

## Checklist of phytophagous insects on citrus from the Sternorrhyncha (Hemiptera) suborder in Mediterranean basin and the risk for introduction and harmfulness in Croatia

### Fitofagni kukci iz podreda Sternorrhyncha (Hemiptera) na agrumima u Mediteranskom bazenu i rizik od unosa i uzrokovanja šteta u Hrvatskoj

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#### ABSTRACT

First aim of this review paper is to make the checklist of the most important phytophagous insects from the Sternorrhyncha (Hemiptera) suborder that may feed on plants from genus *Citrus*, *Fortunella* and *Poncirus*, present in the Mediterranean basin. Second aim is to compare the mentioned list with Croatian findings from relevant literature. Third aim is to separate and describe possible risk for introduction and harmfulness of the most harmful species in Croatia. In the literature review 46 species (17 aphids, 21 scale insects, 6 whiteflies and 2 psyllids) which may feed on citrus plants were found to be present in selected countries. Out of that number, 37 species (13 aphids, 18 scale insects and 6 whiteflies) are reported for Croatia. Based on their potential to cause damages, ability to spread and the vicinity of the countries in which they are found, following species if introduced could be potential threat for citrus growing areas in Croatia: *Toxoptera citricida* (Kirkaldy), *Aonidiella citrina* (Craw, 1890), *Parasaissetia nigra* (Nietner, 1861), *Trioza erytrae* (Del Guercio, 1918), *Aleurothrixus floccosus* (Maskell, 1896) and *Parabemisia myricae* (Kuwana, 1927).

**Keywords:** citrus, Croatia, introduction, phytophagous insects, Sternorrhyncha

#### SAŽETAK

Prvi cilj ovog preglednog rada je napraviti popis najvažnijih fitofagnih kukaca iz podreda Sternorrhyncha (Hemiptera) prisutnih u Mediteranskom bazenu kojima domaćini mogu biti biljne vrste iz rodova *Citrus*, *Fortunella* i *Poncirus*. Drugi cilj je usporediti navedeni popis s vrstama utvrđenim u Hrvatskoj temeljem dostupne relevantne literature. Treći cilj je izdvojiti i opisati najštetnije vrste za koje postoji rizik od unosa i uzrokovanja šteta u Hrvatskoj. Literaturnim pregledom u odabranim zemljama utvrđeno je 46 vrsta kukaca kojima domaćini mogu biti agrumi (17 lisnih uši, 21 štitastih uši, 6 štitastih moljaca i 2 lisne buhe). Od toga je 37 vrsta kukaca (13 lisnih uši, 18 štitastih uši i 6 štitastih moljaca) nađeno u Hrvatskoj. Na temelju njihovog potencijala uzrokovanja šteta, sposobnosti širenja i blizine zemalja u kojima su prisutni, nekoliko vrsta kukaca u slučaju unosa mogu predstavljati potencijalnu opasnost za uzgojna područja agruma u Hrvatskoj: *Toxoptera citricida* (Kirkaldy), *Aonidiella citrina* (Craw, 1890), *Parasaissetia nigra* (Nietner, 1861), *Trioza erytrae* (Del Guercio, 1918), *Aleurothrixus floccosus* (Maskell, 1896) i *Parabemisia myricae* (Kuwana, 1927).

**Ključne riječi:** agrumi, fitofagni kukci, Hrvatska, Sternorrhyncha, unos

## INTRODUCTION

Citrus fauna has been in the focus of producer's interest from the beginning of their intensive growing. Therefore, citrus industry and entomologists have been collaborating for more than a century in study of their biology and finding means of their suppression and the results of such cooperation have greatly contributed to their control and suppression (Reuther et al., 1989). During its research on citrus insects in the Middle East in the first half of the 20<sup>th</sup> century, Bodenheimer (1951) had found that the fauna of the citrus trees is limited almost entirely to its pests and to the parasites or predators connected with them, but the citrus fauna of the world and especially within the Mediterranean area is still in full migration and expansion, aided enormously by human agency and commerce. However, the number of species on citrus will doubtless still increase considerably in the future, mainly on account of very occasional feeders of no economic importance and on account of new introductions (Bodenheimer, 1951).

In the first decade of 21<sup>st</sup> century it is evident considerable growth of introduction of new foreign species of phytophagous insects into Croatia and the new introduced insects have favorable preconditions for establishment particularly in the coastal part of Croatia which has Mediterranean climate and abundance of host plants suitable for foreign species of tropical origin (Matošević and Pajač Živković, 2013).

First aim of this review paper is to make the checklist of the most important phytophagous insects from the Sternorrhyncha (Hemiptera) suborder that may feed on plants from genus *Citrus*, *Fortunella* and *Poncirus*, present in the Mediterranean basin. Second aim is to compare the mentioned list with Croatian findings from relevant literature. Third aim is to separate and describe possible risk for introduction and harmfulness of the most harmful species in Croatia.

## Materials and methods

The basis for making the checklist of phytophagous insects from the Sternorrhyncha suborder harmful to

citrus plants were web databases Scale Net (scale insects), Psyllist (jumping plant lice) and CAB International (Invasive Species Compendium), scientific and expert papers, catalogue reviews of species and thesis in the area of entomology. Apart from Croatia, the presence of phytophagous insects is also given for countries in the Mediterranean from which Croatia imports fresh fruits or fruit seedlings which are potential vectors of new species (Greece, Italy, Spain, Portugal, Turkey, Israel, Egypt and Tunisia) and countries with which Croatia shares inland border (Slovenia and Montenegro). For each species present in Mediterranean basin and Croatia, its scientific name and reference was given.

## RESULTS

### Aphids

There are around 4,500 species of aphids in the world (Blackman and Eastop, 1984; 1994; 2000). Fourteen aphid species are recorded on citrus: *Aphis craccivora* Koch, 1854, *Aphis gossypii* Glover, 1877, *Aphis nerii* Boyer de Fonscolombe, 1841, *Aphis spiraeicola* Patch, 1914, *Aulacorthum magnoliae* (Esig & Kuwana), *Aulacorthum solani* Kaltentbach, 1843, *Brachycaudus helichrysi* (Kaltentbach, 1843), *Brachyunguis harmalae* B. Das, 1918, *Macrosiphum euphorbiae* (Thomas, 1878), *Myzus persicae* Sulzer, 1776, *Sinomegoura citricola* van der Goot, *Toxoptera aurantii* (Boyer de Fonscolombe, 1841), *Toxoptera citricida* (Kirkaldy) and *Toxoptera odinae* (Van der Goot). Additionally, five other species have been recorded one or more times from citrus: *Aphis arbuti* Ferrari, 1872, *Aphis fabae* Scopoli, 1763, *Brachycaudus cardui* (Linnaeus, 1758), *Pterochloroides persicae* (Cholodkovsky, 1899) and *Rhopalosiphum maidis* (Fitch, 1856) (Blackman and Eastop, 2000). Data on distribution of mentioned species are given in Table 1. So far in Croatia have been determined 191 species of aphids on 192 different host plants (Gotlin Čuljak et al., 2012). Thirteen out of nineteen species which may feed on citrus plants (according to literature review) were found on different hosts in Croatia (Table 1).

**Table 1.** List of aphids that may feed on citrus plants recorded in the Mediterranean basin and Croatia

Species	Presence in citrus growing areas in the Mediterranean basin	Reference	Presence in Croatia	Reference
<i>Aphis craccivora</i> Koch, 1854 Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Akyürek et al., 2010; Swirski and Amitai, 1999; Allam and El-Kady, 1966; Weigand and Bishara, 1991; Mitrović et al., 2013; UK, CAB International, 1983; Kavallieratos et al., 2007; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Aphis gossypii</i> Glover, 1877 Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Akyürek et al., 2010; Swirski and Amitai, 1999; UK, CAB International, 1968; Halima-Kamel and Hamouda, 1993; Milevoj, 2002; Mitrović et al., 2013; Tsitsipis et al., 2007	+	Gotlin Čuljak et al., 2012
<i>Aphis nerii</i> Boyer de Fonscolombe, 1841 Aphididae	Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Swirski and Amitai, 1999; Grant Morse et al., 1996; Ben Halima, 2012; Mitrović et al., 2013; Tsitsipis et al., 2007; Cavalloro, 1986; Cambra et al., 2000; Costa and Starý, 1988	+	Gotlin Čuljak et al., 2012
* <i>Aphis spiraeicola</i> Patch, 1914 Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Greece, Italy, Spain, Portugal	Uygun et al., 1987; Swirski et al., 1991; UK, CAB International, 1969; Ben Halima, 2012; Modic and Urek, 2008; Katsoyannos et al., 1997; Melia, 1995; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Aphis fabae</i> Scopoli, 1763 Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Aslan and Uygun, 2005; Swirski and Amitai, 1999; Semeada et al., 2004; Halima-Kamel and Hamouda, 1993; Kos et al., 2008; Mitrović et al., 2013; Lykouressis and Tsitsipis, 1987; UK, CAB International, 1963; Mier Durante and Nieto Nafria, 1974; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Aphis arbuti</i> Ferrari, 1872 Aphididae	Turkey, Italy, Spain, Portugal	Görür et al., 2012; Barbagallo et al., 2011; Ghosh et al., 1994; Rodrigues et al., 2006	-	-
<i>Aulacorthum solani</i> Kaltentbach, 1843 Aphididae	Turkey, Israel, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Görür et al., 2012; Swirski and Amitai, 1999; Boukhris-Bouhachem et al., 2007; UK, CAB International, 1985; Žikić et al., 2012; Tsitsipis et al., 2007; UK, CAB International, 1985; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Brachycaudus helichrysi</i> (Kaltenbach, 1843) Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Görür et al., 2012; Swirski and Amitai, 1999; Abdel-Salam et al., 1972; Ben Halima, 2012; Modic et al., 2009; Žikić et al., 2012; Kavallieratos et al., 2007; Bassi, 1994; Hermoso de Mendoza et al., 1986; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Brachycaudus cardui</i> (Linnaeus, 1758) Aphididae	Turkey, Israel, Tunisia, Slovenia, Montenegro, Italy, Spain, Portugal	Görür et al., 2012; Swirski and Amitai, 1999; Ben Halima, 2012; Modic et al., 2009; Žikić et al., 2012; Barbagallo et al., 2011; Tizado and Nunez Perez, 1998; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Brachyunguis harmalae</i> B. Das, 1918 Aphididae	Israel, Tunisia, Greece, Spain	Swirski and Amitai, 1999; Ben Halima, 2012; Tsitsipis et al., 2007; García Prieto et al., 2004	-	-

Table 1. Continued

Species	Presence in citrus growing areas in the Mediterranean basin	Reference	Presence in Croatia	Reference
<i>Macrosiphum euphorbiae</i> (Thomas, 1878) Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Görür et al., 2012; Swirski and Amitai, 1999; Elnagar et al., 1996; Halima-Kamel and Hamouda, 1993; Modic et al., 2009; Žikić et al., 2012; Tsitsipis et al., 2007; UK, CAB International, 1984; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Myzus persicae</i> Sulzer, 1776 Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	UK, CAB International, 1979; Swirski and Amitai, 1999; Grant Morse et al., 1996; Halima-Kamel and Hamouda, 1993; Kos et al., 2012; Žikić et al., 2012; Tsitsipis et al., 2007; UK, CAB International, 1979; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Pterochloroides persicae</i> (Cholodkovskii, 1899) Aphididae	Turkey, Israel, Egypt, Tunisia, Greece, Italy, Spain	Görür et al., 2012; Swirski and Amitai, 1999; Darwish et al., 1989; Ben Halima, 2012; Tsitsipis et al., 2007; Blackman and Eastop, 1984; Cabello et al., 1995	+	Gotlin Čuljak et al., 2012
<i>Rhopalosiphum maidis</i> (Fitch, 1856) Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Greece, Italy, Spain, Portugal	Görür et al., 2012; Swirski and Amitai, 1999; UK, CAB International, 1971; Ben Halima, 2012; Pajmon, 1997; Tsitsipis et al., 2007	+	Gotlin Čuljak et al., 2012
* <i>Toxoptera aurantii</i> (Boyer de Fonscolombe, 1841) Aphididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Görür et al., 2012; Swirski and Amitai, 1999; UK, CAB International, 1961; Ben Halima, 2012; Seljak, 2013; Žikić et al., 2012; Lykouressis and Tsitsipis, 1987; Liotta and Manzella, 1993; Melia, 1993; Rodrigues et al., 2006	+	Gotlin Čuljak et al., 2012
<i>Toxoptera citricida</i> (Kirkaldy) Aphididae	Tunisia, Spain, Portugal	Tsai, 1999; Ilharco et al., 2005	-	-
<i>Toxoptera odinae</i> (Van der Goot, 1917) Aphididae	Egypt	Aziza et al., 2014	-	-

\* Found on citrus plants in Croatia

### Scale insects

Approximately 16,000 species are described within the Sternorrhyncha suborder and 7,500 out of that number are scale insects (Gullan and Martin, 2003). According to Scale Net (2020), 433 scales are associated with Rutaceae family and 337 may appear on plants within the genus *Citrus*. Most of scale insects are polyphagous and they easily adapt to different conditions regarding food and climate. Pasive spread of scale insects in the world is very

intensive nowadays considering dynamic of marketing with fruit seedlings, fresh fruits and ornamental plants. In Croatia have been determined 111 species of scale insects (Masten Milek, 2007). In total, literature data on presence of 24 the most important scale insects which may feed on citrus plants have been examined for Croatia and selected countries. Data on distribution of mentioned species are given in Table 2.

**Table 2.** List of the most important scale insects that may feed on citrus plants recorded in the Mediterranean basin and Croatia

Species	Presence in citrus growing areas in the Mediterranean basin	Reference	Presence in Croatia	Reference
* <i>Aonidiella aurantii</i> (Maskell, 1879) Diaspididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Rosen and DeBach, 1979; Ezzat, 1958; Balachowsky, 1932; Seljak, 2010; Franco et al., 2006; Rosen and DeBach, 1978; Viggiani, 1970; Blay Goicoechea, 1993; Franco et al., 2011	+	Masten Milek, 2007
<i>Aonidiella citrina</i> (Craw, 1890) Diaspididae	Turkey, Greece, Italy	Kaydan et al., 2007; Milonas et al., 2007; Longo et al., 2001	-	-
* <i>Aspidiotus nerii</i> Bouché, 1833 Diaspididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Gerson and Zor, 1973; Ezzat, 1958; Mansour et al., 2011; Seljak, 2010; Velimirović, 1985; Milonas et al., 2007; Viggiani, 1970; Blay Goicoechea, 1993; Fernandes, 1992	+	Masten Milek, 2007
* <i>Chrysomphalus dictyospermi</i> (Morgan, 1889) Diaspididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Ben-Dov, 1980; Ezzat, 1958; Balachowsky, 1932; Seljak, 2010; Velimirović, 1985; Milonas et al., 2007; Longo et al., 1995; Blay Goicoechea, 1993; Franco et al., 2011	+	Masten Milek, 2007
* <i>Chrysomphalus aonidium</i> (Linnaeus, 1758) Diaspididae	Turkey, Israel, Egypt, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Gerson and Zor, 1973; Ezzat, 1958; Seljak, 2010; Velimirović, 1985; Milonas et al., 2007; Pellizzari and Vacante, 2007; Martin-Mateo, 1983; Franco et al., 2011	+	Masten Milek, 2007
* <i>Hemiberlesia rapax</i> (Comstock, 1881) Diaspididae	Turkey, Israel, Egypt, Tunisia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Ben-Dov, 2012; Ezzat, 1958; Balachowsky, 1932; Velimirović, 1985; Milonas et al., 2007; Longo et al., 1995; Blay Goicoechea, 1993; Fernandes, 1992	+	Masten Milek, 2007
* <i>Lepidosaphes beckii</i> (Newman, 1869) Diaspididae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Bodenheimer, 1949; Bytinski-Salz, 1966; Hall, 1922; Danzig and Pellizzari, 1998; Seljak, 2010; Velimirović, 1985; Milonas et al., 2007; Longo et al., 1995; García-Marí and Rodrigo, 1995; Franco et al., 2011	+	Masten Milek, 2007
* <i>Lepidosaphes glowerii</i> (Packard, 1869) Diaspididae	Turkey, Egypt, Tunisia, Greece, Italy, Spain, Portugal	Danzig and Pellizzari, 1998; Abd-Rabou, 2001; Milonas et al., 2007; Longo et al., 1995; Gómez-Menor Ortega, 1937; Franco et al., 2011	+	Masten Milek, 2007
* <i>Parlatoria ziziphi</i> (Lucas, 1853) Diaspididae	Turkey, Egypt, Tunisia, Greece, Italy, Spain, Portugal	Kaydan et al., 2013; Abd-Rabou, 1999; Danzig and Pellizzari, 1998; Milonas et al., 2007; Longo et al., 1995; Blay Goicoechea, 1993; Franco et al., 2011	+	Masten Milek, 2007
<i>Unaspis citri</i> (Comstock, 1883) Diaspididae	Egypt, Portugal	Newstead, 1907; Franco et al., 2011	-	-
* <i>Ceroplastes japonicus</i> (Green, 1921) Coccidae	Turkey, Slovenia, Italy	Fetykó and Kozár, 2012; Seljak, 2008; Kozár et al., 1984	+	Masten Milek, 2007

Table 2. Continued

Species	Presence in citrus growing areas in the Mediterranean basin	Reference	Presence in Croatia	Reference
* <i>Ceroplastes rusci</i> (Linnaeus, 1758) Coccidae	Turkey, Israel, Egypt, Tunisia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Hodgson, 1994; Ezzat and Hussein, 1969; Fetykó and Kozár, 2012; Velimirović, 1985; Kozár et al., 1991; Longo et al., 1995; Gómez-Menor Ortega, 1948; Carvalho et al., 1996	+	Masten Milek, 2007
* <i>Ceroplastes sinensis</i> (Del Guercio, 1900) Coccidae	Turkey, Egypt, Tunisia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Hall, 1924; Hodgson and Peronti, 2012; Velimirović, 1985; Milonas et al., 2007; Longo et al., 1995; Carvalho et al., 1996	+	Masten Milek, 2007
* <i>Coccus hesperidum</i> Linnaeus, 1758 Coccidae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Uygun et al., 1998; Ben-Dov, 1993; Ezzat and Hussein, 1969; Jarraya, 1970; Seljak, 2010; Velimirović, 1985; Kozár et al., 1991; Longo et al., 1995; Lin et al., 2013; Carvalho et al., 1996	+	Masten Milek, 2007
* <i>Coccus pseudomagnoliarum</i> (Kuwana, 1914) Coccidae	Turkey, Israel, Slovenia, Montenegro, Greece, Italy, Spain	Kaydan et al., 2007; Ben-Dov, 1993; Seljak, 2010; Velimirović, 1985; Ben-Dov, 1993; Marotta, 1987; Tena and Garcia-Mari, 2008	+	Masten Milek, 2007
<i>Parasaissetia nigra</i> (Nietner, 1861) Coccidae	Turkey, Israel, Egypt, Italy, Spain, Portugal	Kaydan et al., 2007; Ben-Dov, 1993; Ezzat and Hussein, 1969; Pellizzari, 2010; Gómez-Menor Ortega, 1958; Fernandes, 1992	-	-
* <i>Parthenolecanium persicae</i> (Fabricius, 1776) Coccidae	Turkey, Israel, Egypt, Slovenia, Greece, Italy, Spain, Portugal	Kaydan et al., 2007; Ben-Dov and Drishpoun, 2012; Ezzat and Hussein, 1969; Seljak, 2010; Stathas, 2004; Marotta, 1987; Gómez-Menor Ortega, 1960; Carvalho et al., 1996	+	Masten Milek, 2007
* <i>Saissetia coffeae</i> (Walker, 1852) Coccidae	Turkey, Israel, Egypt, Slovenia, Greece, Italy, Spain, Portugal	Ben-Dov, 1993; Rosen et al., 1971; Ezzat and Hussein, 1969; Seljak, 2008; Ben-Dov, 1993; Longo et al., 1995; Gómez-Menor Ortega, 1965; Carvalho et al., 1996	+	Masten Milek, 2007
* <i>Icerya purchasi</i> Maskell, 1878 Margarodidae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Uygun et al., 1998; Mendel and Blumberg, 1991; Ezzat and Nada, 1987; UK, CAB International, 1971; Seljak, 2010; Velimirović, 1985; Milonas et al., 2007; Barbagallo et al., 1995; Martin-Mateo, 1985; Fernandes, 1992	+	Masten Milek, 2007
* <i>Planococcus citri</i> (Risso, 1813) Pseudococcidae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Uygun et al., 1998; Ben-Dov, 1994; Mahfoudhi and Dhouibi, 2009; Seljak, 2010; Velimirović, 1985; Michelakis and Hamid, 1995; Longo et al., 1995; Martin-Mateo, 1985; Carvalho et al., 1996	+	Masten Milek, 2007
* <i>Pseudococcus longispinus</i> (Targioni Tozzetti, 1867) Pseudococcidae	Turkey, Israel, Egypt, Tunisia, Slovenia, Montenegro, Greece, Italy, Spain, Portugal	Kaydan et al., 2013; Ben-Dov, 1994; Seljak, 2010; Velimirović, 1985; Milonas and Kozár, 2008; Longo et al., 1995; Carvalho et al., 1996	+	Masten Milek, 2007

\* Found on citrus plants in Croatia

### Whiteflies

Whiteflies belong to only one family Aleyrodidae which, according to Martin and Mound (2007), comprises of 1,556 whiteflies registered all around the world listed in 161 order. According to Evans (2008) 90 species of whiteflies may appear on citrus plants and only 9 species are registered to make serious damage in intensive citrus production. Data on distribution of mentioned species are given in Table 3. Whiteflies have successfully adapted to environmental factors within the areas of citrus

production (Rapisarda et al., 1990), but only 3 species are reported as economically important pests on citrus plants in the Mediterranean: *Dialeurodes citri* (Ashmead, 1885), *Aleurothrixus floccosus* (Maskell, 1896) and *Parabemisia myricae* (Kuwana, 1927) (Barbagalo et al., 1986; Žanić et al., 2000). In Croatia have been determined 30 species of whiteflies listed in 18 different genera and 5 species out of that number were found on citrus plants (Šimala, 2008; Žanić et al., 2012; Šimala et al., 2013; 2019).

**Table 3.** List of whiteflies that may feed on citrus plants recorded in the Mediterranean basin and Croatia

Species	Presence in citrus growing areas in the Mediterranean basin	Reference	Presence in Croatia	Reference
* <i>Aleurothrixus floccosus</i> (Maskell, 1866) Aleyrodidae	Turkey, Israel, Egypt, Tunisia, Greece, Italy, Spain, Portugal	Özer and Kismali, 2003; Roll et al., 2007; Genduso and Liotta, 1976/1980; Chermiti et al., 1993; Anagnou-Veroniki et al., 2008; Ippolito and Laccone, 1987; Carvalho, 1994	+	Žanić et al., 2012
* <i>Aleurocanthus spiniferus</i> Quaintance, 1903 Aleyrodidae	Montenegro, Italy	Radonjić et al., 2014; Porcelli, 2008	+	Šimala, 2013; Šimala et al., 2019
* <i>Bemisia tabaci</i> (Gennadius, 1889) Aleyrodidae	Turkey, Israel, Egypt, Tunisia, Montenegro, Greece, Italy, Spain, Portugal	Ozgun et al., 1989; Bink-Moenen and Gerling, 1992; Abdel-Gawaad et al., 1990; Gorsane et al., 2011; Hrnčić et al., 2012; Mound and Halsey, 1978; Minelli et al., 1995; Guirao et al., 1997	+	Šimala, 2008
* <i>Dialeurodes citri</i> (Ashmead, 1885) Aleyrodidae	Turkey, Israel, Egypt, Greece, Italy, Spain	Uygun et al., 1990; Bink-Moenen and Gerling, 1992; Nada, 1988-1989; Minelli et al., 1995; International Institute of Entomology, 1996	+	Šimala, 2008
* <i>Parabemisia myricae</i> (Kuwana, 1927) Aleyrodidae	Turkey, Israel, Egypt, Tunisia, Greece, Italy, Spain, Portugal	Öztemiz & Doğanlar, 2015; Bink-Moenen and Gerling, 1992; Abd-Rabou, 2011; EPPO, 1992; Michalopoulos, 1989; Minelli et al., 1995; Garrido, 1995; Franco et al., 1996	+	Šimala et al., 2016
<i>Siphoninus phillyreae</i> (Haliday, 1835) Aleyrodidae	Turkey, Israel, Egypt, Tunisia, Greece, Italy, Spain, Portugal	CABI/EPPO, 2013; Bink-Moenen and Gerling, 1992; Mound and Halsey, 1978; CABI/EPPO, 2013; Evans, 2008; Rapisarda and Patti, 1983	+	Šimala, 2008

\* Found on citrus plants in Croatia

**Table 4.** List of psyllids that may feed on citrus plants recorded in the Mediterranean basin

Species	Presence in citrus growing areas in the Mediterranean basin	Reference
<i>Agonoscena cisti</i> (Puton, 1882) Aphalaridae	Turkey, Israel, Greece, Italy, Spain	Burckhardt and Önuçar, 1993; Halperin et al., 1982; Burckhardt, 1988; Conci et al., 1993; Hodkinson and Hollis, 1981
<i>Trioza erytrae</i> (Del Guercio, 1918) Triozidae	Spain, Portugal	Llorens Climent, 2009; Tumminelli et al., 2006

### Psyllids

Psyllids belong to the superfamily of Psylloidea and constitute an important component of the hemipterous fauna. The Psylloidea comprises of more than 1,500 species and most of them are associated with only a few corresponding host plants, and are relatively specific in their food selection (Aubert, 1987).

According to Psyllist internet data base (2020), 17 psyllid occurs on citrus plants: *Agonoscena cisti* (Puton, 1882), *Cacopsylla citricola* (Yang & Li, 1984), *Cacopsylla citrisuga* (Yang & Li, 1984), *Cacopsylla heterogena* Li, 2011, *Cacopsylla murrayi* (Mathur, 1975), *Diaphorina amoena* Capener, 1970, *Diaphorina auberti* Hollis, 1987, *Diaphorina citri* Kuwayama, 1908, *Diaphorina communis* Mathur, 1975, *Diaphorina punctulata* (Petty, 1924), *Diaphorina zebrana* Capener, 1970, *Leuronota fagarae* Burckhardt, 1988, *Mesohomotoma lutheri* (Enderlein, 1918), *Powellia vitreoradiata* Maskell, 1879, *Trioza citroimpura* Yang & Li, 1984, *Trioza erytrae* (Del Guercio, 1918) and *Trioza litseae* Bordage, 1898. Up to now there were no faunistic research on presence of psyllids on citrus plants and it is unknown if some of above listed species are present on Croatian territory, therefore data listed in Table 4. refer to psyllids present in selected countries in the Mediterranean.

### DISCUSSION

The results presented in Tables 1-4 show the presence of 37 insects from the Sternorrhyncha suborder in Croatia that may feed on citrus plants and 25 species out of 37 are determined on citrus plants. With regard to Mediterranean basin, the majority of psyllids that may feed on citrus are absent from the selected countries as well

as aphids *Aulacorthum magnoliae*, *Sinomegoura citricola*, *Toxoptera odinae* and whiteflies harmful to citrus plants *Paraleyrodes citri*, *Dialeurodes citrifolii* and *Aleurocanthus woglumi*. Based on pest distribution given in Tables 1-4, their potential to spread, growth of international trade and suitable climatic and environmental conditions, several phytophagous insects have a potential for introduction and establishment in Croatia.

*Toxoptera citricida* is present Tunisia, Spain and Portugal (Table 1). *T. citricida* mostly feeds on citrus plants, and the most favorable environment for its development is in warm and moisture areas, while in desert, semiarid and cold regions conditions for development are seasonable. Therefore, it is not likely that *T. citricida* can survive outside of the areas or climate respectively where citrus are grown. Investigations conducted in 2006 and 2007 have shown that *T. citricida* in Europe is distributed along the northwest coast of Iberian Peninsula from north Portugal to Cantabria (Hermoso de Mendoza et al., 2008).

*Aonidiella citrina* is most common on citrus plants and it is not as widely distributed as *Aonidiella aurantii* (Miller and Davidson, 2005). Many potential hosts of *A. citrina* have similar climatic requirements as citrus species and their geographic distributions overlap with the citrus-growing areas. Therefore, they are mainly distributed in the southern EU member states Portugal, Spain, France, Italy, Malta, Croatia, Greece and Cyprus, even though ornamental hosts are available throughout the EU (EFSA, 2014). On the EU territory *A. citrina* was found for the first time in 1994 in Calabria, Italy (Longo et al., 1995) when no serious damages on host plants were recorded and again in the same region in 2001 (Longo et al., 2001).



*Parasaissetia nigra* in Europe is naturalized in the Azores, Canary Islands, Madeira, Mediterranean coast of France, Corsica, Portugal and Spain (EFSA, 2013). Former findings confirm that in central and northern Europe *P. nigra* is rather common in greenhouses, while in southern Europe is more present outdoors (Pellizzari and Germain, 2010). In parts of south Europe (France, Italy, Portugal and Spain) *P. nigra* was found on several localities but population on those localities was too low to cause some serious damage, (Frank et al., 2013).

*Aleurothrixus floccosus* was introduced in South Europe in early 70s (Mound and Halsey, 1978; Žanić et al., 2000) and became one of major pests in citrus orchards in Italy (Barbagalo et al., 1986). A single findings of *A. floccosus* on citrus plants without outbreak were recorded in Croatia two times (Žanić et al., 2007; Šimala, 2008).

*Parabemisia myricae* in Palearctic region is recorded in Cyprus, Crete, Japan, Egypt, Greece, Italy including Sardinia and Sicily, Spain including Canary Islands, Tunisia and Turkey (Šimala et al., 2016). In Croatia, *P. myricae* was found once on Island Korčula in back-yard on lemon tree and paper mulberry *Broussonetia papyrifera* L. Ventenat. Preliminary risk assessment has shown that basic preconditions for introduction and spread of this pest are satisfied, similarly like in the case of *D. citri* and *A. floccosus* in the past (Šimala et al., 2016).

*Trioza erytreae* belongs to an African group of 10 species attacking four plant families Rutaceae, Menispermaceae, Araliaceae and Salicaceae. In the EU it was found in Spain (Llorens Climent, 2009) and Portugal (Tumminelli et al., 2006). Furthermore, it appeared again in 2014 in the north-western Iberian Peninsula and despite the initial insecticide treatments to eradicate it, *T. erytreae* is now spreading from the north-west to the south-west of the Iberian Peninsula (Pérez-Rodríguez et al., 2019).

From data given in Tables 1-4 it is obvious that several described insects originating in Asian countries have been recently discovered or even spread in EU countries in the Mediterranean. In Croatia that clearly confirms recent findings of *Aleurocanthus spiniferus* in nursery in Split (Šimala, 2013) and after a few years in citrus orchard

near the Montenegro border and in vineyard on the island of Hvar (Šimala et al., 2019) as well as single finding of *Parabemisia myricae* on host plants in house garden on the island of Korčula (Šimala et al., 2016).

Croatian citrus production is not so considerable like in other Mediterranean countries, but mandarin for example is a third important fruit culture in Croatia following apple and olive, with total growing area of around 2,100 hectares and fruit production from 20,000 to 65,000 metric tons in five-year period (Statistical Yearbook of the Republic of Croatia, 2018). Varieties and citrus species which are grown in Croatia are rather specific since the majority of production refers to mandarins from Satsuma group (Velimirović, 1985). The biggest area planted with Satsuma mandarin is situated in the Neretva river valley, whereas small commercial orchards are dispersed on Dalmatian islands, mostly on Brač and Vis (Gugić and Cukrov, 2011).

The risk from further introduction of phytophagous insects from the Sternorrhyncha suborder in Croatia is very high due to similar climatic conditions in coastal part of Croatia and Mediterranean countries where these insects are spread, which is the basic precondition for adaptation and sustainability of introduced species. In addition, apart from citrus plants there is a lot of other plant species which may be suitable hosts for introduced insects and could facilitate their active spread along the coast. Therefore, the synergy of international commercial pathways, satisfactory climatic conditions and abundance of host plants provides relatively easy entry into Croatia for mentioned insects, their further spread and consequently harmfulness for important citrus production and ornamental plants along the coastal part of the country.

## CONCLUSIONS

The most important fauna from the Sternorrhyncha suborder that may feed on citrus species and it is determined on different host plants in Croatia by literature review, includes 37 phytophagous insects (13 aphids, 18 scale insects and 6 whiteflies). 25 species out

of that number are determined on citrus plants (2 aphids, 18 scale insects and 5 whiteflies). By literature review it is determined that mentioned insects are also present in the selected countries in the Mediterranean, as well as some insects which are not found in Croatia and where in total by literature review it is determined 46 species (17 aphids, 21 scale insects, 6 whiteflies and 2 psyllids).

Based on their potential to cause damages, ability to spread, distribution in the neighbouring countries (Tables 1-4), suitable climatic conditions and abundance of different host plants along the Adriatic coast, the following species if introduced could be harmful for citrus growing areas in Croatia: *Toxoptera citricida*, *Aonidiella citrina*, *Parasaissetia nigra* and *Trioza erytrae*. Additionally, two whiteflies *Aleurothrixus floccosus* and *Parabemisia myricae* have been already found occasionally in Croatia on few locations so far without visible damages or yield loss.

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