallo & Patti, 1986). Our results are consistent with this seasonal pattern. The autumn population density in Izmir is low and does not reach pest status. This low aphid density may help to maintain populations of natural enemies in the orchards. Also, many parasitoids and predators consume aphid honeydew; the presence of aphids may enhance biological control exerted on other herbivores (Evans, 2008).

The composition of the arthropod predator complex varied among the orchards and *Coccinella septempunctata* and *Chrysoperla carnea* were the dominant species in all orchards. Predatory families listed in order of abundance were Coccinellidae, Chrysopidae, Cecidomyiidae, Syriphidae, and Chamaemyiidae. The predator species differ in their capacity to consume aphids and impact aphid populations. For example, larvae of *C. septempuncata* have a much greater capacity for predation than those of *C. carnea* and *Aphidoletes aphidimyza* (Yoldaş, 1994; Yoldaş & Sanjrani, 1999; Turanlı & Yoldaş, 2002). But predatory species, especially coccinellids, have an immediate impact on aphid population densities; they reduce the initial aphid density and also reduce the rate of aphid increase.

The parasitoid complex associated with aphids in this study did not differ greatly among the orchards. *Lysiphlebus testaceipes* is an introduced parasitoid and *Aphidius colemani*, *Binodoxys angelicae*, *Ephedrus persicae*, and *Praon volucre* are native parasitoids (Starý, 1976). *A. colemani* was found generally

throughout the region and *P. volucre* was found only at one site on a few occasions. In Greece, the parasitoids *Aphidius matricariae* Haliday, 1834; *Aphidius urticae* Haliday, 1834; *Binodoxys acalephae* (Marshall, 1896); *Diaeretiella rapae* (M'Intosh, 1855), *Lysiphlebus confusus* Tremblay & Eady, 1978 and *Lysiphlebus fabarum* (Marshall, 1896) were also reported (Kavallieratos et al., 2005). Although parasitoids seem to be minor mortality factors for aphids, they supplement the control exerted by arthropod predators.

None of the predator and parasitoid species found in this study has the capacity to suppress aphid densities individually. Initial activity by predators and later activity by parasitoids seem to be generate sufficient mortality to suppress aphid populations so that other crop-protection tactics are unnecessary in Satsuma mandarin in Izmir. Therefore, conservation of natural enemies seems to be effective for aphid control in Satsuma mandarins in Izmir and such conservation should be encouraged.

Özet

İzmir ili Satsuma mandarini bahçelerindeki yaprakbiti türleri ve doğal düşmanlarının mevsimsel değişimi

İzmir ilinde dört Satsuma mandarini bahçesinde Ocak 2006 ve Kasım 2007 arasında yürütülen bu çalışmada, yaprakbiti türleri ve bunların doğal düşmanları ve populasyon yoğunlukları belirlenmiştir. Yaprakbiti türleri olarak *Aphis craccivora* Koch, 1854; *Aphis gossypii* Glover, 1877; *Aphis spiraecola* Patch, 1914; *Myzus (Nectarosiphon) persicae* (Sulzer, 1776) ve *Toxoptera aurantii* (Boyer de Fonscolombe, 1841) saptanmıştır. Avcı olarak Coccinellidae (Coleoptera), Chrysopidae (Neuroptera), Syrphidae, Cecidomyiidae ve Chamaemyiidae (Diptera) familyasına bağlı türler, parazitoit olarak ise Braconidae (Hymenoptera) familyasına bağlı türler belirlenmiştir. Bahçelerde yaprakbitleri nisan ayı başından temmuz ayının başına kadar olan dönemde görülmekte ve populasyon düzeyleri en yüksek değerlere nisan ayının sonundan haziran ayının başlarına kadar olan dönemde ulaşmaktadır. Bu çalışmada, yaprakbitleri ve doğal düşmanlarının populasyon yoğunluklarının artan sıcaklık ile birlikte herhangi bir kimyasal savaşa gerek duymadan sıfıra indiği belirlenmiştir. Bu nedenle Izmir ilinde bulunan Satsuma mandarini bahçelerinde zararlı olan yaprakbitlerine karşı yürütülecek savaşta doğal düşmanların korunmasının yeterli olduğu gözlenmiştir.

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