Dialeurodes citri (Ashmead, 1885) in the Adriatic Region of Croatia

Katja ŽANIĆ [1]
Jasminka IGRC BARČIĆ [2]
Sonja KAČIĆ [1]

SUMMARY

Dialeurodes citri (Hom. Aleyrodidae) first invaded citrus orchards in the South Adriatic, near Dubrovnik, during 1977. Since the characteristics of the pest have not been studied in Croatia, this paper reviews its morphology, locations, host plant range and biology.

Leaf samples, collected all over the Croatian coast and islands, were observed in the laboratory for purpose of creating a map with citrus whitefly locations, morphological description and a list of host plants. The pest biological cycle and population trend were investigated in the region of Split (May 1996-May 1998).

The presence of citrus whitefly was confirmed in all citrus-growing areas of Croatia. The number of noted host plants was somewhat lower than in Mediterranean countries. Other than citrus, it also colonised and harmed laurustinus (*Viburnum tinus* Hemsl.), persimmon (*Diospyros kaki* Thunb.) and several plants of Oleaceae.

The citrus whitefly had three generations on citrus per year. However, the part of larval population that belonged to second generation did not finish the post-embryonic development and it remained on the summer flush leaves and awaited the hibernation. The appearance of adults followed the appearance of young citrus growth. All development stages had three population peaks during vegetation period. The presence of young larval stages (L-1, L-2) was pronounced during the middle of June, August and October. The pest overwintered mainly as fourth instar larva. On deciduous persimmon trees it had two generations per year.

KEY WORDS

Citrus whitefly, morphology, distribution, biology

[1] Institute for Adriatic Crops and Karst Reclamation
Put Duilova 11, p.p. 288, 21000 Split, Croatia
E-mail: katja@stijena.krs.hr

[2] Department of Agricultural Zoology, Faculty of Agriculture, University of Zagreb
Svetošimunska cesta 25, 10000 Zagreb, Croatia

Received: June 14, 2000

Štitasti moljac agruma, *Dialeurodes citri* (Ashmead, 1885) (Homoptera: Aleyrodidae) u mediteranskom dijelu Hrvatske

Katja ŽANIĆ [1]
Jasminka IGRC BARČIĆ [2]
Sonja KAČIĆ [1]

SAŽETAK

Nazočnost vrste *Dialeurodes citri* (Hom. Aleyrodidae) prvi put je zabilježena na području Južnog Jadrana, u nasadima agruma u okolici Dubrovnika 1977 godine. Budući da obilježja ovog štetnika u Hrvatskoj nisu istraživana, rad sadrži njegovu morfologiju, nalazišta, biljke domaćine i biologiju.

Uzorci listova, skupljani na obalnom i otočnom dijelu Hrvatske, su pregledavani u laboratoriju kako bi se izradila karta nalazišta, morfološki opis i popis biljaka domaćina ove insekatske vrste. Biološki ciklus i dinamika populacije su istraživani na području Splita (svibanj 1996 – svibanj 1998).

Nazočnost štitastog moljca agruma je utvrđena na čitavom području uzgoja agruma u Hrvatskoj. Broj utvrđenih biljka domaćina je bio nešto manji u usporedbi s podacima iz ostalih mediteranskih zemalja. Osim agruma štetnik je naseljavao i oštećivao lempriku (*Viburnum tinus* Hemsl.), kaki (*Diospyros kaki* Thunb.) i nekoliko vrsta familije Oleaceae.

Štetnik je ostvarivao tri generacije godišnje na agrumima. Ipak, dio populacije ličinki druge generacije nije završavao postembrionalni razvoj već je ostajao na listovima ljetnog porasta i čekao prezimljavanje. Pojava odraslih oblika je slijedila pojavu mladog porasta agruma. Svi razvojni stadiji su ostvarivali tri populacijska maksimuma u vegetacijskom razdoblju. Nazočnost mladih ličinačkih stadija (L-1, L-2) je bilježena sredinom lipnja, kolovoza i listopada. Štetnik je uglavnom prezimljavao kao ličinka četvrtog stadija. Na listopadnom domaćinu kakiju, zabilježene su dvije generacije.

KLJUČNE RIJEČI

štitasti moljac agruma, morfologija, nalazišta, biologija

[1] Institut za jadranske kulture i melioraciju krša
Put Duilova 11, p.p. 288, 21000 Split, Hrvatska
E-mail: katja@stijena.krs.hr

[2] Zavod za poljoprivrednu zoologiju, Agronomski fakultet Sveučilišta u Zagrebu
Svetošimunska cesta 25, 10000 Zagreb, Hrvatska

Primljeno: 14. lipnja 2000.

INTRODUCTION

The citrus whitefly - *Dialeurodes citri* (Ashmead, 1886) - seems to have originated in the Indian Region, having spread through the whole Temperate Zone. It now occurs in Oriental, Paleartic, Nearctic and Neotropical Regions (Mound & Halsey 1978). The first reports on its appearance in the Mediterranean Basin date from the mid-20th century (Grandi 1951, Della Beffa 1961). Currently, *Dialeurodes citri* is one of the three economically important whiteflies on citrus in the Mediterranean Region (Uygun et al. 1990, 1996; Rapisarda et al. 1996). Namely, two harmful pest species: *Aleurothrixus floccosus* (Maskell) and *Parabemisia myricae* (Kuwana) are domesticated in nearly all countries of the Region (Barbagallo et al. 1986).

Dialeurodes citri is a polyphagous insect that infests evergreen and deciduous plants of 30 different families (Mound & Halsey 1978). In the Mediterranean countries, it mainly lives on *Citrus* spp., but its presence has also been noted on plants other than the family of Rutaceae. For example, Uygun et al. (1990) recorded 15 plants other than citrus as hosts of *D. citri* in the Mediterranean part of Turkey. In northwestern Italy (Piedmont) six plant species were noted, the highest pest population density (338 larvae per leaf) being recorded on *Ligustrum ovalifolium* (Arzone & Vidano 1990; Alma et al. 1991).

Citrus whitefly adults damage their host plants by ovipositing and feeding. Immature stages pierce the undersides of leaves with their mouthparts and suck a lot of plant juice, although no quantitative method has determined exactly how much damage this causes. They excrete large quantities of honeydew that stimulates the sooty mould fungus growth. The sooty mould coats the leaves and stems of infested plants and interferes with the normal functioning of the leaves. Heavy attacks may result in leaf-fall, especially during the summer. An additional form of damage is the external coating of fruits by sooty mould, which lowers their market value. *Dialeurodes citri* has not been recorded as vector of plant diseases.

The citrus whitefly has mainly 2-3 generations per year in the Mediterranean Basin (Barbagallo et al. 1986; Uygun et al. 1990; Alma et al. 1991; Lloréns & Capilla 1994). It overwinters in the larval stages, mainly as fourth instar, less as third instar.

In Croatia, *Dialeurodes citri* was first noted in citrus orchards near Dubrovnik in 1977 (Bakarić 1983). Today it is an important pest on all *Citrus* spp. throughout Croatian citrus-growing areas but its characteristics have been cursorily investigated to date (Žanić et al. 2000). The aim of this investigation was to record pest characteristic as distribution, morphology, host plants and various aspects of biology. The particular aim was to establish the young larval presentation to target appropriate control.

MATERIALS AND METHODS

Field and laboratory investigations were conducted during the years of 1996/1998.

Leaf samples of citrus and plants other than citrus, collected all over the Croatian coast and islands, were observed in the laboratory in order to determine the citrus whitefly locations and a list of host plants. The key according to Martin (1987), based on the pupal case morphology, was used for pest identification. The length of development stages important to get detailed morphological informations was measured by Video Imaging System Argus 2.0 (50 individuals per each stage).

Feeding tests included 15 plant species, recognised as citrus whitefly hosts in Mediterranean countries. Plant seedlings, separated per species, were put in cages (70 x 70 x 70 cm), three seedlings per cage. The cages were placed outdoors, in the yard of the Institute for Adriatic Crops in Split. Pest adults, collected from a citrus orchard, were released in the cages, approximately 100 adults per cage. The presence of living immature stages and empty puparium on leaves was continuously observed.

Biological cycle, flight dynamic and preimaginal stages population dynamic of *Dialeurodes citri* were investigated in the suburb of Split according to the models of Alma et al. (1991) and Uygun et al. (1994). Samples of 30 leaves (10 leaves of either lemon, mandarin or persimmon) were collected weekly during the warm periods of the year and once per month during the winter. The number of eggs, larvae (L-1, L-2, L-3, L-4) and "pupae" (P) on all leaves were counted under the stereomicroscope, converted into the number of these per 200 cm^2 and at the end presented as percentage composition. In order to simplify the presentation, population trend data for the youngest larval stages (L-1 and L-2) as well as the last preimaginal stages (L-4, P) are showed together. Adult number per leaf was noted in the orchard early in the morning. It was converted into the number per 200 cm^2 after 100 already observed young leaves had been picked and measured in the laboratory.

RESULTS AND DISCUSION

Distribution within Croatia

Figure 1 shows that citrus whitefly has invaded all citrus-growing areas of Croatia, situated in the Adriatic districts with mild Mediterranean climate. It is absent only in the Northern Adiratic, where climatic conditions are somewhat harsher. The optimal citrus-growing area expands from 20° – 40° N and S. Croatia is the northernmost citrus-growing area in the world,

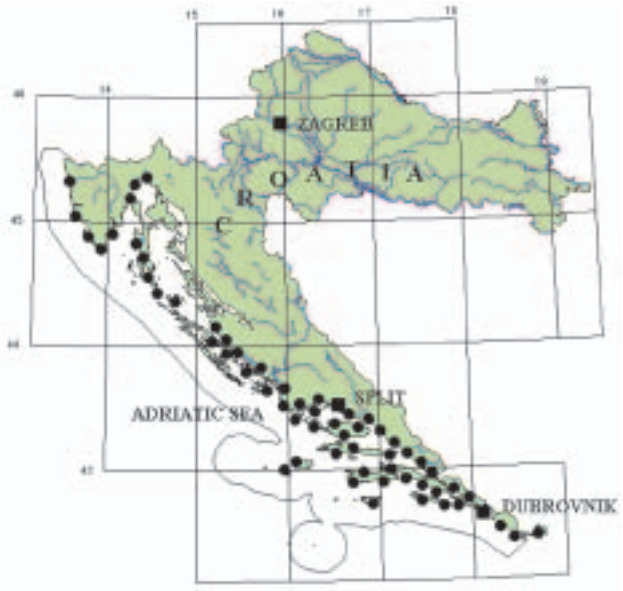

Figure 1. *Dialeurodes citri* locations in Croatia

Morphological description

as well as the northernmost area where *Dialeurodes citri* attacks citrus trees. For comparison, in the neighbouring Italy it inhabits the Turin County (Piedmont), situated at about 45° N (Arzone & Vidano 1990; Alma et al. 1991). However, there it is a pest of several Oleaceae plants, not the citrus itself.

Morphological characteristics, appearance and dimensions of all *Dialeurodes citri* development stages do not differ greatly from morphological properties noted in other Mediterranean countries.

The adult is a tiny insect. It is an active flier. Its body is orange, but covered with white, waxy powder, as

Figure 2: Resting adult

Figure 3: Young eggs

Figure 4: 4th instar larva on lemon

Figure 5: Distorted 4th instar larva on persimmon

Figure 6: Distorted "pupa" on persimmon

Figure 7: Empty puparium

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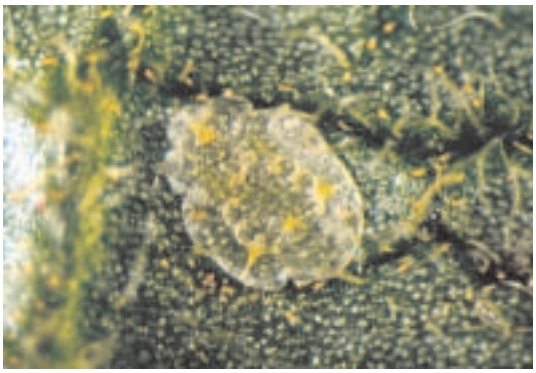

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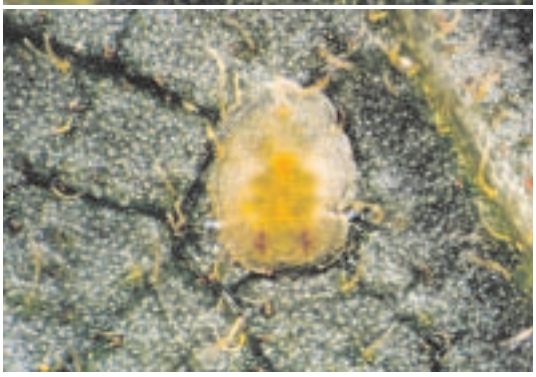

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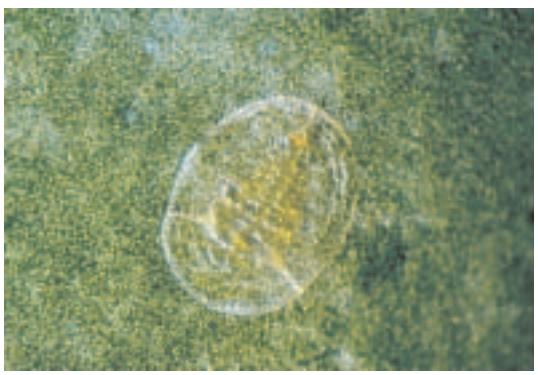

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is the case with wings (Fig. 2). The average body length is 1.6 mm. The microscopic cylindrical egg is attached to the undersurface of leaf by a pedicel. A fresh laid egg is pale yellow-green (Fig. 3). It turns to slightly brownish colour in the course of development. The average egg length is 0.22 mm.

The larval instars are flat, oval and transparent. Only the first instar larva is vagile. Its average body length is 0.32 mm. The second, third and fourth instar larvae are sessile. They have atrophied legs and antennae. The dorsal surface of all larval instar is simple, without wax secretion of any kind. From the 2nd instar, that has an average body length of 0.47 mm, onward two thoracic tracheal folds form the Y–shaped structure together with the central part of the body structure. The average body length of 3rd instar is 0.73 mm. Y – shaped structure is best visible in the 4th instar that has an average body length of 1.46 mm (Fig. 4). Depending on leaf hairiness of the host plant, the body margin can be distorted. This deformation has mainly been recorded on larvae fixed on persimmon leaves. Marginal distortion has been most frequent in the 4th instar (Fig. 5).

The adult develops inside the fourth instar and this is then known as a "pupa". It is opaque and convex dorsally. The outline of the adult takes form; the compound red eyes are visible by the naked eye. The average body length is 1.48 mm. In the case of pupa having developed from a deformed 4th instar, its body margin is distorted (Fig. 6). The adult emerges through a T- shaped split in the dorsal surface of the white pupal case (Fig. 7).

Host plants

Only plants with empty puparіums of *Dialeurodes citri* were considered as hosts. Mound & Halsey (1978) recorded more than 70 plant species other than citrus, belonging to 30 families, as hosts of *D. citri* in the world. According to Arzone & Vidano (1990); Uygun et al. (1990); Alma et al. (1991); Pollini et al. (1993), about 20 plants other than Rutaceae were recorded as its hosts in the Mediterranean Basin.

Table 1 presents the list of *Dialeurodes citri* host plants found in the Adriatic regions of Croatia during our study. Only seven plants other than citrus were recorded as pest hosts. Among these plants, *Jasminum* spp. and *Diospyros kaki* were the most infested. The leaf underside of infested *Jasminum* spp. plants was often fully covered with immature stages of citrus whitefly.

It was observed that *D. citri* had laid eggs on the lower surface of *Bougainvillea* spp. leaf, but no first instar larvae developed from those eggs.

Feeding tests were performed with respect to the fact that the noted number of host plants was somewhat lower than in Mediterranean countries. Out of 15 plant species, known as hosts to pest in Mediterranean countries and spread in the region of Split, empty pest puparіums were found only on *Ligustrum vulgare*, which served as test–plant (Table 2). Thus, the results of feeding tests correspond with the data obtained through investigations under natural conditions.

Biological cycle of *Dialeurodes citri* in Split region

Investigations conducted in the period of May 1996 – May 1998, complemented with observations from the whole vegetation period of 1998, served for preparation of a model of *Dialeurodes citri* biological cycle on citrus and persimmon.

Table 3a shows that *D. citri* had three generations per year on citrus. The pest overwintered in larval stages (mainly as fourth instar). The pupal stage started appearing at the beginning of April and the adults

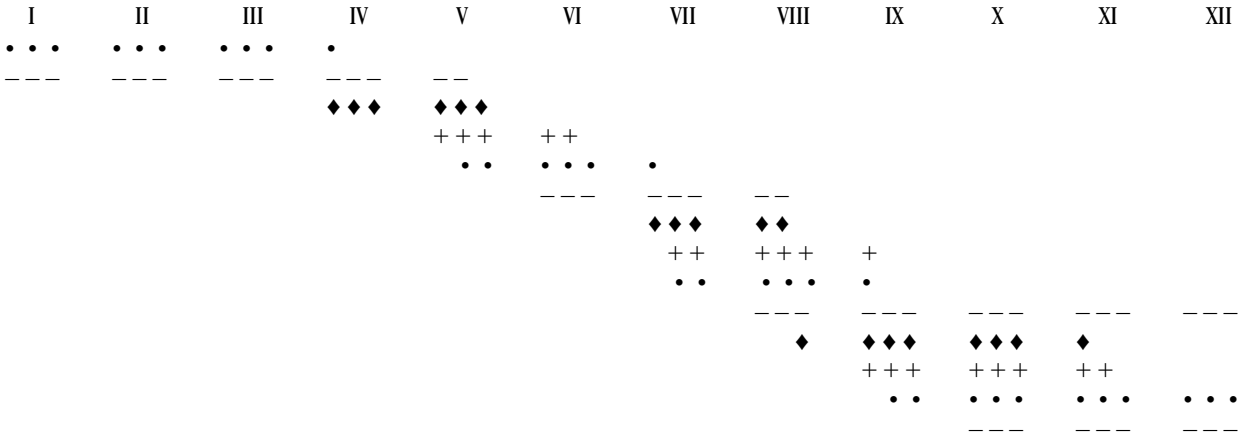
Table 1. List of *Dialeurodes citri* host plants in Croatia

Family	Plant species
Caprifoliaceae	*Viburnum tinus* Hemsl.
Ebenaceae	*Diospyros kaki* Thunb.
Oleaceae	*Jasminum nudiflorum* Lindl.; *J. polyanthum* Franch.; *Ligustrum vulgare* L.; *L. ovalipholium* Hassk.; *L. japonicum* Thunb.
Rutaceae	*Citrus medica* L.; *C. lemonia* Osbeck.; *C. paradisi* Macf.; *C. sinensis* Osbeck.; *C. aurantium* L.; *C. reticulata* Blanco; *C. mitis* Blanco; *Poncirus trifoliata* Raf.; *Fortunella japonica* Swingle; *F. margarita* Swingle

Table 2. Results of feeding tests

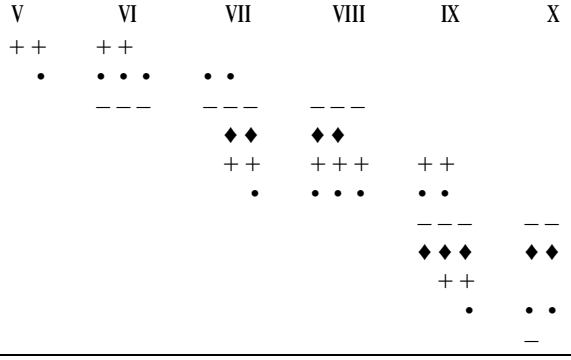
Family	Species	Host
Actinidiaceae	*Actinidia chinensis* Planch.	–
Apocynaceae	*Nerium oleander* L.	–
Araliaceae	*Hedera helix* L.	–
Celastraceae	*Evonimus japonica* Thunb.	–
Lauraceae	*Laurus nobilis* L.	–
Lythraceae	*Lagerstroemia indica* L.	–
Moraceae	*Ficus carica* L.	–
Oleaceae	*Ligustrum vulgare* L.	+
Oleaceae	*Syringa vulgaris* L.	–
Punicaceae	*Punica granatum* L.	–
Rosaceae	*Crategus* sp.	–
Rosaceae	*Prunus laurocerasus* L.	–
Rosaceae	*Pyracantha coccinea* L.	–
Theaceae	*Camellia japonica* L.	–
Vitaceae	*Parthenocissus tricuspidata* Planch.	–

Table 3a. *Dialeurodes citri* - Biological cycle on citrus in the region of Split (1996/1998)



Development stages: + adult; • egg; – larva; ♦ pupa

Table 3b. *Dialeurodes citri* - Biological cycle on persimmon in the region of Split (1996/1998)



Development stages: + adult; • egg; – larva; ♦ pupa

emerged in the first days of May. Females laid eggs on young, fully expanded leaves. Oviposition took place only on the underside of leaves, especially in the base section, along the main vein, rarely in the apical part. Eggs were laid one by one and were occasionally found on scion, but never on fruit. A manifest second emergence of adults took place in mid-July. The third emergence occurred in the beginning of September. The appearance of adults and young vegetation growth (spring, summer and autumn flush) were contemporaneous. Generation overlapping was highly expressed from the beginning of September, when larvae of mature stages, belonging to second generation, were present at the same time as adults and larval stages belonging to third generation. A part of the second-generation larval population did not finish their post-embryonic development, remaining on summer flush leaves and awaiting hibernation.

Table 3b shows that citrus whitefly passed two generations during the vegetation period on deciduous persimmon trees. Adults from citrus trees colonised young persimmon leaves in mid-May and then started laying eggs. It should be added that the population density of the first generation was higher than that of the second generation. The few eggs and young larvae belonging to third generation, as well as the remaining second-generation development stages, were lost with leaf-fall.

Population trend of *Dialeurodes citri* on citrus

The population trend of *Dialeurodes citri* in Split region is established. Our data are similar to those from other Mediterranean countries (Barbagallo et al. 1986; Arzone & Vidano 1990; Alma et al. 1991; Lloréns & Caplilla 1994). Fig. 8 presents the series of average daily temperatures in the period of investigation.

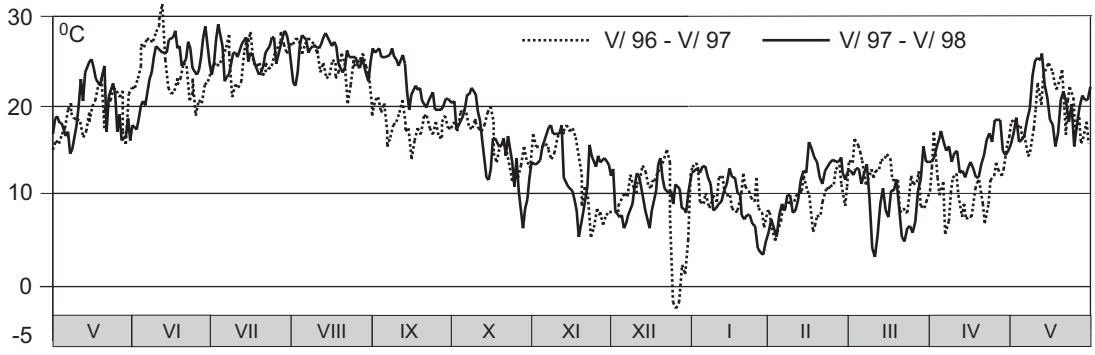


Figure 8: Series of average daily temperatures in periods V/96 – V/97 and V/97 – V/98 year

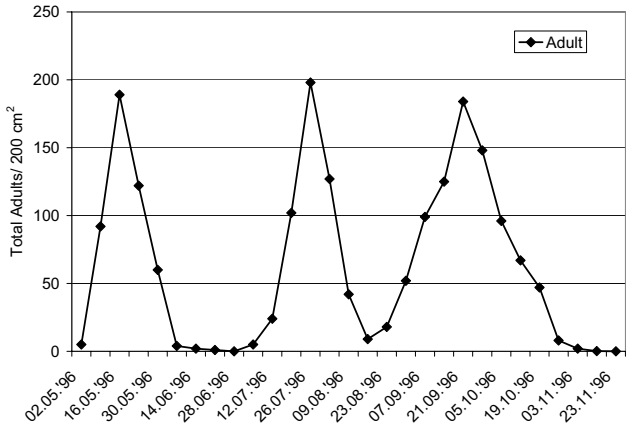


Figure 9a: The flight dynamics of *Dialeurodes citri* in 1996

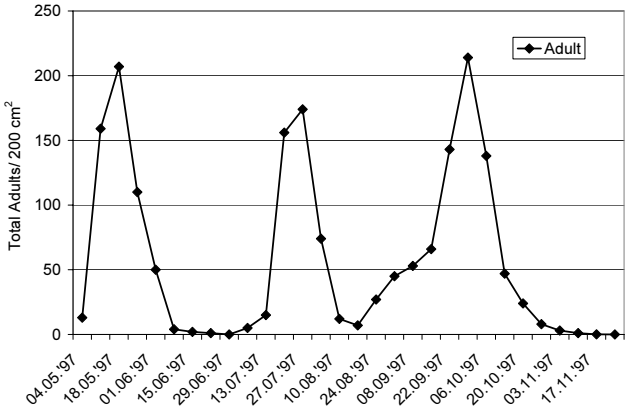


Figure 10a: The flight dynamics of *Dialeurodes citri* in 1997

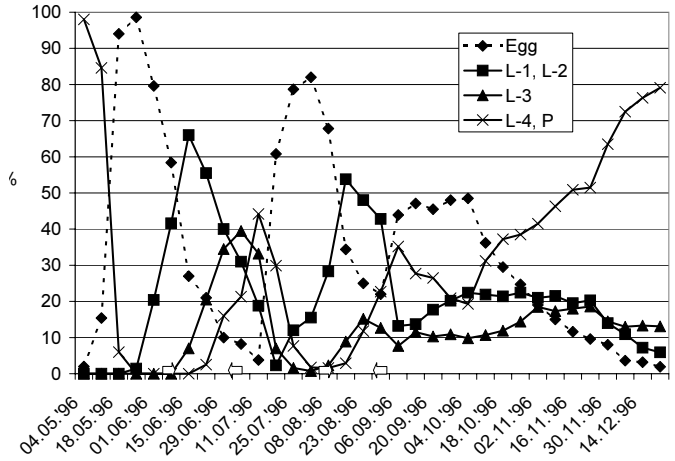


Figure 9b: Percentage composition of *Dialeurodes citri* preimaginal stages/ 200 cm^2 citrus leaves (May – December 1996)

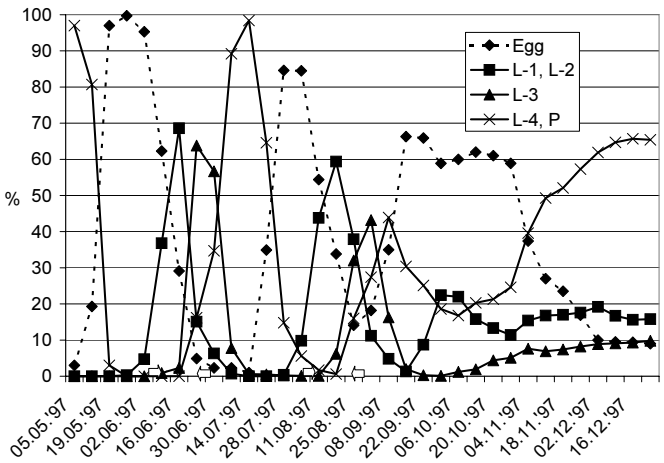


Figure 10b: Percentage composition of *Dialeurodes citri* preimaginal stages/ 200 cm^2 citrus leaves (May – December 1997)

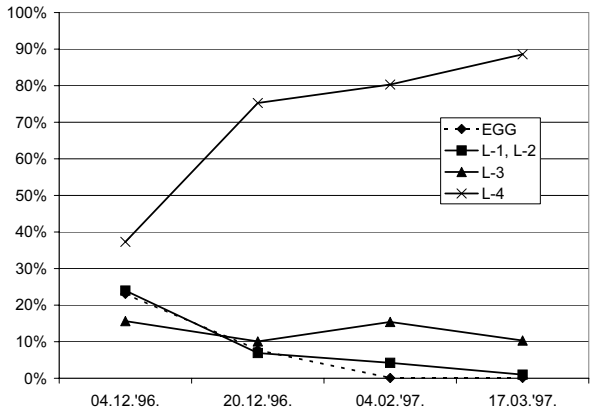


Figure 9c: Hibernation of *Dialeurodes citri* in the region of Split (1996/1997)

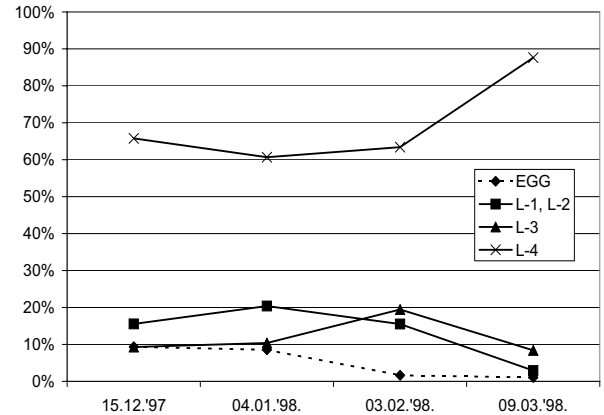


Figure 10c: Hibernation of *Dialeurodes citri* in the region of Split (1997/1998)

The flight dynamic

The flight dynamic in 1996 is showed by Fig. 9a and in 1997 by Fig. 10a. The appearance of adults and young vegetation growth (spring, summer and autumn flush) were contemporaneously in both years. The emergence of adults took place at the beginning of May, middle of July and the beginning of September. Three flight maximums were recorded (middle of May, the beginning of August and the end of September). Adult activity finished till middle of November.

Population trend of preimaginal stages in vegetation period

Population trend of preimaginal stages in period May – December 1996 is showed by Fig. 9b and in period May – December 1997 by Fig. 10b. Generaly, all preimaginal stages had three population peaks during the vegetation in both periods. The selection is: young larval instars (L-1 , L-2) were presented in high percent from the middle to the end of July (the first generation) and from the middle to the end of

August (the second generation). These periods are marked with arrows on the charts.

Hibernation

In the Middle Adriatic area, the citrus whitefly was in hibernation in larval stages (mainly as fourth instar and, to a less degree, as third instar).

Figs 9c and 10c present levels of infestation, expressed as percentage of each development stage per 200 cm^2, found on lemon and mandarin during the winters of 1996/1997 and 1997/1998. All preimaginal stages except for the "pupa" were present in citrus orchards during both winter periods in December. We point out the presence of egg and L-1 stages. Abiotic factors, such as low temperatures and cold dry winds, adversely influenced the population density of young stages (egg, L-1, L-2). The surviving young larvae of the third generation froze, especially in early February. The eggs, laid by females of autumnal generation, resumed normal appearance for a long time, but young larvae did not hatch from them. One part of the mature larval population (L-3, L-4) was lost too. The population of *Dialeurodes citri* consisted of L-4 stage (nearly 90 %) and L-3 stage (nearly 10 %) at the end of winter in both periods. The share of L-1 and L-2 stages was insignificant. In general, the surviving larvae fixed on autumnal flush, usually damaged by citrus leaf miner, belonged to third generation; while the surviving larvae fixed on summer flush belonged to the part of second generation that did not finish their development during the summer.

CONCLUSION

Main *Dialeurodes citri* characteristics are recorded.

Presence of young larval instars, L-1 and L-2, is dominant in two periods: the middle – the end of July and the middle – the end of August. Selected periods are advisable to apply control measures against these susceptible instars. The third period of their occurrence during October is disregarded to apply control measures because they are not present in high percent. This is also the period of mandarine harvesting.

Control measures against *Dialeurodes citri,* based on IPM principles, have to be the subject for the next investigation.

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