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DIVERSITY OF CICADOMORPHA (HEMIPTERA: AUCHENORRHYNCHA) IN CITRUS ORCHARDS IN NORTHEASTERN ARGENTINA

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ABSTRACT

Among phytophagous insects, the Cicadomorpha are important economically because they damage crops by sucking plant sap and by transmitting plant pathogens, such as *Spiroplasma citri* and *Xylella fastidiosa* to citrus. In Argentina little knowledge exists about this subject. The aim of this work was to study the diversity of Cicadomorpha associated with citrus orchards in Entre Ríos province, and their seasonal fluctuation in relation with climatic and phenological conditions. A total of 1,554 specimens belonging to 28 species of Cicadomorpha were collected with yellow sticky traps in sweet orange (*Citrus* × *sinensis* (L.) Osbeck) and tangerine (*Citrus unshiu* Marc) orchards. The Shannon index and the Simpson index suggested a similar trend in the distribution of the dominant species in both crops. In the orange orchard, Cicadomorpha populations increased in the summer coincidently with temperature increases. On the other hand, a significant increase in abundance during the winter months was coincident with increase of early sprouts of the citrus plants. Entre Ríos province represents a new distribution record for 13 species. Tangerine is a newly recorded host-plant for 16 species studied, and eight species are reported for the first time on 'Valencia Late' orange.

Key Words: *Xylella fastidiosa*, Cicadellidae, Membracidae, Cercopidae, sweet orange, tangerine

RESUMEN

Dentro de los insectos fitófagos, los Cicadomorpha tienen importancia económica por ocasionar daños por succión de savia en plantas y transmitir fitopatógenos como *Spiroplasma citri* y *Xylella fastidiosa* en cítricos. En Argentina es escaso el conocimiento acerca de esta temática. El objetivo del trabajo fue estudiar la diversidad de los Cicadomorpha asociados a cultivos cítricos en la provincia de Entre Ríos y su fluctuación estacional en relación con las condiciones climáticas y fenológicas. Los especímenes se colectaron con trampas adhesivas amarillas. En total fueron colectados 1554 especímenes pertenecientes a 28 especies de Cicadomorpha en cultivos de naranja dulce (*Citrus* × *sinensis* (L.) Osbeck) y mandarina (*Citrus unshiu* Marc). Los valores del índice de Shannon, sugieren una tendencia similar en la distribución de las especies dominantes en ambos cultivos. Esto también fue reflejado por el índice de Simpson. En el cultivo de naranja, los Cicadomorpha presentaron incrementos poblacionales en verano, coincidentes con los aumentos de la temperatura. Por otro lado, el incremento en la abundancia de especímenes durante los meses de invierno, fue coincidente con el aumento de brotes tempranos en los cítricos. La provincia de Entre Ríos fue citada como nuevo registro de distribución para 13 especies. El cultivo de mandarina es un nuevo registro de planta huésped para 16 especies estudiadas, y ocho especies son registradas por primera vez sobre naranja Valencia.

Palabras Clave: *Xylella fastidiosa*, Cicadellidae, Membracidae, Cercopidae, naranja dulce, mandarina

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The citrus (Sapindales: Rutaceae) industry is the most economically important activity in the world fruit market. The major producers of citrus are Brazil, China and the United States. Argentina ranks ninth and its geographical position has allowed the country to become a supplier of fresh citrus fruit during the boreal summer. Citrus orchards are located in 2 regions: Northwest

(NOA) (Jujuy, Salta, Catamarca and Tucumán provinces) and Northeast (NEA) (Entre Ríos, Corrientes and Misiones provinces). The species grown mainly in NEA are sweet orange (*Citrus* × *sinensis* (L.) Osbeck) and tangerine (*Citrus unshiu* Marc) trees, which constitute 90% of agricultural production in this region (Segovia 2003; FEDERCITRUS 2011).

Among the most biodiverse lineages of phytophagous insects, the hemipteran infraorder Cicadomorpha comprises the superfamilies Cicadoidea (cicadas), Cercopoidea (spittlebugs and froghoppers) and Membracoidea (leafhoppers and treehoppers). To date, approximately 30,000 cicadomorphan species have been described worldwide (Dietrich 2002; Cryan 2005).

These insects have received much attention because of their economic importance. They can damage crops by sucking plant sap and transmitting plant disease organisms such as viruses, mollicutes and bacteria (Nielson 1968; Purcell 1985).

The causal agent of Citrus Stubborn Disease (CSD) is *Spiroplasma citri*, a phloem-limited mollicute that infects most citrus species as well as a wide range of non-rutaceous plant species. It is distributed in the United States, Northern Africa, the Mediterranean countries and Southeast Asia. CSD is naturally transmitted by leafhopper vectors such as *Circulifer tenellus* Baker and species of genus *Scaphytopius* Ball in the United States (Nejat et al. 2011).

Xylella fastidiosa Wells et al. 1987, is a xylem-limited bacterium that cause diseases such as 'Pierce's Disease' in grape (*Vitis vinifera* L.), 'Phony Peach Disease', 'Citrus Variegated Chlorosis' (CVC), and 'Leaf Scorch' in coffee, oleander, mulberry, oak, and maple, among others (Hopkins & Purcell 2002). It has a wider distribution in the Americas, from the United States to Argentina. Insect dissemination of *X. fastidiosa* is possible by vector insects belonging to the families Cicadellidae (leafhoppers) and Cercopidae (spittlebugs) (Redak et al. 2004). Recently species of Membracidae (treehoppers) have also tested DNA positive for *X. fastidiosa* in oaks (Zhang et al. 2011).

In citrus orchards, *X. fastidiosa* causes 'Citrus Variegated Chlorosis' (CVC), which was detected in northeastern Argentina in 1984 and in Brazil 3 yr later (Hopkins & Purcell 2002). This disease is considered a potential threat to the production of oranges, if a suitable vector is present (Damsteegt et al. 2006). In total, 11 species of leafhoppers have been shown to be vectors of CVC in Brazil (Lopes 1996; Gravena et al. 1998; Parra et al. 2003).

In Argentina, studies conducted by De Coll et al. (1996, 2000) in Misiones province revealed that many species of cicadomorphs were able to acquire *X. fastidiosa*, including leafhoppers: *Bucephalogonia xanthophis* (Berg), *Diedrocephala bimaculata* (Gmelin), *Hortensia similis* (Walker) *Macugonalia cavifrons* (Stål), *Sibovia sagata* (Signoret), *Sonesimia grossa* (Signoret), *Frequenamia spiniventris* (Linnavuori), *Scaphytopius bolivianus* (Oman), *Curtara samera* De Long & Freytag; and treehoppers: *Ceresa ustulata* Fairmaire, *Entylia carinata* (Forster). CVC was also observed in Corrientes province, where species associated with citrus were studied (Beltrán et al. 2004). In the last decade, CVC has been recorded in Concordia department, Entre Ríos province (Costa et al. 2009) in sweet orange and tangerine, but the insects associated with the affected orchards have not yet been studied.

Considering the importance of these insects for the transmission of *X. fastidiosa* and other plant pathogens, the aim of this work was to study the diversity of Cicadomorpha associated with citrus orchards in Entre Ríos province, Argentina, and their seasonal fluctuation in relation with climatic and phenological conditions.

The knowledge of cicadomorph species composition in citrus orchards and their abundance in the community are essential for integrated pest management, and can be used to predict situations that favor population peaks of these insects.

Materials and Methods

Study Sites and Record of Climatic and Phenological Conditions

The study was conducted at the Agricultural Experimental Station of INTA, in Concordia department, Entre Ríos, Argentina (S 31° 22' 27" W 58° 06' 59"; 46 m asl). Two orchards were chosen as study sites: sweet orange, variety 'Valencia Late', grafted onto trifoliate orange (*Poncirus trifoliate* (L.) Raf.), planted at 7 × 3.5 m row spacing, which were 25 yr-old at the beginning of the experiment (779 trees); and tangerine orchard, variety 'Satsuma Okitsu' (*Citrus unshiu* Marc), grafted onto trifoliate orange, planted at 5 × 2 m row spacing, 12 yr-old at the beginning of the experiment (200 trees).

Between 2006 and 2009, the phenological stages of sweet orange plants were recorded monthly as follows: F1 (early sprouts), F2 (elongating shoots, small leaves), F3 (elongated shoots, leaves completing expansion), F4 (leaves reaching final size), and F5 (no new shoots, twigs and leaves predominantly adult). Meteorological data were collected by the weather station located in the Agricultural Experimental Station of INTA, in Concordia, Entre Ríos.

Sampling Method and Specimen Identification

The specimens were collected with yellow sticky traps, measuring 12.5 × 10 cm, installed at 1.5 m height. Four traps were installed in the orange orchard, and in the tangerine orchard 2

TABLE 1. ABUNDANCE (N) AND SPECIES RICHNESS (S) OF CICADOMORPHA FAMILIES, ON SWEET ORANGE AND TANGERINE ORCHARDS IN ENTRE RÍOS.

	Orange		Tangerine	
Superfamily/Family	N	S	N	S
CERCOPOIDEA (Spittlebugs, Froghoppers)				
Aphrophoridae	3	1	6	1
Cercopidae	3	1	3	1
MEMBRACOIDEA				
Cicadellidae (Leafhoppers)	1013	17	435	15
Membracidae (Treehoppers)	49	5	42	3
Total Identified	1038	24	447	20
TOTAL	1068		486	

traps (1 trap per 100 plants, approximately) (Felippe et al. 2006); traps were replaced every 2 wk between Oct 2006 and Jan 2009. The specimens collected from sticky traps were removed using benzene to dissolve the glue and separately placed in plastic tubes with 70% alcohol.

Taxonomic terminology for the Cicadomorpha at the family and subfamily levels followed Remes Lenicov et al. (1999) and Dietrich (2005). Species identifications were based on literature available for identifying leafhoppers: Lawson (1931), Christensen (1942), Linnavuori (1959), Nielson (1968), De Long & Freytag (1976), and Young (1952, 1968, 1977); treehoppers: Barreira & Sakakibara (2001) and Andrade (2004a, 2004b), and spittlebugs: Torres (1950) and Costa & Sakakibara (2002). The collected specimens were deposited in the Entomological Collection of Museo de La Plata, Argentina (MLP). Material that was damaged by removal from the traps could not be identified.

The geographic distribution for each identified species was taken from the literature and summarized in a table, along with the new information provided by this work.

Data Analysis

The Cicadomorpha samples were identified to the subfamily and species level and counted under a stereo microscope. Total numbers of collected individuals (N) and species (S) were recorded monthly.

The relative importance (RI) of a species takes into account not only its abundance but also its

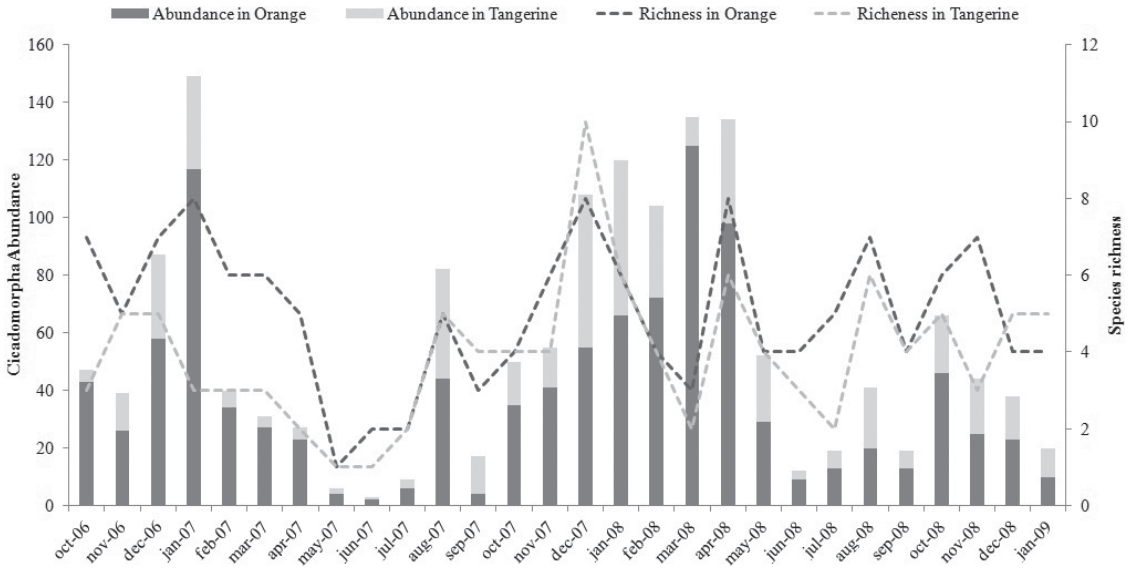

Fig. 1. Seasonal abundance and species richness of Cicadomorpha on sweet orange and tangerine orchards in Entre Ríos during 2006-2009.

TABLE 2. ABUNDANCE (N) AND RELATIVE IMPORTANCE (RI) OF CICADOMORPHA SPECIES COLLECTED FROM SWEET ORANGE AND TANGERINE ORCHARDS IN ENTRE RÍOS.

Family/ Subfamily	Species	Orange		Tangerine	
		N	RI	N	RI
	CERCOPOIDEA				
APHROPHORIDAE					
Aphrophorinae	*Cephisus siccifolius* (Walker)	3	*	6	**
CERCOPIDAE					
Tomaspidinae	*Deois* sp.	3	*	2	*
Unidentified		0		1	
	MEMBRACOIDEA				
CICADELLIDAE					
Agallinae	*Agalliana ensigera* Oman	28	**	0	
	Unidentified	9		3	
Cicadellinae	*Bucephalogonia xanthophis* (Berg)	1	*	7	**
	Diedrocephala bimaculata (Gmelin)	1	*	2	**
	Hortensia similis (Walker)	0		1	*
	Macugonalia cavifrons (Stål)	2	*	1	*
	*Molomea lineiceps*Young	99	***	37	***
	Sibovia sagata (Signoret)	0		1	*
	Sonesimia grossa (Signoret)	0		1	*
	Tapajosa rubromarginata Signoret	29	**	45	***
	Tretogonia notatifrons Melichar	1	*	0	
	Unidentified	0		7	
Deltocephalinae	*Amplicephalus marginellanus* Linnavuori	0		1	*
	Atanus serricauda (Linnavuori)	1	*	0	
	Atanus sp.	1	*	0	
	Balclutha sp.	1	*	0	
	Dalbulus maidis (De Long & Wolcott)	2	*	0	
	Frequenamia spiniventris Linnavuori & De Long	570	***	203	***
	Osbornellus infuscatus Linnavuori	12	**	10	**
	Scaphytopius bolivianus (Oman)	169	***	82	***
	Unidentified	14		24	
Gyponinae	*Curtara samera* (De Long & Freytag)	9	**	4	**
	Unidentified	3		1	
Typhlocybinae	*Protalebrella brasiliensis* Young	51	**	1	*
	Unidentified	4		2	
Xerophloeinae	*Xerophloea viridis* (Fabricius)	6	**	2	*
	MEMBRACIDAE				
Smiliinae	*Ceresa* sp.	7	**	7	**
	Cyphonia sp.	35	**	31	***
	Unidentified	0		1	
	Sp1	4	*	3	**
	Sp2	2	**	0	
	Sp3	1	*	0	

(*) Rare or occasional, (**) Frequent, (***) Very frequent

TABLE 3. DIVERSITY INDEXES OF CICADOMORPHA ON SWEET ORANGE AND TANGERINE ORCHARDS IN ENTRE RÍOS.

Index	D_{Mg}	H'	D
Orange	3.312	1.6	0.342
Tangerine	3.113	1.8	0.261

D_{Mg} is the specific richness index of Margalef. H' is the Shannon-Wiener, and D is the dominance index of Simpson.

occurrence or frequency. Thus, species poorly represented in terms of individual numbers but frequently recovered over a long period can be balanced with abundant species with sporadic occurrence (Remes Lenicov & Virla 1993; Murúa et al. 2006). For each sampled site the relative importance of species was determined using the formula: $RI = (n_i/n_t) \times (m_i/m_t) \times 100$, where n_i = number of individuals of species "i", n_t = number of individuals of all species, m_i = number of samples containing species "i", and m_t = total number of samples. A "very frequent" species is defined as having a RI equal to or higher than 1%, the RI of "frequent" species lies between 0.02% and 0.99%; and "rare or occasional" species have a RI equal to or lower than 0.019% (Paradell et al. 2001).

Community or habitat diversity, can be measured by methods that consider only the number of species (Margalef's index), or methods that highlight the structure of the community considering both the number of species and their relative importance. Such methods may highlight the dominance of a few species (Simpson's index), or else the degree of evenness among the whole set of species (Shannon-Wiener's index). The specific richness index of Margalef (D_{Mg}), the Shannon-Wiener index (H'), and the dominance index of Simpson (D) were calculated as follows: $H' = -\Sigma p_i \times \log 2p_i$; $D = 1-\Sigma (p_i)^2$; $D_{Mg} = S-1/LnN$; where $p_i = n_i/N$, n_i = number of individuals of species "i", N = number of individuals of all species, and S = number of species (Moreno 2001).

Seasonal fluctuation of Cicadomorpha in sweet orange orchards was evaluated through monthly values of collected individuals and analyzed with respect to climatic and phenological variables.

RESULTS AND DISCUSSION

A total of 1,554 specimens were collected (1,068 on sweet orange and 486 in tangerine plants) belonging to 4 families of Cicadomorpha, of which Cicadellidae was the most abundant in both orchards, followed by Membracidae. Other studies in citrus have shown similar results in terms of higher abundance of Cicadellidae (De Coll et al. 2006; Giustolin et al. 2009). Of all collected specimens, 95.56% (1,485 specimens) were identified and used in further analysis (Table 1).

The number of collected specimens varied between samples (Fig. 1). The highest number was obtained in Jan 2007 (N = 149) and the lowest number in Jun 2007 (N = 3).

In total, 28 species of Cicadomorpha were collected. Of these, 24 species were found in the orange orchard, while 20 species were collected in

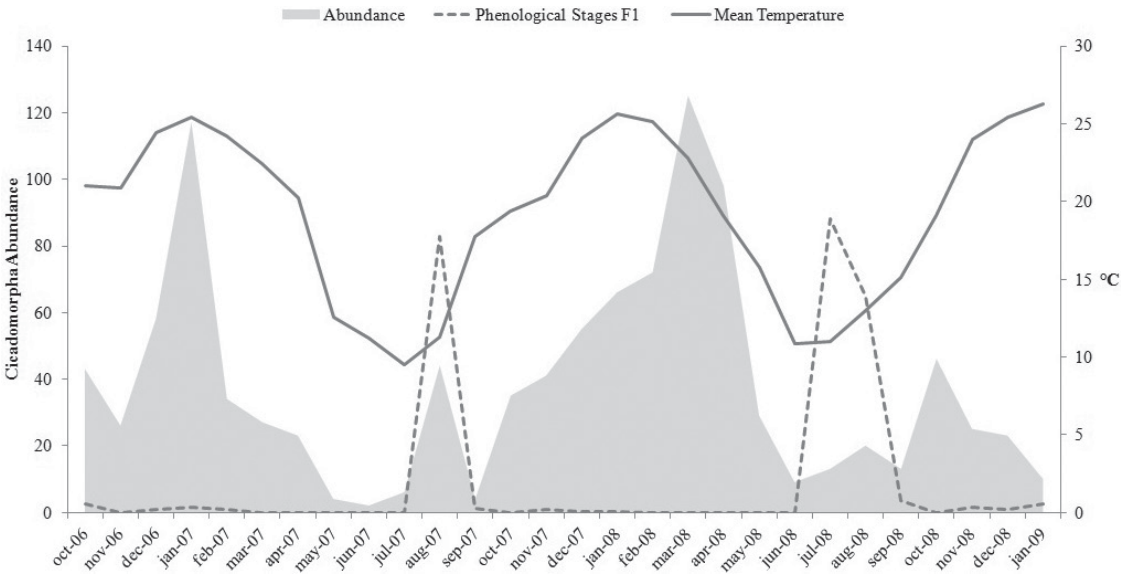

Fig. 2. Relationships between climatic and phenological conditions and seasonal abundance of Cicadomorpha on sweet orange orchards in Entre Ríos during 2006-2009.

TABLE 4. GEOGRAPHIC DISTRIBUTION OF CICADOMORPHA COLLECTED SPECIES AND THEIR ASSOCIATION WITH CITRUS ORCHARDS IN ENTRE RÍOS.

Species	Geographic Distribution	Host Plants
Agalliana ensigera Oman	Brazil; Bolivia; Argentina: Salta, Jujuy, Tucumán, Córdoba, San Juan, Mendoza, Chaco, Misiones, Buenos Aires, La Pampa, Río Negro[7,10]. New record for Entre Ríos province	New record of *Citrus sinensis* (L.) Obs.
Amplicephalus marginellanus Linnavuori	Brazil; Bolivia; Paraguay; Argentina: Jujuy, Tucumán, Córdoba, San Luis, Chaco, Santa Fe, Misiones, Corrientes, Entre Ríos, Buenos Aires[7]	New record of *Citrus unshiu* Marc.
Atanus serricauda (Linnavuori)	Argentina: Tucumán, San Luis, Santa Fe[6]. New record for Entre Rios province	New record of *Citrus sinensis* (L.) Obs.
Bucephalogonia xanthophis (Berg)	Brazil; Bolivia; Argentina: Jujuy, Córdoba, Santa Fe, Misiones, Corrientes, Mendoza, Salta, Buenos Aires[1,2,13,17]. New record for Entre Ríos province	*Citrus sinensis* (L.) Obs.[1, 13] New record of *Citrus unshiu* Marc.
Cephisus siccifolius (Walker)	Mexico; Central America; Brazil; Paraguay; Uruguay; Argentina: Salta, Tucumán, Misiones, Buenos Aires[3]. New record for Entre Ríos province.	*Citrus sinensis* (L.) Obs.[3] New record of *Citrus unshiu* Marc.
Curtara samera De Long & Freytag	Brazil; Argentina: Jujuy, Misiones[8]. New record for Entre Ríos province	*Citrus sinensis* (L.) Obs.[8] New record of *Citrus unshiu* Marc.
Dalbulus maidis (De Long & Wolcott)	United States; Mexico; Central America; Colombia; Venezuela; Peru; Brazil; Bolivia; Argentina: Salta, Jujuy, Catamarca, Tucumán, Santiago del Estero, Chaco, Santa Fe, Entre Ríos, Buenos Aires[5,7,12,15].	New record of *Citrus sinensis* (L.) Obs.
Diedrocephala bimaculata (Gmelin)	Mexico; Honduras; El Salvador; Nicaragua; Costa Rica; Panama; Colombia; Venezuela; Guyana; Suriname; French Guiana; Peru; Brazil; Bolivia; Paraguay; Argentina: Tucumán, Chaco, Misiones, Santa Fe, Corrientes[1,13,17]. New record for Entre Ríos province.	*Citrus sinensis* (L.) Obs.[1,13] New record of *Citrus unshiu* Marc.
Frequenamia spiniventris Linnavuori & De Long	Brazil; Paraguay; Argentina: Misiones, Corrientes[1,8]. New record for Entre Rios province	*Citrus sinensis* (L.) Obs.[1,8] New record of *Citrus unshiu* Marc.
Hortensia similis (Walker)	United States; Mexico; Puerto Rico; Nicaragua; Panama; Antilles; Cuba; Colombia; Venezuela; Suriname; Guyana; French Guiana; Ecuador; Peru; Bolivia; Brazil; Paraguay; Argentina: Misiones, Corrientes, Santa Fe, Entre Ríos, Buenos Aires, Salta, Jujuy, Chaco[11,13,14,17]	*Citrus sinensis* (L.) Obs.[1,13,17] New record of *Citrus unshiu* Marc.
Macugonalia cavifrons (Stål)	Venezuela; Colombia; Peru; Brazil; Bolivia; Paraguay; Argentina: Misiones[13,17]. New record for Entre Ríos province	*Citrus sinensis* (L.) Obs.[13] New record of *Citrus unshiu* Marc.

[1]Beltrán et al. 2004, [2]Catalano 2011, [3]De Coll 1996, [4]Dellapé et al. 2011, [5]Gimenez Pecci et al. 2002, [6]Linnavuori 1959, [7]Paradell 1995, [8]Paradell et al. 2000, [9]Paradell et al. 2012, [10]Remes Lenicov 1982, [11]Remes Lenicov & Tesón 1985, [12]Remes Lenicov et al. 1997, [13]Remes Lenicov et al. 1999, [14] Remes Lenicov et al. 2006, [15]Saluso 2006, [16] Young 1968, [17]Young 1977.

TABLE 4. (CONTINUED) GEOGRAPHIC DISTRIBUTION OF CICADOMORPHA COLLECTED SPECIES AND THEIR ASSOCIATION WITH CITRUS ORCHARDS IN ENTRE RÍOS.

Species	Geographic Distribution	Host Plants
Molomea lineiceps Young	Brazil; Paraguay; Argentina: Córdoba, Corrientes, Entre Ríos[1,16]	*Citrus sinensis* (L.) Obs.[1] New record of *Citrus unshiu* Marc.
Osbornellus infuscatus Linnavuori	Brazil; Paraguay; Argentina: Tucumán, Córdoba, Formosa, Misiones, Buenos Aires[6]. New record for Entre Ríos province	New record of *Citrus sinensis* (L.) Obs. and *C. unshiu* Marc.
Protalebrella brasiliensis Young	United States; Mexico; Central America; Colombia; Venezuela; Ecuador; Brazil; Bolivia; Paraguay; Argentina: Tucumán, Córdoba, Mendoza, Chaco, Santa Fe, Misiones, Entre Ríos[2]	New record of *Citrus sinensis* (L.) Obs. and *C. unshiu* Marc.
Scaphytopius bolivianus (Oman)	Bolivia; Argentina: Misiones[8]. New record for Entre Ríos province	*Citrus sinensis* (L.) Obs.[8] New record of *Citrus unshiu* Marc.
Sibovia sagata (Signoret)	United States; Mexico; Antilles; Brazil; Bolivia; Argentina: Jujuy, Misiones, Corrientes, Buenos Aires[13,17]. New record for Entre Ríos province	*Citrus sinensis* (L.) Obs.[13] New record of *Citrus unshiu* Marc.
Sonesimia grossa (Signoret)	Brazil; Bolivia; Paraguay; Argentina: Misiones, Corrientes[1,13,17]. New record for Entre Rios province	*Citrus sinensis* (L.) Obs.[1,13] New record of *Citrus unshiu* Marc.
Tapajosa rubromarginata Signoret	Brazil; Paraguay; Argentina: Salta, Tucumán, Chaco, Córdoba, Entre Ríos [4,7,9,12,14,16].	New record of *Citrus sinensis* (L.) Obs. and *C. unshiu* Marc.
Tretogonia notatifrons Melichar	Suriname; French Guiana; Brazil; Ecuador; Bolivia; Paraguay; Argentina: Chaco, Misiones, Corrientes, Córdoba, Entre Ríos, Buenos Aires[11,16]	New record of *Citrus sinensis* (L.) Obs.
Xerophloea viridis (Fabricius)	United States; Mexico; Venezuela; Peru; Brazil; Bolivia; Argentina: Salta, Catamarca, Tucumán, Santiago del Estero, Córdoba, Neuquén, Chaco, Misiones, Santa Fe, Buenos Aires[8]. New record for Entre Ríos province	Weeds associated with citrus[8] New record of *Citrus sinensis* (L.) Obs. and *C. unshiu* Marc.

[1]Beltrán et al. 2004, [2]Catalano 2011, [3]De Coll 1996, [4]Dellapé et al. 2011, [5]Gimenez Pecci et al. 2002, [6]Linnavuori 1959, [7]Paradell 1995, [8]Paradell et al. 2000, [9]Paradell et al. 2012, [10]Remes Lenicov 1982, [11]Remes Lenicov & Tesón 1985, [12]Remes Lenicov et al. 1997, [13]Remes Lenicov et al. 1999, [14] Remes Lenicov et al. 2006, [15]Saluso 2006, [16] Young 1968, [17]Young 1977.

tangerine trees, and 16 were shared by both study sites. Cicadellidae presented the highest species richness in both orchards (Table 1).

Species composition also varied between different months. The highest value of species richness was recorded in Jan and Dec 2007, and Apr 2008 for the orange orchard (S = 8) and only in Dec 2007 for tangerines (S = 10). The lowest species richness was recorded in May 2007 in both orchards (S = 1) (Fig. 1).

Frequenamia spiniventris was the most abundant species in all samples with 773 specimens, followed by the leafhoppers *S. bolivianus* (251 specimens), *Molomea lineiceps* Young (136), *Tapajosa rubromarginata* Signoret (74), and the treehoppers *Cyphonia* sp. with 66 specimens. All other species comprised less than 60 collected specimens (Table 2). Other studies conducted in Argentina have shown similar results, although *F. spiniventris* was more abundant in weeds associated with citrus (Beltrán et al. 2004; De Coll et al. 2006).

Frequenamia spiniventris was also the most frequent species in all samples, followed by *S. bolivianus* and *M. lineiceps*. The species *T. rubromarginata* had not been previously reported in citrus, whereas in this study it was very frequent in the tangerine orchard and frequent in oranges, similarly to *Cyphonia* sp. (Table 2).

Other frequent species in the sweet orange orchard were *Osbornellus infuscatus* Linnavuori, *Curtara samera* (De Long & Freytag), *Ceresa* sp., *Agalliana ensigera* Oman, *Protalebrella brasiliensis* Young, and *Xerophloea viridis* (Fabricius). The first 3 were also frequent in tangerine, along with *Cephisus siccifolius* (Walker), *B. xanthophis* and *D. bimaculata* (Table 2). The remaining species were rare or occasional in both orchards. Similar results have been obtained by studies in Brazil (Molina et al. 2006; Nunes et al. 2007; Menegatti et al. 2008; Miranda et al. 2009; Molina et al. 2010), where *Dilobopterus costalimai* Young was the dominant species; but other research has shown *B. xanthophis* as the most abundant and frequent species on citrus (Yamamoto et al. 2001; 2002; Coelho et al. 2008).

Both orchards presented high species richness with D_{Mg} = 3.312 for sweet orange, and D_{Mg} = 3.113 for tangerine. For the diversity analysis we used the Shannon-Wiener index and the Simpson dominance index. The results obtained for the Shannon index in the orange (H' = 1.6) and tangerine orchards (H' = 1.8) suggested a similar trend in the distribution of dominant species. This was also reflected by the Simpson index with D = 0.342 for orange and D = 0.261 for tangerine) (Table 3).

In sweet orange orchards, Cicadomorpha presented 2 population increases throughout the sample: 1 in the summer, between the months of Dec and Feb; and another in the winter (Jul-Aug). Results also showed that temperature increases (spring and summer) were coincident with increases in abundance of specimens. On the other hand, a significant increase in the number of specimens during winter months was coincident with the increases of early sprouts (phenological stage F1) of the citrus plants (Fig. 2).

Most Cicadomorpha tend to be extremely polyphagous and range widely within a number of agricultural and native plant communities (Redak et al. 2004; Giustolin et al. 2009). Citrus are not primary but occasional hosts for them, while other alternative host plants are also important for the development of the different cicadomorphan species (Milanez et al. 2001). This may explain why the number of collected insects was so low in some months during the sampling. These studies require further analysis, since species with a wide range of host plants will exhibit low seasonality (Novotny 1998).

Following a literature review, all known information on geographic distribution of the species found in this study and their associations with citrus was summarized in Table 4. Entre Ríos province was cited as a new distribution record for the following species: *A. ensigera*, *Atanus serricauda* (Linnavuori), *B. xanthophis*, *C. siccifolius*, *C. samera*, *D. bimaculata*, *F. spiniventris*, *M. cavifrons*, *O. infuscatus*, *S. bolivianus*, *S. sagata*, *S. grossa*, and *X. viridis*.

Tangerine represents a new record as hostplant for all species studied here, while the occurrence of *A. ensigera*, *A. serricauda*, *Dalbulus maidis* (De Long & Wolcott), *O. infuscatus*, *P. brasiliensis*, *T. rubromarginata*, *Tretogonia notatifrons* Melichar, and *X. viridis* in Valencia Late Orange is reported for the first time (Table 4).

The present work, along with research conducted by De Coll (1996, 2000, 2006), Remes Lenicov et al. (1999) and Paradell et al. (2000), gathers all information about diversity, frequency and seasonal fluctuation of Hemiptera Cicadomorpha associated with citrus orchards in Argentina. This knowledge is essential for the control of the vectors of one of the most important diseases of citrus in America.

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References Cited

Andrade, G. S. 2004a. Uma nova espécie do genero *Cyphonia* Laporte (Hemiptera, Auchenorrhyncha, Membracidae). Rev. Brasileira Zool. 21(1): 13-14.

Andrade, G. S. 2004b. As espécies do gênero *Ceresa* Amyot & Serville (Hemiptera, Auchenorrhyncha, Membracidae). Rev. Brasileira Zool. 21 (4): 671-738.

BARREIRA, R. L., AND SAKAKIBARA, A. M. 2001. Duas species novas de *Cyphonia* Laporte da regiao central do Brasil (Homoptera, Membracidae, Smiliinae). Rev. Brasileira Zool. 18(1): 239-244

BELTRÁN, V. M., CÁCERES, S., ZUBRZYCKI, H., PLOPER, D., WILLINK, E., AND JALDO, H. 2004. CVC associated vectors in Valencia Orange of Corrientes, Argentina. Proc. Intl. Soc. Citriculture, 10th Intl. Citrus Congress 75-83.

CATALANO, M. I. 2011. Cicadélidos vectores de fitoplasmas a cultivos de importancia económica en la Argentina. Sistemática y bioecología (Insecta- Auchenorrhyncha- Cicadellidae). PhD Thesis. UNLP. 134 pp. Available online http://sedici.unlp.edu.ar/bitstream/handle/10915/5330/Documento_completo.pdf?sequence=1

CHRISTENSEN, J. R. 1942. Nota sobre *Agalliana ensigera* Oman (Homoptera). Notas del Museo de La Plata VII. 55: 27-38.

COELHO, J. H. C., XIMENES, N. L., FELIPPE, M. R., MONTESINO, L. H., GARBIM, L. F., SANCHES, A. L., DALLA PRIA, W. J., AND YAMAMOTO, P. T. 2008. Faunistic Analysis of Sharpshooters (Hemiptera: Auchenorrhyncha, Cicadellidae) in a 'Westin' Sweet Orange Orchard. Neotropical Entomol. 37(4): 449-456.

COSTA, A. C. F., AND SAKAKIBARA, A. M. 2002. Reestrturaçao do genero *Deois* Fennah; descrçao de um novo genero e de novas species (Homoptera, Cercopidae, Tomaspidinae). Rev. Brasileira Entomol. 46(2): 195-207.

COSTA, N., PLATA, M. I., GARRÁN, S. M., AND MIKA, R. 2009. Detección de Clorosis Variegada de los Cítricos (CVC) en el Departamento de Concordia, provincia de Entre Ríos. XIII Jornadas Fitosanitarias Argentinas E021.

CRYAN, J. R. 2005. Molecular phylogeny of Cicadomorpha (Insecta: Hemiptera: Cicadoidea, Cercopoidea and Membracoidea): adding evidence to the controversy. Syst. Entomol. 30: 563-574.

DAMSTEEGT, V. D., BRLANSKY, R. H., PHILLIPS, P. A., AND ROY, A. 2006. Transmission of *Xylella fastidiosa*, causal agent of Citrus Variegated Chlorosis, by the glassy-winged sharpshooter, *Homalodisca coagulata*. Plant Dis. 90: 567-570.

DE COLL, O. R. 1996. Estudio sistemático y bioecológico de Homópteros Cicadélidos, potenciales vectores de la "Clorosis Variegada de los Cítricos". PhD Thesis. UNLP. 268 pp.

DE COLL, O. R., REMES LENICOV, A. M. M., AGOSTINI, J., AND PARADELL, S. 2000. Detection of *Xylella fastidiosa* in weeds and sharpshooters in orange groves affected with Citrus Variegated Chlorosis in Misiones, Argentina, pp. 216-222 *In* Proc. 14th Conf. Intl. Org. Citrus Virologists, Insect-Transmitted Procaryotes.

DE COLL, O. R., REMES LENICOV, A. M. M., PARADELL, S., AND AGOSTINI, J. 2006. Comportamiento poblacional de chicharritas (Homoptera: Auchenorrhyncha) presentes en el Departamento Montecarlo, Misiones. EEA Montecarlo Publ. N°6: 1-17.

DELLAPÉ, G., LOGARZO, G. A., VIRLA, E. G., AND PARADELL S. L. 2011. New records on the geographical distribution of South American Sharpshooters (Cicadellidae: Cicadellinae: Proconiini) and their potential as vectors of *Xylella fastidiosa*. Florida Entomol. 94(2): 364-366.

DE LONG, D. M., AND FREYTAG, P. H. 1976. Studies of the world Gyponinae (Homoptera-Cicadellidae). A synopsis of the genus *Curtara*. Brenesia 7: 1-97.

DIETRICH, C. H. 2002. Evolution of Cicadomorpha (Insecta, Hemiptera). Denisia. 4: 155-170.

DIETRICH, C. H. 2005. Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). Florida Entomol. 88(4): 502-517.

FEDERCITRUS. 2011. The Argentine Citrus Industry. Available online: http://www.federcitrus.org/actividad-citricola-2011.pdf

FELIPPE, M. R., UEHARA-CARMO, A., RUGNO, G. R., COELHO, J. H., XIMENES, N. L., GARBIN, L. F., AND YAMAMOTO, P. T. 2006. Influência de las armadilhas adesivas amarelas na fluctuação populacional de insetos vetores da CVC e HLB (Hemiptera: Cicadellidae e Psyllidae) na bordure e área central de pomar cítrico. Huanglongbing Greening Wkshp. Intl. 100.

GIMENEZ PECCI, M. P., LAGUNA, I. G., AVILA, A. O., REMES LENICOV, A. M. M., VIRLA, E. G., BORGOGNO, C., NOME, C. F., AND PARADELL, S. L. 2002. Difusión del Corn Stunt Spiroplasma del maíz (*Spiroplasma kunkelii*) y el vector (*Dalbulus maidis*) en la Argentina. Rev. Fac. Agronom. 105 (1): 1-8.

GIUSTOLIN, T. A., LOPES, J. R. S., QUERINO, R. B., CAVICHIOLI, R. R., ZANOL, K., AZEVEDO FILHO, W. S., AND MENDES, M. A. 2009. Diversidade de Hemiptera Auchenorrhyncha em Citros, Café e Fragmento de Floresta Nativa do Estado de São Paulo. Neotropical Entomol. 38(6): 834-841.

GRAVENA, S., LOPES, J. R. S., PAIVA, P. E. B., YAMAMOTO, P. T., AND ROBERTO, S. R. 1998. The *Xylella fastidiosa* vetors, pp. 36-53 *In* L. C. Donadio and C. S. Moreira [eds.], Citrus Variegated Chlorosis. Bebedouro, Estação Experimental de Citricultura.

HOPKINS, D. L., AND PURCELL, A. H. 2002. *Xylella fastidiosa*: Cause of Pierce´s disease of grapevine and others emergent diseases. Plant Dis. 86: 1056-1066.

LAWSON, P. B. 1931. The Genus *Xerophloea* in North America (Homoptera, Cicadellidae). The Pan-Pacific Entomol. 7(4): 159-169.

LINNAVUORI, R. 1959. Revision of the Neotropical Deltocephalinae and some related subfamilies (Homoptera). Ann. Zool. Soc. 'Vanamo' 20 (1): 1-370.

LOPES, J. R. S. 1996. Mecanismo de transmissão de *Xylella fastidiosa* por cigarrinhas. Laranja 17: 79-92.

MENEGATTI, A. C. O., GARCIA, F. R. M., AND SAVARIS, M. 2008. Análise faunística e flutuação populacional de cigarrinhas (Hemiptera, Cicadellidae) em pomar cítrico no município de Chapecó, Santa Catarina. Biotemas 21(1): 53-58.

MILANEZ, J. M., PARRA, J. R. P., AND MAGRI, D. C. 2001. Alternation of host plants as a survival mechanism of leafhoppers *Dilobopterus costalimai* and *Oncometopia facialis* (Hemiptera: Cicadellidae), vectors of the citrus variegated chlorosis (CVC). Sci. Agric. 58(4): 699-702.

MIRANDA, M. P., LOPES, J. R. S., DO NASCIMENTO, A. S., DOS SANTOS, J. L., AND CAVICHIOLI, R. R. 2009. Levantamento Populacional de Cigarrinhas (Hemiptera: Cicadellidae) Associadas à Transmissão de *Xylella fastidiosa* em Pomares Cítricos do Litoral Norte da Bahia. Neotropical Entomol. 38(6): 827-833.

MOLINA, R. O., NUNES, W. M. C., GONÇALVES, A. M. O., CORAZZA-NUNES, M. J., ZANUTTO, C. A., YAMAMOTO, A. Y., AND VARGAS, R. G. 2006. Ocorrência de cigarrinhas vetoras de *Xylella fasidiosa* em pomares cítricos do município de Loanda, no noroeste do Paraná. Laranja 27: 243-250.

MOLINA, R. O., GONÇALVES, A. M. O, ZANUTTO, C. A., AND NUNES, W. M. C. 2010. Populational Fluctuation of Vectors of *Xylella fastidiosa* Wells in Sweet Orange [*Citrus sinensis* (L.) Osbeck] Varieties of Northwest Paraná State, Brazil. Brazilian Arch. Biol. Technol. 53: 549-554.

MORENO, C. 2001. Métodos para medir la biodiversidad. M&T - Manuales y Tesis SEA, vol. 1. Zaragoza: CIT-ED, UNESCO & SEA.

MURÚA, M. G., MOLINA-OCHOA, J., AND COVIELLA, C. 2006. Population dynamics of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and its parasitoids in Northwestern Argentina. Florida Entomol. 89(2): 175-182.

NEJAT, N., VADAMALAI, G., AND DICKINSON, M. 2011. *Spiroplasma citri*: a wide host range phytopathogen. Plant Pathol. J. 10(2): 46-56.

NIELSON, M. W. 1968. The Leafhopper Vectors of Phytopathogenic Viruses (Homoptera, Cicadellidae): Taxonomy, Biology, and Virus Transmission. United States Dept. Agr. Tech. Bull. 1382, 386 pp.

NOVOTNY, V., AND BASSET, Y. 1998. Seasonality of sap-sucking insects (Auchenorrhyncha, Hemiptera) feeding on *Ficus* (Moraceae) in a lowland rain forest in New Guinea. Oecologia. 115: 514-522.

NUNES, W. M. C., MOLINA, R. O., ALBUQUERQUE, F. A., CORAZZA-NUNES, M. J., ZANUTTO, C. A., AND MACHADO, M. 2007. Flutuação populacional de cigarrinhas vetoras de *Xylella fastidiosa* em pomares comerciais de citros no noroeste do Paraná. Neotropical Entomol. 36: 254-260.

PARADELL, S. 1995. Especies argentinas de homópteros Cicadélidos asociados al cultivo de maíz *Zea mays* L. Rev. Fac. Agronom. 71(2): 213-234.

PARADELL, S., REMES LENICOV, A. M. M., DE COLL, O., AND AGOSTINI, J. 2000. Cicadélidos asociados a citrus afectados por la Clorosis Variegada de los citrus (CVC) en Montecarlo, Misiones, República Argentina (Hemiptera-Auchenorrhyncha). Rev. Soc. Entomol. Argentina 59 (1-4): 103-118.

PARADELL, S., VIRLA, E., AND TOLEDO, A. 2001. Leafhoppers species richness and abundance on crops in Argentina (Insecta-Hemiptera-Cicadellidae). Bol. San. Veg. Plagas 27 (4): 465-475.

PARADELL, S., VIRLA, E. G., LOGARZO, G. A., AND DELLAPÉ, G. 2012. Proconiini Sharpshooters of Argentina, with notes on its distribution, host plants, and natural enemies. J. Insect Sci. 12 (116): 1-17.

PARRA, J. R. P., OLIVEIRA, H. N., AND PINTO, A. S. 2003. Pragas e insetos benéficos com Citros. FEALQ, Piracicaba, Brasil, 73 pp.

PURCELL, A. H. 1985. The ecology of bacterial and mycoplasma plant diseases spread by leafhoppers and planthoppers, pp. 351-380 *In* L. R. Nault and J. G. Rodriguez [eds.], The Leafhoppers. J. Wiley & Sons Publishers.

REDAK, R., PURCELL, A., LOPES, J. R. S., BLUA, M., MIZELL, R. F., AND ANDERSEN, P. C. 2004. The biology of xylem fluid-feeding insect vectors of *Xylella fastidiosa* and their relation to disease epidemiology. Annu. Rev. Entomol. 49: 243-270.

REMES LENICOV, A. M. M. 1982. Aportes al conocimiento de los Agallinae argentinos (Homoptera-Cicadellidae). Neotrópica 28(80): 215-138.

REMES LENICOV, A. M. M., AND TESÓN, A. 1985. Hallazgo de uno de los vectores del "Mal de Río Cuarto" del maíz. Gaceta Agronómica 5(25): 251-258.

REMES LENICOV, A. M. M., AND VIRLA, E. 1993. Homópteros auquenorrincos asociados al cultivo de trigo en la República Argentina. I. Análisis de la importancia relativa de las especies. Stud. Neotropical Fauna Environ. 28: 211-222.

REMES LENICOV, A. M. M., PARADELL, S., VIRLA, E., MARIANI, R., COSTAMAGNA, A., AND VARELA, G. 1997. Cicadélidos y Delfácidos perjudiciales al cultivo de maíz en la República Argentina (Insecta-Homoptera). VI Congreso de Maíz. I: 58-74.

REMES LENICOV, A. M. M., PARADELL, S., DE COLL, O. R., AND AGOSTINI, J. 1999. Cicadelinos asociados a citrus afectados por Clorosis Variegada (CVC) en la República Argentina (Insecta: Homoptera: Cicadellidae). Rev. Soc. Entomol. Argentina 58(3-4): 211-225.

REMES LENICOV, A. M. M., PARADELL, S., AND CATALANO, M. I. 2006. Hemípteros Auquenorrincos asociados al cultivo de sorgo en la Argentina (Insecta-Hemiptera). RIA 35(2): 3-20.

SALUSO, A. 2006. Insectos vectores de enfermedades del maíz en el Departamento de Paraná. Primer registro de *Dalbulus maidis* "chicharrita del maíz" (Hemiptera: Cicadellidae). Actualización técnica-MAIZ. EEA Paraná. Serie Extensión N°4: 85-87.

SEGOVIA, F. 2003. Potencial y Limitantes de la Producción de Cítricos en Argentina. Available online: http://www.producirconservando.org.ar/documentos/informe_citricos.pdf

TORRES, A. B. 1950. El cercópido *Cephisus siccifolius* (Walker 1851). Notas del Museo de La Plata XV. 131: 7-21.

WELLS, J. M., RAJU, B. C., HUNG, H. Y., WEISBURG, W. G., MANDELCO-PAUL, L., AND BRENNER, D. J. 1987. *Xylella fastidiosa*: Gram-negative, xylem-limited, fastidious plant bacteria related to *Xanthomonas*. Intl. J. Syst. Bacteriol. 37: 136-143.

YAMAMOTO, P. T., DALLA PRIA, W. J., ROBERTO, S. R., FELIPPE, R. M., AND FREITAS, E. P. 2001. Flutuação populacional de cigarrinhas (Hemiptera: Cicadellidae) em pomar cítrico em formação. Neotropical Entomol. 30: 175-177.

YAMAMOTO, P. T., ROBERTO, S. R., DALLA PRIA, W. J., FELIPPE, R. M., AND FREITAS, E. P. 2002. Espécies e flutuação populacional de cigarrinhas em viveiro de citros no município de Mogi-Guaçu-SP. Rev. Brasileira Frut. 24: 389-394.

YOUNG, D. A. 1952. A reclassification of Western Hemisphere Typhlocybinae (Homoptera, Cicadellidae). Univ. Kansas Sci. Bull. 35(1): 3-217.

YOUNG, D. A. 1968. Taxonomic study of the Cicadellinae (Homoptera: Cicadellidae). Part 1. Proconiini. Bull. United States. Nat. Mus. 261:1-287.

YOUNG, D. A. 1977. Taxonomic Study of the Cicadellinae (Homoptera: Cicadellidae). Part 2. New World Cicadellini and the Genus *Cicadella*. North Carolina Agric. Exp. Sta. Tech. Bull. 239: 1-1135.

ZHANG, J., LASHOMB, J., GOULDM, A., AND HAMILTON, G. 2011. Cicadomorpha insects associated with bacterial leaf scorch infected oak in central New Jersey. Environ. Entomol. 40(5): 1131-43.