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INTERRELATIONS OF *QUADRASPIDIOTUS ZONATUS* (FRAUENFELD) AND ITS ENCYRTID PARASITE OF THE GENUS *METAPHYCUS* MERCET

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ABSTRACT

Preliminary observations on the life cycle of *Quadraspidiotus zonatus* (Frauenfeld) and its encyrtid parasite of the genus *Metaphycus* Mercet were made in Poland. They revealed that *Quadraspidiotus zonatus* (Frauenfeld) was univoltine, while *Metaphycus* sp. was bivoltine in the given climatic conditions.

KEY WORDS'. *Quadraspidiotus zonatus* (Frauenfeld), *Metaphycus* sp., life cycle, Poland.

Quadraspidiotus zonatus (Frauenfeld) (Homoptera: Diaspididae) is a Palearctic species, widely distributed in Europe, the Middle East and North Africa. It occurs mainly on oaks, but has also been recorded on other trees such as *Fagus sylvatica, Betula* sp., *Sorbus aucuparia* and *Juglans regia* (Zahradnfk, 1990). In Poland it is biparental, univoltine and common on oaks on which it develops on trunk, twigs and branches. It overwinters as fertilized female.

Preliminary observations on the biology of *Q. zonatus* and its parasites were carried out in Warsaw in 1991.

Females of the scale began to oviposit in the second half of June. First-instar nymphs hatched after several days. Male crawlers moved to leaves and settled on their underside, whereas female crawlers remained on the bark. Second-instar nymphs appeared in the middle of July. Prepupal and pupal stages occurred predominantly in August. Adult females and males appeared in the second half of August and in the first half of September.

The observations revealed that the scale was heavily parasitized; consequently, about 80% of the females died without oviposition.

Three species of chalcidoid parasites of *Q. zonatus*, belonging to the family of Aphelinidae, namely: *Pteroptrix dimidiata* Westwood, *Aphytis mytilaspidis* Le Baron and *Azotus atomon* Walker, were recorded in the literature (Schmutterer, 1959). All these species are known as parasites of Diaspididae (Jasnosh, 1978). *P. dimidiata* is an endoparasite, *A. mytilaspidis* is an ectoparasite and *A. atomon* is a hyperparasite.

In Poland *P. dimidiata* and A. *mytilaspidis* are the most frequent primary parasites of *Q. zonatus.* In addition, the scale was found to be parasitized by a species of *Metaphycus.*

The *Metaphycus* sp. has two generations per year: the overwintering and the summer generation. It overwinters as a larva within the host female adults. In Warsaw adult parasites emerged in July. The summer generation of the parasite develops in second-instar males and females of the host. The females lay eggs into the host female adults, thus initiating the overwintering generation.

Some species of *Metaphycus* are parasites of Diaspididae. In order to determine the *Metaphycus* sp. parasitizing *Q. zonatus* it is necessary to test whether it is able to develop on other species of Diaspididae. Since *M. botanicus* (Mercet) had been reported to develop on *Carulaspis juniperi* (Bouché) (Nikolskaja, 1952), I tested whether the above mentioned *Metaphycus* sp. may develop on the latter, and proved that the parasite female did not oviposit in this scale.

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POPULATION DYNAMICS OF *AONIDIELLA AURANTII* (MASKELL) (HOMOPTERA: DIASPIDIDAE) AND ITS NATURAL ENEMIES ON CITRUS IN THE MEDITERRANEAN REGION OF TURKEY FROM 1976 TO 1993

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ABSTRACT

The California red scale (CRS), *Aonidiella aurantii* (Maskell), is a most harmful pest of citrus orchards in the East Mediterranean region of Turkey. The long-term population changes of CRS and its natural enemies were studied in an orchard where Integrated Pest Management (IPM) programs have been applied since its foundation in 1976. The study site was a 70-ha citrus orchard consisting of lemon (18 ha), grapefruit (20 ha), mandarin (20 ha) and orange (12 ha) groves at the Research Farm of the Agricultural Faculty, University of Çukurova, Adana, Turkey. Pest management studies were initiated in 1976 and IPM programs developed according to the pest succession, with minimized use of insecticides. The population densities during the first two years were reduced by sprays with oil and oil–methidathion mixtures. Later they were kept at low levels by oil only sprays. The natural enemies of CRS, especially *Aphytis melinus* DeBach, started to exert pressure on CRS by 1985 and have stabilized CRS populations since then.

KEY WORDS: California red scale, integrated pest management, population dynamics, natural enemies, Turkey.

INTRODUCTION

The California red scale (CRS), *Aonidiella aurantii* (Maskell), is a world-wide pest of citrus, and is multivoltine with overlapping generations (Bodenheimer, 1951; Ebeling, 1959). CRS is a most harmful insect pest in citrus orchards in the East Mediterranean region of Turkey. When not controlled, the scale may cause heavy damage. Although well-timed sprays of petroleum oil alone (1–1.5%) keep CRS populations at a low level (Uygun and Şekeroğlu, 1981, 1984; Uygun et al., 1987, 1988, 1992), multiple application of broad spectrum insecticides has been a common control strategy by the growers in Turkey. This use of insecticides upsetting the natural balance resulted in the appearance of a complex pest situation in most of the citrus orchards.

The aim of this paper is to present the long-term population changes of CRS and its natural enemies in an orchard where Integrated Pest Management (IPM) programs have been applied since the foundation of the orchard in 1976, at the Research Farm of the Agricultural Faculty, University of Çukurova, Adana, Turkey.

MATERIALS AND METHODS

The study site was a 70-ha citrus orchard, planted in 1976, consisting of lemon (18 ha), grapefruit (20 ha), mandarin (20 ha) and orange (12 ha) groves at the Research Farm of the Agricultural Faculty, University of Çukurova, Adana, Turkey. Pest management studies were initiated in 1976 and IPM programs developed according to the pest succession, with minimized use of insecticides.

Each grove was sampled biweekly between May and October and monthly during the remaining months of the year. For CRS and other sessile insect pests and mites, 100 leaves, 25 twigs (25 cm in length and 1 cm in diameter), and 25 fruits (when present) were sampled randomly from each grove at each sampling date. Samples were brought to the laboratory and all the individuals on the whole surface of the tissue substrate were counted under a stereomicroscope.

Aphid infestation was determined by counting the infested shoots on 100 randomly chosen trees in each grove. Populations of the Mediterranean fruit fly, *Ceratitis capitata* Wiedemann, were determined by use of Clensel bottles.

Mobile pests and predators of all citrus pests were sampled by the Steiner (1962) method. A collecting bag was held under a branch, and the branch was struck strongly three times. Hundred branches (one branch/tree) were sampled in each grove.

In order to study the parasitization rate of CRS by *Aphytis melinus* DeBach, another experiment was set up between May 1986 and April 1988. In each grove of lemon, grapefruit, mandarin and orange, a randomized block design with 5 replications (a single tree being a plot) was established. Samples were taken biweekly, and 16 leaf, 4 shoot, and 4 fruit samples were taken from each tree on every sampling date. After counting all the individuals under the stereomicroscope, the entire surface area of each substrate was measured to determine the number of individuals per area. Parasitized scales were determined by counting the scales with parasite emergence holes and by lifting the cover of all other scales and checking for eggs, larvae or pupae of the parasitoid. Percent parasitization was calculated by the following formula:

Parasitization (%) = [Parasitized scales/(Parasitized scales + unparasitized scales)] × 100.

RESULTS AND DISCUSSION

Besides CRS, several other pests (Table 1) were observed sporadically in some years at certain localities of the study site. However, only aphids required chemical control measures in 1977, the first year after planting the orchard. Soil application of aldicarb 10 G (40 g AI per tree) successfully reduced aphid populations levels. Tree vigor, and activity of natural enemies (Table 2) prevented the aphid populations from reaching high densities in the following years. *Ceratitis capitata,* first observed in 1982, was kept under control by use of partial bait sprays. Selective acaricides were applied only to restricted areas where mite populations had started to build up. The above mentioned control measures had negligible effects on the natural enemy complex and enabled the establishment of a natural balance.

CRS was a major pest during the early years of this study (Figs. 1, 2 and 3) and we assume that it was introduced on infested seedlings in 1976. The data of CRS counts are given here only for leaf samples. Because no data for branches were available before 1984, and fruit counts started in 1980 (and only for a certain period of the year), we found that leaf counts

TABLE 1
Pest species observed in the IPM citrus orchard in Adana between 1977 and 1993
(L: lemon, O: orange, G: grapefruit, M: mandarin; +: observed, –: not observed)

Species	Order	Family	L	O	G	M
Phyllocoptruta oleivera (Ashmead)	Acarina	Phyllocoptidae	+	+	+	+
Aceria sheldoni (Ewing)	Acarina	Phyllocoptidae	+	–	–	–
Aonidiella aurantii (Maskell)	Homoptera	Diaspididae	+	+	+	+
Chrysomphalus dictyospermi (Morgan)	Homoptera	Diaspididae	+	+	+	+
Ceroplastes floridensis Comstock	Homoptera	Coccidae	+	+	+	+
Coccus pseudomagnoliarum (Kuwana)	Homoptera	Coccidae	+	+	+	+
Icerya purchasi Maskell	Homoptera	Margarodidae	+	+	+	+
Planococcus citri (Risso)	Homoptera	Pseudococcidae	+	+	+	+
Parabemisia myricae (Kuwana)	Homoptera	Aleyrodidae	+	+	+	+
Dialeurodes citri (Ashmead)	Homoptera	Aleyrodidae	+	+	+	+
Aphis citricola v.d. Goot.	Homoptera	Aphididae	+	+	+	+
A gossypii Glover	Homoptera	Aphididae	+	+	+	+
A. craccivora Koch	Homoptera	Aphididae	+	–	–	+
Toxoptera aurantii Fonscolombe	Homoptera	Aphididae	+	–	–	+
Myzus persicae (Sulzer)	Homoptera	Aphididae	+	–	–	+
Asymmetrasca decedens (Paoli)	Homoptera	Cicadellidae	+	+	+	+
Empoasca decipiens Paoli	Homoptera	Cicadellidae	+	+	+	+
Ceratitis capitata (Wiedemann)	Diptera	Tephritidae	–	+	+	+
Cryptoblabes gnidiella Millière	Lepidoptera	Pyralidae	–	+	+	–

TABLE 2
Predator natural enemies observed in the IPM orchards in Adana between 1977 and 1993

Species	Order	Family
Parascymnus phoroides Marseul	Coleoptera	Coccinellidae
Scymnus rubromaculatus (Goeze)	Coleoptera	Coccinellidae
Sc. pallipediformis Gürther	Coleoptera	Coccinellidae
Sc. subvillosus (Goeze)	Coleoptera	Coccinellidae
Sc. flagellisiphonatus Fürsch	Coleoptera	Coccinellidae
Sc. syriacus Marseul	Coleoptera	Coccinellidae
Sc. levaillanti Mulsant	Coleoptera	Coccinellidae
Exochomus quadripustulatus (L.)	Coleoptera	Coccinellidae
Lindorus lophantae (Blaisdell)	Coleoptera	Coccinellidae
Chilocorus bipustulatus (L.)	Coleoptera	Coccinellidae
Rodolia cardinalis (Mulsant)	Coleoptera	Coccinellidae
Coccinella septempunctata (L.)	Coleoptera	Coccinellidae
Serangium parcesetosum Sicard	Coleoptera	Coccinellidae
Cybocephalus fodori minor Endrody-Younga	Coleoptera	Cybocephalidae
Chrysoperla carnea (Stephens)	Neuroptera	Chrysopidae

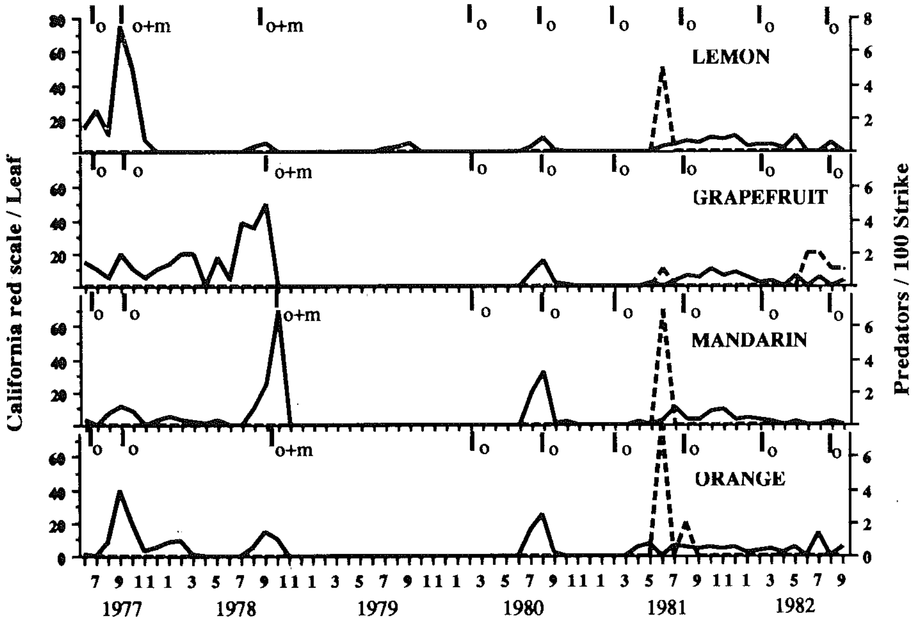

Fig. 1. Population trends of California red scale (solid line) and predators (dashed line) (*C. bipustulatus, L. lophantae, C. f. minor*) (o: mineral oil, m: methidathion), Adana, Turkey, 1977–1982.

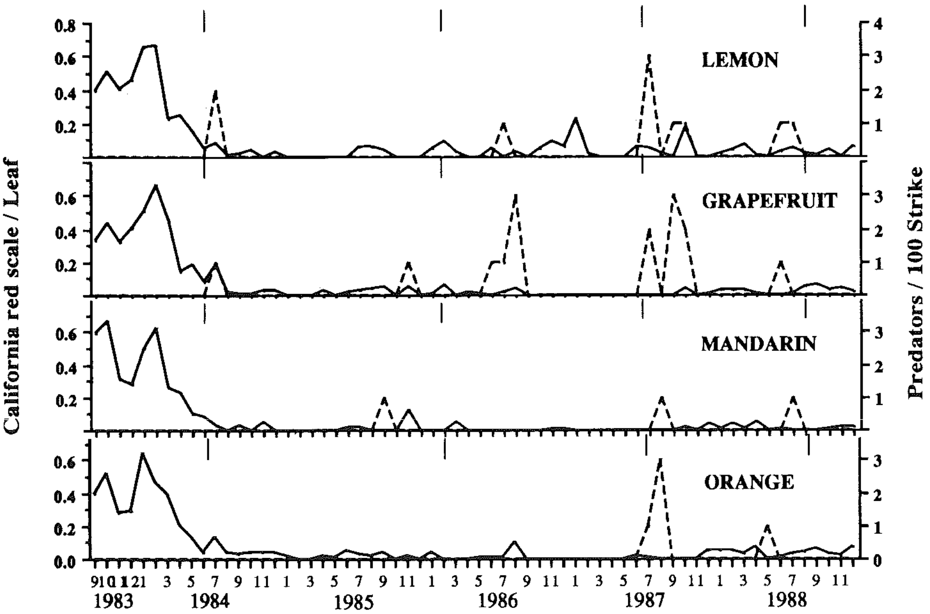

Fig. 2. Population trends of California red scale (solid line) and predators (dashed line) (*C. bipustulatus, L. lophantae, C. f. minor*) (vertical bars: mineral oil), Adana, Turkey, 1983–1988.

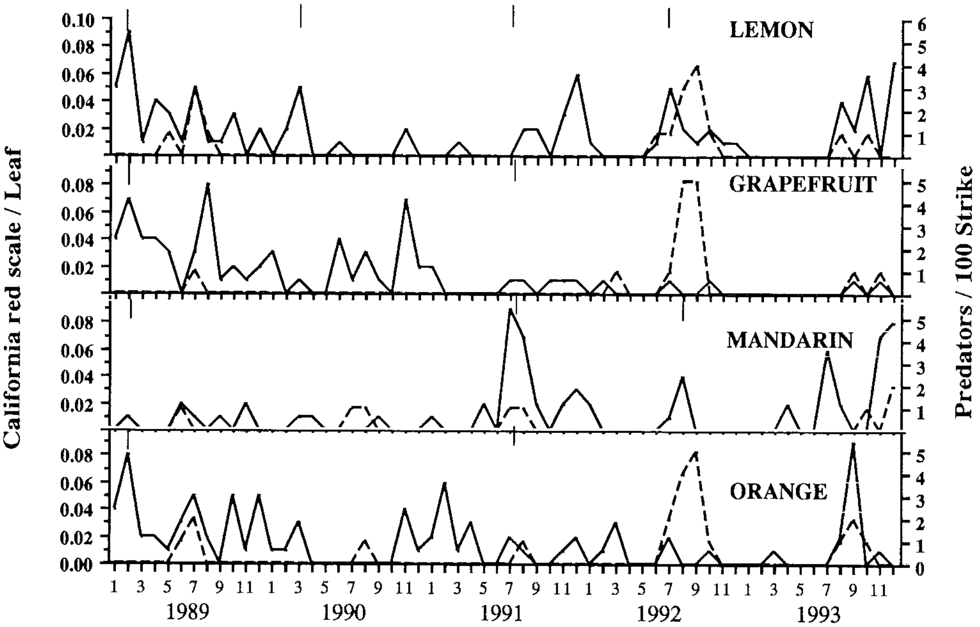

Fig. 3. Population trends of California red scale (solid line) and predators (dashed line) (*C. bipustulatus, L. lophantae, C. f. minor*) (vertical bars: mineral oil), Adana, Turkey, 1989–1993.

represent the CRS development throughout the year. In 1977, petroleum oil (1%) was applied to all groves by June, giving only temporary control. In fall CRS populations rapidly reached a peak of 73 in lemon, and 15, 10, and 38 individuals per leaf in grapefruit, mandarin, and orange, respectively (Fig. 1). In September 1977 all groves were sprayed with petroleum oil, with methidathion (40 ml AI/100 l) added in the lemon plot. In the first half of 1978 CRS populations were low but started to build up in June–July. The lowest population was observed in the lemon grove, probably due to the effect of methidathion. In September 1978 all groves were sprayed with a mixture of oil and methidathion. After this date, methidathion was excluded from the spray schedule, and oil only sprays were used against CRS. Due to the effect of the oil–methidathion mixture in September 1978 and of a single oil spray in winter in grapefruit, mandarin and orange groves, no CRS population increase occurred in 1979 and in the first half of 1980.

From 1980 to 1982, two applications of oil per year — one in February and one in July — kept CRS population density below five individuals per sampled leaf (Fig. 1). Between 1984 and 1988 (Fig. 2), oil was limited to only one application per year in either summer or fall; from 1989 to 1993 it was applied only when necessary. For example, the grapefruit grove was sprayed twice between 1989 and 1993, and none of the other groves was sprayed in 1993 (Fig. 3).

Despite the limited use of oil sprays, the CRS population has been stable at very low levels (below 1 individual/leaf) since 1984 (Figs. 2 and 3). Neither visual nor emergence bag inspections gave any indications on parasitization of CRS until 1982, although very few adult

A. melinus were observed in the field (Uygun and Şekeroğlu, 1984). Therefore, we assume that parasitoids were not responsible for the low numbers of CRS before 1984. Although the specific predators of CRS, namely *Chilocorus bipustulatus*, *Lindorus lophantae* and *Cybocephalus fodori minor*, have been observed only at very low population densities since 1981, we suppose that these natural enemies also contributed to the control of CRS.

The populations of *A. melinus*, a parasitoid of CRS, started to build up after 1985 and reproduced in the orchard. Our parasitization study showed that *A. melinus* populations got established and started to exert pressure on CRS (Fig. 4). Even in this unsprayed experimental plot CRS populations did not exceed 5 individuals/cm^2 in lemon and 2 individuals/cm^2 in grapefruit, mandarin and orange (Fig. 4). In general, the rate of parasitization was higher on leaves than on branches or fruits; however, the parasitization rate on fruits equaled or exceeded the rate on leaves in 1987 (Fig. 5).

As shown in other studies (DeBach, 1969; Reeve and Murdoch, 1986), CRS is controlled by the parasitoid *A. melinus*. According to our results the populations of the latter appeared to be dynamically stable at very low levels at the study site. This indicates that when the lethal effects of dust and pesticides are eliminated, *A. melinus* can successfully control CRS in citrus orchards in the East Mediterranean region of Turkey, and stabilizes CRS populations at low levels for a long period. High parasitization rates (Fig. 5) and low CRS densities indicate that *A. melinus* stabilized its host populations in a density-independent fashion at the study site, thus resembling the results reported by Reeve and Murdoch (1986). Since *A. melinus* is a stage- and size-specific parasite (Opp and Luck, 1986; Yu and Luck, 1988) there seemed to be a constant, although very

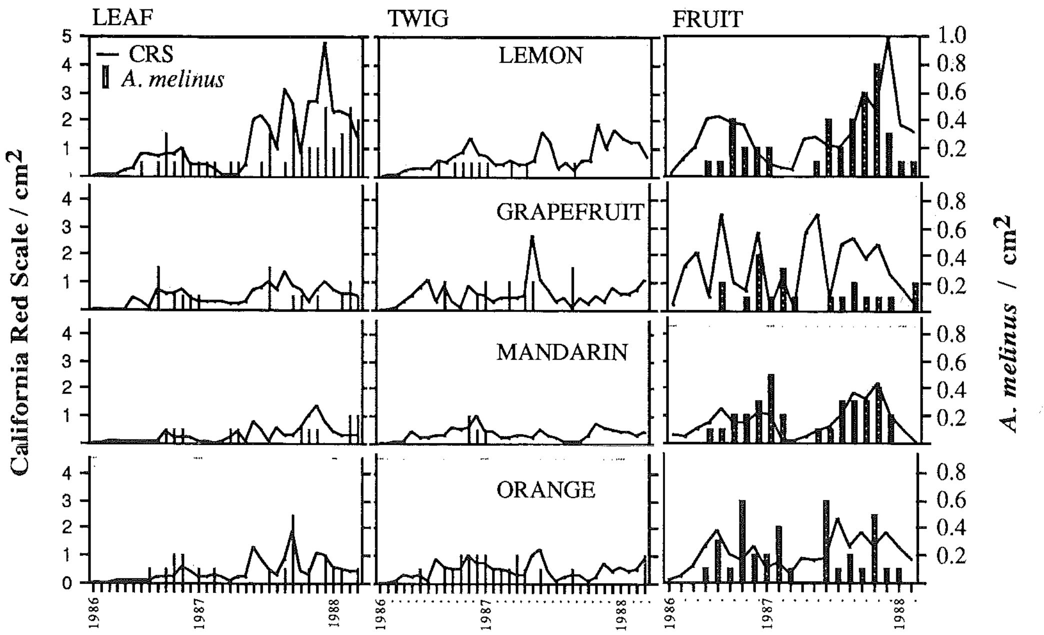

Fig. 4. Population trends of California red scale (solid line) and *Aphytis melinus* (vertical bars), Adana, Turkey.

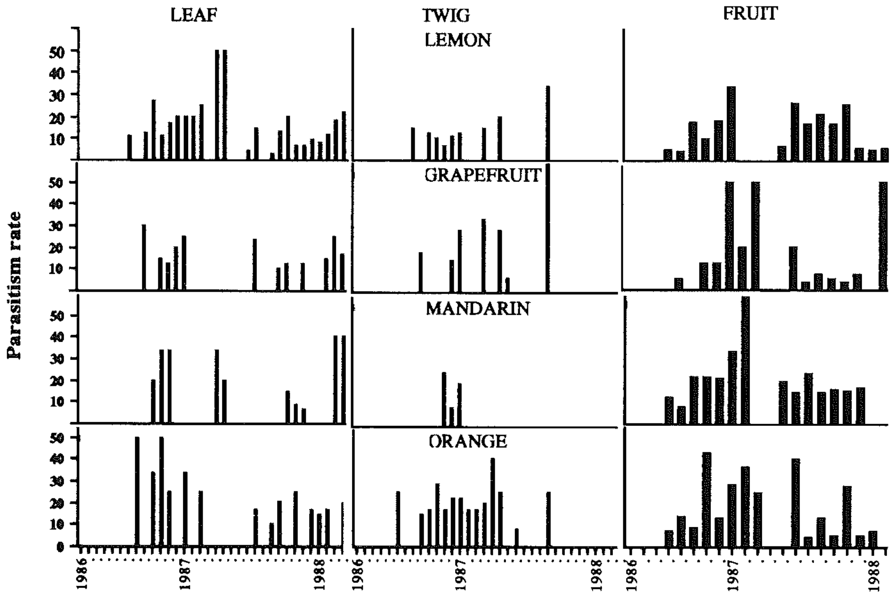

Fig. 5. Parasitization rate in per cent of California red scale by *Aphytis melinus*, Adana, Turkey.

low, supply of host. A spatial refuge, as suggested by Reeve and Murdoch (1986), may also play an important role for a long-term CRS population stabilization.

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