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BIOLOGICAL CONTROL

Egg Parasitoid Complex of the Corn Leafhopper, *Dalbulus maidis* (DeLong) (Hemiptera: Cicadellidae), in Argentina

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Abstract
The corn leafhopper, *Dalbulus maidis* (DeLong), is the most important leafhopper pest of maize, *Zea mays*, in the Americas. A survey of the diversity of its egg parasitoids was carried out in northwestern Argentina. During summer from 2004 to 2007, the samples were collected, using sentinel eggs of *D. maidis* on corn leaves, exposed in 48 cornfields. Sixteen species belonging to four families of Chalcidoidea (Hymenoptera) were identified. Among the parasitoid groups, Trichogrammatidae was the most represented family with eight species, followed by Mymaridae with six species. The mymarid *Anagrus incarnatus* Haliday and the trichogrammatid *Pseudoligosita longifrangiata* (Viggiani) were the most abundant and frequent parasitoids. The mean percentage of parasitism of *D. maidis* eggs was 16.4% and varied greatly among the sites, ranging from 0 to 56.7%; generally, it was higher in Yungas and lower in Monte province sites. The species richness was higher in the localities within the Yungas, with 13 parasitoid species, of which two species were dominant, comprising 83.6% of the collected individuals. Monte was the province that showed the highest diversity index (H´ = 1.62). In addition, we present information on the distribution, known host associations of each parasitoid species and an identification key to all species of egg parasitoids of *D. maidis* in Argentina.

Introduction

The corn leafhopper, *Dalbulus maidis* (DeLong) (Hemiptera: Cicadellidae), is widely distributed in the Americas, from the southern USA to subtropical Argentina (Nault 1998), extending its range to the temperate areas further south during summers (Carloni *et al* 2013, Virla *et al* 2013). It is an oligophagous species feeding only on plants of the genera *Zea* L., including maize and teosintes, and *Tripsacum* L. (Nault 1990). In Argentina, it is the most common leafhopper by frequency and abundance, feeding on corn crops north of parallel 30°S, while further south its occurrence is sporadic (Luft Albarracin *et al* 2008, Virla *et al* 2013).

Corn is an important staple food that is grown widely throughout the world in a range of agroecological environments. In America, where it originated, its importance is both economic and cultural. Northern Argentina is a complex enclave due to its particular geography: near the Andes and in a relatively narrow area, five biogeographic provinces are represented (Morrone 2001) where in four of them different varieties of corn are grown. The occurrence of insects associated with corn crop is closely related to the location where it grows. The community composition and structure is a result of multiple interactions, having an important influence from the environment, trophic relationships, historical processes, and chance events (Samuels & Drake 1997).

Dalbulus maidis causes great losses to corn crops in most tropical and subtropical zones in the New World because of its

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ability to transmit three important pathogens: corn stunt spiroplasma (CSS), maize bushy stunt phytoplasma (MBSP), and maize rayado fino virus (MRFV) (Nault & Ammar 1989, Oliveira *et al* 1998). These diseases are persistent and propagative, so once a vector acquires the pathogen, it remains infected during the whole life. The diseases caused by these pathogens adversely affect corn in Argentina, and CSS is the most important due to its high incidence in the subtropical areas (Giménez Pecci *et al* 2002a, b, Virla *et al* 2004). The decrease of the yield of plants with CSS can be very high, from 12 to 100%, depending on the severity of symptoms (Oliveira *et al* 2003, Virla *et al* 2004). The CSS disease is caused by the pathogen *Spiroplasma kunkelii* Whitcom *et al. Dalbulus maidis* is the main vector, but recently, another leafhopper, *Exitianus obscurinervis* (Stål), has been recorded in Argentina as a new experimental vector of CSS (Carloni *et al* 2011).

Eggs of various leafhoppers are commonly parasitized by members of Mymaridae and Trichogrammatidae (Hymenoptera: Chalcidoidea), as well as by some species of other chalcidoids such as Aphelinidae and Eulophidae (Freytag 1985). Moreover, several species of Mymaridae have been successfully utilized in biological control of crop pests (Huber 1986).

Dalbulus maidis has a rich natural enemy complex, including fungal pathogens, predators, and parasitoids. The parasitoids are antagonists that can be divided into two guilds: those attacking eggs, and those affecting nymphs and adults. The egg parasitoids of *D. maidis* are known in several countries of Central and South America, as Peru, Nicaragua, Brazil, Mexico, and Argentina. In Argentina, nymphs and adults of *D. maidis* are parasitized by Dryinidae (Hymenoptera) as well as by some Pipunculidae (Diptera), whereas its eggs are parasitized by a number of species of Mymaridae, Trichogrammatidae, one species of Aphelinidae, and one of Eulophidae (Hymenoptera) (Polaszek & Luft Albarracin 2011, Virla & Luft Albarracin 2012).

Knowledge of the interrelationships of a pest insect and its parasitoids, for the purpose of developing effective management tactics, has been highlighted by several authors. So, taking into account the status of the corn leafhopper as a pest, the economic importance of the diseases transmitted by this vector, and the lack of comprehensive knowledge of the egg parasitoid complex affecting its populations in different environments of South America, the goals of this study were to investigate the diversity of parasitoids that attack eggs of *D. maidis* in a subtropical area of northwestern Argentina, comprising different biogeographic provinces, and to better understand their natural distribution in the region. In addition, a brief review on the distribution and known host associations of each parasitoid species, and a key for the identification of female parasitoids associated with *D. maidis* in Argentina are provided.

Material and Methods

Study area

Sentinel eggs of *D. maidis* were exposed in different localities of the provinces of Tucumán (27), Salta (10), Jujuy (5), Santiago del Estero (5), and Catamarca (1), in the northwestern region of Argentina, between the 23°4'S–27°5'S and 63°5'W–66°5'W (Table 1; Fig 1) during corn growing season (November to April) from 2004 to 2007. The sites were surveyed each year when possible. All the sentinel eggs were located in subsistence cornfields under 1 ha, surrounded by the native vegetation, where the crop received the conventional cultural practices adopted in the region but without the use of pesticides.

The main characteristics of the considered biogeographic provinces are outlined as follows (Morrone 2001):

Yungas (Neotropic region, Amazonian subregion). It is an elongate area in the eastern piedmont of the Andes Mountains, a submontane and montane evergreen forest with altitudes between 500 to 2000 m, from northern Peru to northwestern Argentina. This forest is characterized by a great variation in rainfall; being all tropical and frequently foggy, it also has a low annual range of temperatures. Annual precipitation of the Yunga's forest ranges between 1000 and 2000 mm; the dry season lasts 2 to 5 months. Yunga's forest is extremely diverse and rich in Lauraceae and Myrtaceae, ranging from moist lowland forest and evergreen mountain forest to cloud forest.

Chaco (Neotropic region, Chaquenian subregion). It comprises an extended area near the Altiplano Plateau from about 17° S to 33° S latitude and between 65° W and 60° W longitude (southern Bolivia, western Paraguay, southwestern Brazil and northern and central Argentina). It is a tropical deciduous dry forest with annual precipitation ranging from 500 to 900 mm; the dry season lasts 5 to 8 months. Chaco is a wooded region where the average temperature in the coldest month is greater than 13°C; it is widely disturbed by the agricultural and forestry activities.

Yungas-Chaco ecotone. In the occidental part of the Chaco, a pre-mountain wooded area transitional between Chaco and Yungas provinces is present. Like Chaco province, this stretch of terrain is highly modified by human activities. Because of the environmental disturbances present in the sampled sites located in this area, it was considered in the analysis as an independent biogeographic entity.

Monte (Neotropic region, Chaquenian subregion). It is located in the arid region of Argentina. It extends from Salta to Chubut provinces. The climate is dry and warm, with a wide thermal amplitude (day/night) and with summer rain. The flora is characterized mostly by

Table 1 Locations in northwestern Argentina sampled for the eggs parasitoids of *Dalbulus maidis* on maize.

Province	Locality	Latitude (S)	Longitude (W)	Elevation (masl)	Bp	Total exposed eggs	Parasitism rate (%)
Catamarca	San José	26°48`41.4"	66°4`27.6"	1976	M	250	16.0
Jujuy	Callilegua	23°46`29.8"	64°46`1.6"	436	Y	54	0
	Purmamarca	23°44`47.2"	65°28`56.4"	2241	M	60	15.0
	San Pedro	24°15`22.7	64°53`21.5	634	Y-Ch	36	0
	San Salvador de Jujuy	24°10`51.8"	65°20`39.7"	1355	Y	69	0
	Santa Clara	24°16`58.4"	64°41`5.2"	518	Y-Ch	78	0
Salta	Animaná	25°57`53.8"	65°56`54.6"	1614	M	300	13.3
	Cafayate	26°04`30.7"	65°58`54.2"	1626	M	179	0
	El Tunal	25°14`47.9"	64°23`34.5"	448	Ch	60	31.7
	Güemes	24°48`39.9"	65°00`58.6"	797	Ch	32	0
	Joaquín V. Gonzáles	25°7`34.1"	64°7`14.4"	386	Ch	70	8.6
	La Candelaria	26°6`32.2"	65°10`12.9"	880	Ch	13	38.5
	Los Baños	25°49`59.9"	64°55`7.6"	783	Y-Ch	280	16.8
	Metán	25°27`9.2"	64°57`50.7"	862	Y-Ch	948	11.5
	S. Ramón de la Nueva Orán	23°8`47.4"	64°20`5.4"	365	Y	55	29.1
	Pichanal	23°17`47.2"	64°13`7.9"	301	Y-Ch	48	14.6
Santiago del Estero	Forres	27°52`5.8"	63°58`18.1"	159	Ch	230	4.3
	El Naranjito	27°33`24.9"	64°46`12.3"	280	Ch	334	22.4
	Pozo Hondo	27°12`48.1"	64°28`11"	270	Ch	347	18.4
	Rubia Moreno	27°46`13.2"	64°14`11.7"	236	Ch	180	12.8
	Termas de Río Hondo	27°30`55.3"	64°51`59,9"	263	Ch	381	8.4
Tucumán	Ampimpa	26°37`27.2"	65°50`21.6"	2521	M	98	11.2
	Alberdi	27°37`23.3"	65°41`34.2"	435	Y-Ch	160	13.7
	Bella Vista	27°2`14.5"	65°17`57.3"	364	Ch	57	0
	Burruyacu	26°29`57.1"	64°44`23.6"	524	Ch	358	17.4
	Colalao del Valle	26°21`57.4"	65°57`33.2"	1712	M	358	13.9
	El Cadillal	26°38`10.9"	65°11`32.2"	540	Y	656	22.7
	El Manantial	26°49`50.2"	65°16`59.4"	495	Y	44,125	56.7
	El Mollar	26°55`58.4"	65°42`56.1"	1930	M	5430	5.5
	El Sunchal	26°37`26.9"	65°3`24.9"	657	Ch	139	38.1
	Famaillá	27°3`11.7"	65°23`22.5"	280	Y-Ch	131	6.9
	Garmendia	26°34`2.3"	64°33`7.4"	370	Ch	104	1.4
	Horco Molle	26°46`50.1	65°19`38.3	703	Y	865	24.5
	Lamadrid	27°39`38.4"	65°14`39.2"	291	Ch	186	13.9
	La Ramada	26°41`44.6"	64°57`8.4"	550	Ch	554	24.4
	La Virginia	26°74`78.8	64°74`8.0"	224	Ch	274	44.9
	Las Cejas	26°52`59.9"	64°44`31.2"	338	Ch	286	21.3
	Las Salinas	26°43`5.6"	65°9`12.3"	494	Ch	539	18.9
	Las Talitas	26°46`57.7"	65°12`4.0"	475	Y-Ch	2111	14.3
	León Rougues	27°21`9.0"	65°52`7.0"	809	Y-Ch	110	24.5
	Los Nogales	26°42`27.5"	65°13`3.9"	585	Y-Ch	4744	49.8
	Monteros	27°10`8.4"	65°29`24.8"	354	Y-Ch	69	11.6
	San Miguel de Tucumán	26°48`35.7"	65°16`25.3"	470	Y-Ch	16,152	41.9
	San Pedro de Colalao	26°14`1.9"	65°29`13.4"	1020	Y-Ch	285	15.4
	Simoca	27°15`27.8"	65°21`18.4"	326	Ch	42	7.1
	Tápia	26°35`33.5"	65°16`15.8"	678	Ch	71	0
	Trancas	26°13`30.2"	65°16`29.4"	774	Ch	261	18.4
	Vipos	26°28`26"	65°18`50.5"	736	Ch	309	7.7

BP biogeographic provinces, *Y* yungas, *CH* chaco, *Y-Ch* yungas/chaco ecotone, *M* monte.

scattered shrubs and trees as the genera *Larrea* Cavanilles, *Parkinsonia* L., and *Prosopis* L.

Egg parasitoid sampling

To obtain sentinel eggs, 6–10 females of *D. maidis* were placed in PET (polyethylene-terephthalathe) cylindrical cages (35 cm high × 18 cm diameter) on leaves of potted maize plants in the vegetative stage (three to six leaves) for oviposition. After 48 h, the adult females were removed, and the eggs laid in each maize leaf were counted. The pots that contained sentinel host eggs were then exposed to parasitism in a cornfield for 3 or 4 days. The sentinel eggs were placed in a maize field 3 m from the border and 10 m from each other.

The corn leafhopper individuals came from a laboratory colony maintained at room temperature (25 ± 2°C), at 60–70% RH, and with a natural photoperiod.

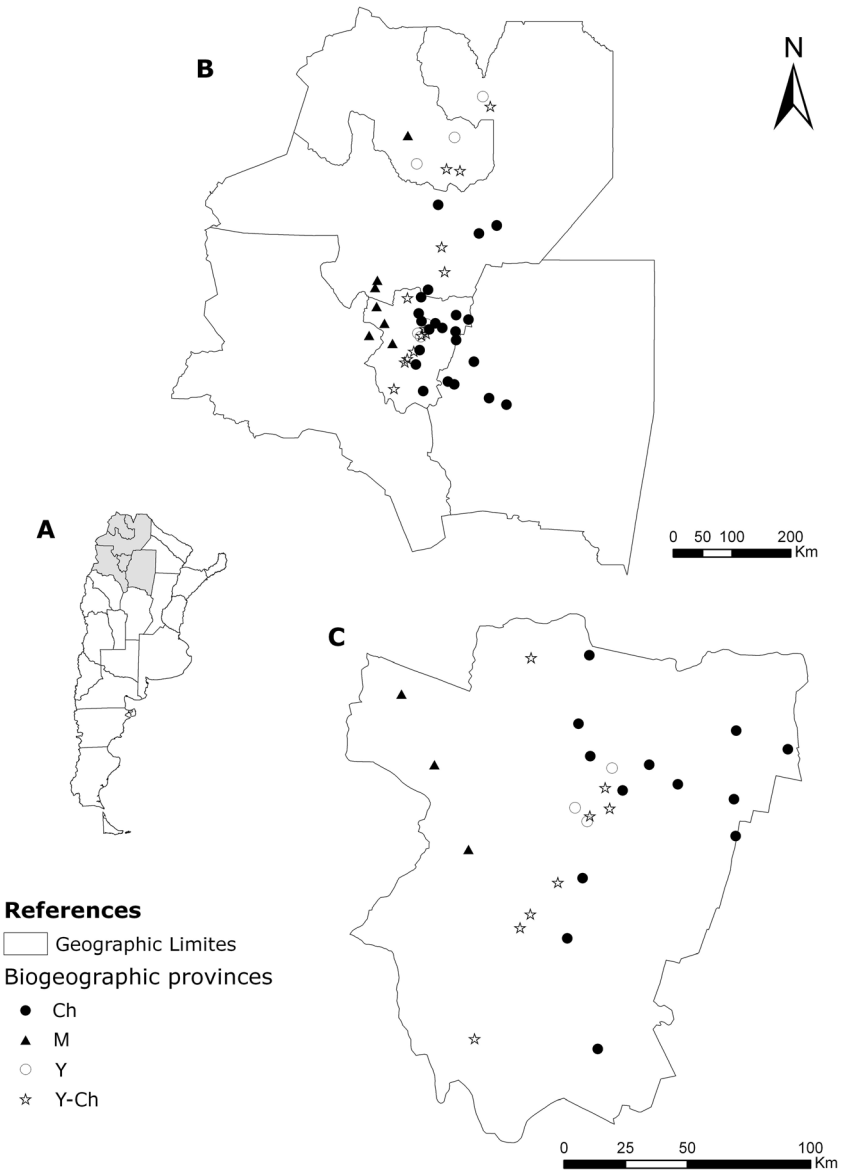


Fig 1 Sampled localities in northwestern Argentina; expositions of sentinel eggs of *Dalbulus maidis* on maize. **A** Argentina Country. **B** Northwestern Argentina. **C** Tucumán Province. Biogeographic provinces: Yungas (Y), Chaco (Ch), Yungas/Chaco ecotone (Y-Ch), and Monte (M).

After 8 days, the leaves with exposed eggs were cut from the plant and transferred to Petri dishes containing wet tissue paper on the bottom and covered with a polyethylene film to avoid desiccation of eggs and leaves, and to contain the emerging parasitoids. The eggs were checked daily to ensure leaf quality until the emergence of all the adult wasps in case the eggs were parasitized. The parasitoid specimens were preserved in 70% ethanol and later slide-mounted in Canada balsam following the traditional practices (Noyes 1982). Unless stated otherwise, all parasitoids listed below were collected by E. Luft Albarracin.

Parasitoid identification

All the emerged parasitoids were identified at least to genus level. Terminology for the morphological features is that of Gibson (1997). In the key, the abbreviation "F" means "funicle segment of the female antenna". Voucher specimens were deposited in the insect collection of Fundación Miguel Lillo, San Miguel de Tucumán, Tucumán, Argentina (IMLA), which is the default depository; alternate depositories of specimens (indicated in the "Material Examined" sections) are La Plata Museum, La Plata, Buenos Aires, Argentina (MLPA); Entomology Research Museum, University of California, Riverside, California, USA (UCRC); and Natural History Museum, London, UK (NHM).

Parasitoids diversity relative to the biogeographic regions

In order to determine the diversity and its relationship with the environment, the different sampled sites were grouped taking

into consideration the biogeographic zone to which they belong; data were analyzed using the Shannon-Wiener (*H'*) and Berger-Parker Dominance (*d*) indexes. The Jaccard Index was used to identify the similarities between the biogeographic provinces (Moreno 2001). Analyses were performed using InfoStat computer software (Di Rienzo *et al* 2008).

Results and Discussion

A total of 82,478 exposed eggs were distributed in 48 sites during the 4 years of surveys in five provinces of Argentina, from which 21,962 parasitoids emerged in 30 sites. The results showed that the egg parasitoid complex associated with *D. maidis* in northwestern Argentina comprises 16 species belonging to four families of Chalcidoidea: *Encarsia dalbulae* Polaszek & Luft Albarracin (Aphelinidae); *Aprostocetus* (*Oostetrastichus*) *infulatus* (De Santis) (Eulophidae); *Anagrus incarnatus* Haliday [*A. breviphragma* Soyka (Triapitsyn 2015b)], *A. flaveolus* Waterhouse, *A. miriamae* Triapitsyn & Virla, *A. nigriventris* Girault, *Polynema* (*Doriclytus*) sp. A, *Polynema* (*Doriclytus*) sp. B (Mymaridae); *Aphelinoidea semifuscipennis* Girault, *Burksiella platensis* (De Santis), *Zagella nanula* De Santis, *Paracentrobia tapajosae* Viggiani, *Paracentrobia* sp. A, *Oligosita desantisi* Viggiani, *Oligosita girault*i Crawford, and *Pseudoligosita longifrangiata* (Viggiani) (Trichogrammatidae).

Anagrus incarnatus and *P. longifrangiata* were relatively common in all the biogeographic regions surveyed. This species was previously registered attacking this corn leafhopper also in Brazil and Mexico (Oliveira & Lopes 2000, Virla *et al* 2009a). Species of the genera *Paracentrobia* Howard and *Oligosita* Walker were reported previously from *D. maidis* eggs in Nicaragua and Brazil, respectively (Gladstone *et al* 1994, Oliveira & Lopes 2000). Furthermore, *A. incarnatus*, *Polynema saga* (Girault), *A. semifuscipennis*, *P. tapajosae, Oligosita clarimaculosa* (Girault), and *P. longifrangiata* were reported from Mexico (Moya Raygoza *et al* 2012). Some of these parasitoids are generalists, attacking not only leafhoppers but also planthoppers (Moya Raygoza *et al* 2012).

In this study, we were also able to identify to species several parasitoids previously listed from Argentina by Luft Albarracin *et al* (2005) by their respective generic identifications only: *Oligosita* sp. is *P. longifrangiata*, *Paracentrobia* sp. is *P. tapajosae*, and *Zagella* sp. is *Z. nanula*.

Among the parasitoid groups, Trichogrammatidae was the most represented family with eight species, followed by Mymaridae with six species. Two of the most frequent parasitoids of the corn leafhopper (*P. tapajosae* and *P. longifrangiata*) belong to the Trichogrammatidae.

Considering the total number of the exposed sentinel eggs, the mean percentage of parasitization was 16.4%, ranging from 0 to 56.7% (Table 1). Marín (1987) recorded different levels of egg parasitism depending on the date corn had been sown: 38.6, 42.6, 54.8, 33.6, 10.6, and 4.2% for January, February, March, April, May, and June, respectively. In Brazil, Oliveira & Lopes (2000) reported 84.5% percent parasitism of *D. maidis* eggs for the early growing season of corn, while Gladstone *et al* (1994) indicated a mean egg parasitism of 77.0% in Nicaragua. In Mexico, the mean percentage of parasitized of *D. maidis* was 60.9% at a low elevation site (El Grullo, Jalisco), and 22.6% at a high elevation site (Zapopan, Jalisco) (Moya Raygoza *et al* 2012). Similar results were obtained in this survey, with a low mean rate of parasitism (10.7%) in the elevation zones sampled, Monte region, compared with the other regions studied (Table 2).

Generally, the percentage of parasitized eggs and species richness were higher in the localities within the Yungas, where 13 parasitoid species were collected, followed in order by the ecotone Yungas-Chaco, Chaco, and Monte (Table 2). However, the species richest ecozone (the Yungas) does not have the highest diversity index, as a result of the increased dominance of the two species (*A. incarnatus* and *P. tapajosae*) comprising 83.6% of the collected individuals. Similar results were obtained in Chaco province where 95.6% of the collected individuals were *A. incarnatus* and *P. longifrangiata* (Table 2). Due to the low dominance of particular species (d = 0.33), Monte was the region having the highest diversity index (H' = 1.62).

Anagrus incarnatus seems to be the most important egg parasitoid of *D. maidis*. It is widely distributed and was found at 16 out of 48 sampled sites, and in all the biogeographic provinces sampled. Its occurrence is very important in the areas situated at lower elevations (Chaco, Yungas and the ecotone between them) (Table 2). The other egg parasitoid found in all the regions was *P. longifrangiata* (in 22 out of 48 sites), but this species appears to be relatively more important, by frequency and abundance, within the parasitoid complex affecting corn leafhopper eggs in the Monte province sites.

In the Chaco and Monte biogeographic provinces, low richness and rates of parasitism were recorded. That also was reported in a study on the Cicadellinae leafhoppers in Argentina by Paradell *et al* (2012), where they found few sharpshooters in these biogeographic provinces. These zones are dominated by dry environments, and Puna region is at a very high elevation, with scarce vegetation and leafhopper hosts.

The number of shared species between the biogeographic provinces was low. The Yungas and Chaco zones shared a higher number of species with the ecotone Yungas-Chaco (0.64 and 0.5, respectively) in comparison with the Monte (0.15); the Jaccard similarity index values calculated between the sampled sites are shown in Table 3.

An identification key to the females of the egg parasitoids associated with *D. maidis* in Argentina is provided below.

Key to species of egg parasitoids of *Dalbulus maidis* in Argentina (females)

1. Tarsi four or five-segmented.....2
– Tarsi three-segmented (Trichogrammatidae).....9
2. Hind wing not petiolate (Fig 2A); stigmal vein long to sessile; antennal funicle two- to four-segmented (Fig 2B) 3
– Hind wing petiolate (Fig 2C); stigmal vein rudimentary or absent; antennal funicle six-segmented (Fig 2D) (Mymaridae)..... 4
3. Tarsi four-segmented; metasoma anteriorly narrow; body generally with metallic tinge; stigmal vein well-defined, long.....*Aprostocetus* (*Ootetrastichus*) *infulatus* (De Santis) (Eulophidae)
– Tarsi five-segmented; metasoma broadly joined to mesosoma; body non-metallic; stigmal vein not well-defined, short.....*Encarsia dalbulae* Polaszek & Luft Albarracin (Aphelinidae)
4. Metasoma petiolate; mesophragma not projecting into metasoma (Fig 2E) (*Polynema* Haliday).....5
– Metasoma sessile; mesophragma plainly projecting into metasoma (Fig 2F) (*Anagrus* Haliday).....6
5. Fore wing about four times as long as wide, with short marginal setae, about half fore wing width or only a little longer; mesonotum not sculptured.....*Polynema* (*Doriclytus*) sp. A
– Fore wing about five times as long as wide, with long marginal setae, notably longer than half forewing width; mesonotum sculptured.....*Polynema* (*Doriclytus*) sp. B
6. Midlobe of mesoscutum without adnotaular setae (Fig 2G).....*Anagrus incarnatus* Haliday
– Midlobe of mesoscutum with two adnotaular setae (Fig 2H).....7
7. F3 without sensory ridges.....*Anagrus flaveolus* waterhouse
– F3 with one sensory ridge (Fig 2I).....8
8. Body mostly brown to dark.....*Anagrus nigriventris* Girault
– Body mostly yellow to light brown.....*Anagrus miriamae* Triapitsyn & Virla
9. Body brown; marginal vein short, extending about 0.3 length of wing (Fig 2J, L).....10
– Body mainly yellow or red; marginal vein long, extending more than 0.5 length of wing (Fig 2K) 12
10. Funicle absent; fore wing narrow, rounded apically, disc with abundant and dense, randomly distributed setae (Fig 2J).....*Aphelinoidea semifuscipennis* Girault
– Funicle present; fore wing relatively wide, some setae arranged in lines or with several complete vein tracks (Fig 2L) 11
11. Fore wing with marginal and stigmal veins narrow, disc with a dark spot behind stigmal vein, discal setae abundant and mainly randomly distributed [genital capsule of male tube-shaped].....*Burksiella platensis* (De Santis)
– Fore wing with marginal and stigmal veins thick, without a dark spot behind stigmal vein, discal setae scarce and mainly arranged in lines [genital capsule of male expanded at apex] (Fig 2L) .....*Zagella nanula* De Santis
12. Eye red; antenna with two anelli and two funicle segments; setae on fore wing disc more or less arranged in a few tracks; marginal setae short, their maximum length no more than 0.3 wing width (*Paracentrobia* Howard).....13
– Eye dark; antenna with one anellus and one funicle segment; fore wing disc with setae randomly distributed, not in regular tracks; marginal setae long, their maximum length more than 0.8 wing width.....14
13. Mesosoma dark.....*Paracentrobia* sp. A
– Mesosoma yellow.....*Paracentrobia tapajosae* Viggiani
14. Clava with a terminal spindle-shaped sensillum (Fig 2M); fore wing disc sparsely to moderately densely setose; propodeal disc usually only slightly longer than metanotum.....*Pseudoligosita longifrangiata* (Viggiani)
– Clava with a terminal drumstick-shaped sensillum (Fig 2N); setae on fore wing disc scarce, nearly lacking (Fig 2K); propodeal disc usually distinctly longer than metanotum at midline.....15
15. Body mainly reddish .....*Oligosita giraulti* Crawford
– Body yellow.....*Oligosita desantisi* Viggiani

An annotated list of the egg parasitoid species of *Dalbulus maidis* collected in the course of this study

Aphelinidae

Encarsia dalbulae Polaszek & Luft Albarracin

Material examined: ARGENTINA. Santiago del Estero: El Naranjito, 20-26.xii.2006 [1♂ IMLA, 1♂ MLPA, 1♂ UCRC]. Tucumán: El Manantial, 21-27.i.2005 [1♂ NHM]; 24.i-2.ii.2005 [1♂ IMLA, 1♂ UCRC]; 29.xii.2005-4.i.2006 [1♂ NHM]. Los Nogales, 18-25.i.2007 [1♂ IMLA]; 8-12.ii.2007 [4♂♂ IMLA].

Previously, among the Aphelinidae, only species of the genus *Centrodora* Forster were known as parasitoids of

Cicadellidae (Polaszek 1991). Therefore, this is the first record of an *Encarsia* Forster species developing in eggs of a leafhopper (Polaszek & Luft Albarracin 2011). This species was collected in three different sites in the Yungas, Chaco, and the ecotone between them. It is a rare parasitoid associated with *D. maidis* eggs, as it was obtained only on six occasions and always in small numbers. Only males were collected.

Eulophidae

Aprostocetus (Ootetrastichus) infulatus (De Santis)

Material examined: ARGENTINA. Tucumán: El Manantial, E. Luft Albarracin & E. Virla, 24.i–2.ii.2005 [1♀ IMLA, 1♀ MLPA]; 25.ii–2.iii.2005 [1♂IMLA, 1♂ MLPA, 1♂ UCRC]; 9–17.iii.2005 [1♂ IMLA]; 17–26.iii.2005 [2♂♂ IMLA].

This is the only species of Eulophidae recorded in Argentina attacking leafhopper eggs. Like other species of the subgenus, *A.* (*Ootetrastichus*) *infulatus* develops as an external egg parasitoid acting as egg predator. Luft Albarracin & Triapitsyn (2007) described and illustrated its male, redescribed the female, and also updated information on its distribution and host associations. In this study, specimens of both sexes were collected. It is rare, being collected only in one locality in the Yungas.

Mymaridae

Anagrus incarnatus Haliday

Material examined. ARGENTINA. Tucumán: Burruyacu, 13-16.x.2006, 6♀♀. El Cadillal, 13-20.x.2005, 13♂♂ 3♀♀. El Mollar, 17-22.i.2007, 9♀♀. El Manantial, 27-30.xii.2004 [4♀♀ MLPA]; 3-6.i.2005, 13♀♀ 2♂♂; 13-17.i.2004, 246♀♀ 82♂♂; 24.i-2.ii.2005, 317♀♀ 36♂♂; 23-30.i.2006, 261♀♀ 38♂♂; 26-29.xii.2005 [6♀♀ UCRC]; 4-9.i.2006, 17♀♀; 27.ii-2.iii.2006, 60♀♀ 4♂♂; 11-14.iii.2006, 84♀♀ 3♂♂; 21-24.iii.2006, 88♀♀ 3♂♂; 30.iii-7.iv.2006, 211♀♀ 18♂♂. El

Table 2 Shannon-Wienner diversity index (*H´*), Berger-Parker Dominance index (*d*), species richness, number of specimens, and percent total of egg parasitoids of *Dalbulus maidis* found in the different biogeographic provinces and ecotones. Biogeographic provinces: Yungas (Y), Chaco (Ch), Yungas/Chaco ecotone (Y-Ch), and Monte (M).

		Biogeographic provinces and ecotones			
		Y	Y-Ch	Ch	M
	N° of surveyed sites	7	6	13	22
	Mean elevation of the surveyed sites (masl)	1946	649	538	460
	Total n° of exposed eggs	6675	45,824	25,152	4827
	Mean % of parasitism	10.7 (0–16.0)	22.2 (0–56.7)	17.0 (0–49.8)	16.3(0–44.9)
	Species richness	5	13	10	5
	Diversity index (H´)	1.62	1.16	0.98	0.56
	Dominance index (d)	0.33	0.61	0.57	0.85
Relative abundance (%)	*Encarsia dalbulae* Polaszek & Luft Albarracin		0.03	0.08	1.34
	Aprostocetus (*O.*) *infulatus* (De Santis)		0.05		
	Anagrus incarnatus Haliday	15.00	60.70	57.51	84.58
	Anagrus flaveolus Waterhouse		3.18	12.89	0.89
	Anagrus miriamae Triapitsyn & Virla	15.00			
	Anagrus nigriventris Girault		1.72	1.42	
	Polynema (*Doriclytus*) sp. A	33.33			
	Polynema (*Doriclytus*) sp. B			0.15	
	Aphelinoidea semifuscipennis Girault[a]		0.07	1.21	
	Burksiella platensis (De Santis)[b]		0.06		
	Zagella nanula De Santis		3.38	0.15	2.24
	Paracentrobia tapajosae Viggiani		22.88	7.26	
	Paracentrobia sp. A		0.006		
	Oligosita desantisi Viggiani	3.33	0.01		
	Oligosita giraulti Crawford		0.24	0.46	
	Pseudoligosita longifrangiata (Viggiani)	33.33	7.66	18.86	11.01

[a] New distribution.

[b] New host association.

Table 3 Jaccard similarity coefficient of egg parasitoids *Dalbulus maidis* in the different biogeographic provinces and ecotones.

	Monte	Yungas	Y-Ch ecotone	Chaco
Monte	1			
Yungas	0.2	1		
Y-Ch ecotone	0.15	0.64	1	
Chaco	0.25	0.38	0.5	1

A value equal to 1 means that the species present in the regions were exactly similar and equal to 0 shows complete dissimilarity.

Sunchal, 13-16.x.2006, 33♀♀. Horco Molle, 12-19.iv.2006, 67♀♀ 28♂♂. La Ramada, 13-16.x.2006, 10♀♀. Las Salinas, 13-16.x.2006, 38♀♀ 17♂♂. Las Talitas, 12-14.x.2005 [8♀♀ 2♂♂ MLPA, 8♀♀ 2 ♂♂ UCRC]. La Virginia, 5.v.2005 [14♀♀ 5♂♂ MPLA]. Los Nogales, 21-28.xii.2006, 28♀♀ 13♂♂; 18-25.i.2007, 135♀♀ 4♂♂; 8-12.ii.2007, 490♀♀ 78♂♂. San Miguel de Tucumán, iv.2004, 87♀♀ 21♂♂; xi.2004 [10♀♀ MLPA]; xii.2004, 31♀♀ 4♂♂; ii.2005, 116♀♀ 15♂♂; xi.2005, 59♀♀ 10♂♂; i.2005, 180♀♀ 32♂♂; iii.2005, 66♀♀ 8♂♂; i.2006, 152♀♀ 30♂♂.

This species, which was previously reported from Argentina and elsewhere in the New World as *A. breviphragma* Soyka (Luft Albarracin *et al* 2009, Moya Raygoza *et al* 2012), was one of the most frequent and abundant parasitoids of *D. maidis* eggs in the surveyed area. *Anagrus breviphragma* Soyka was recently synonymized under *A. incarnatus* by Triapitsyn (2015b). Specimens were obtained from 12 localities, all in Tucumán Province, and in all the ecozones surveyed. This species constituted 84.6% of all the collected parasitoid in Chaco, 60.7% in the Yunga's forest, and 57.5% in the ecotone of these two biogeographic regions. It is broadly distributed in Europe and South America. *Anagrus incarnatus* attacks various hemipterous species, mainly some Delphacidae, Cicadellidae, and Miridae (Triapitsyn 2015a).

Anagrus flaveolus Waterhouse

Material examined. ARGENTINA. Tucumán: El Manantial, 11-14.i.2005, 52♀♀ 19♂♂; 17-20.i.2005 [3♀♀ 3♂♂ UCRC]; 24-27.i.2006, 17♀♀ 10♂♂; 22-25.ii.2006, 13♀♀; 7-11.iii.2006, 14♀♀ 7♂♂. La Virginia, 5.v.2005 [1♀ 1♂ MPLA]. Las Talitas, 12-14.x.2005, 8♀♀ 1♂. Los Nogales, 21-28.xii.2006, 1♀ 6♂♂; 18-25.i.2007, 9♀♀; 8-12.ii.2007, 15♀♀ 3♂♂. San Miguel de Tucumán, iii.2004 [10♀♀ 2♂♂ MPLA]; xi.2004, 22♀♀ 4♂♂; xii.2004, 13♀♀ 6♂♂; ii.2005, 20♀♀; iv.2005, 15♀♀ 3♂♂; i.2006, 11♀♀ 5♂♂.

It is a species with wide distribution in the New World, both in the Nearctic and Neotropical regions. Several species of Auchenorrhyncha were reported as its hosts, which mainly belong to Delphacidae (Triapitsyn 2015a). *Anagrus flaveolus* was previously reported attacking eggs of *D. maidis* in Argentina (De Santis *et al* 1992, Virla *et al* 2013).

All the specimens of *A. flaveolus* obtained in this study were collected occasionally in Tucumán Province in Chaco and Yungas ecozones, and also in the ecotone between them.

Anagrus miriamae Triapitsyn & Virla

Material examined. ARGENTINA. Tucumán: El Mollar, 18-22.xii.2006, 9♀♀.

Anagrus miriamae Triapitsyn & Virla was reared from *D. maidis* eggs only at El Mollar (Tucumán Province), a site located at elevation of above 1900 m in the Monte ecozone.

This species is known only from several provinces of Argentina (Buenos Aires, Misiones, Neuquén, Santiago del Estero, and Tucumán). Its known hosts were *Delphacodes sitarea* Marino de Remes Lenicov & Tesón (Delphacidae) (Triapitsyn & Virla 2004) and *D. maidis* (Moya Raygoza *et al* 2012).

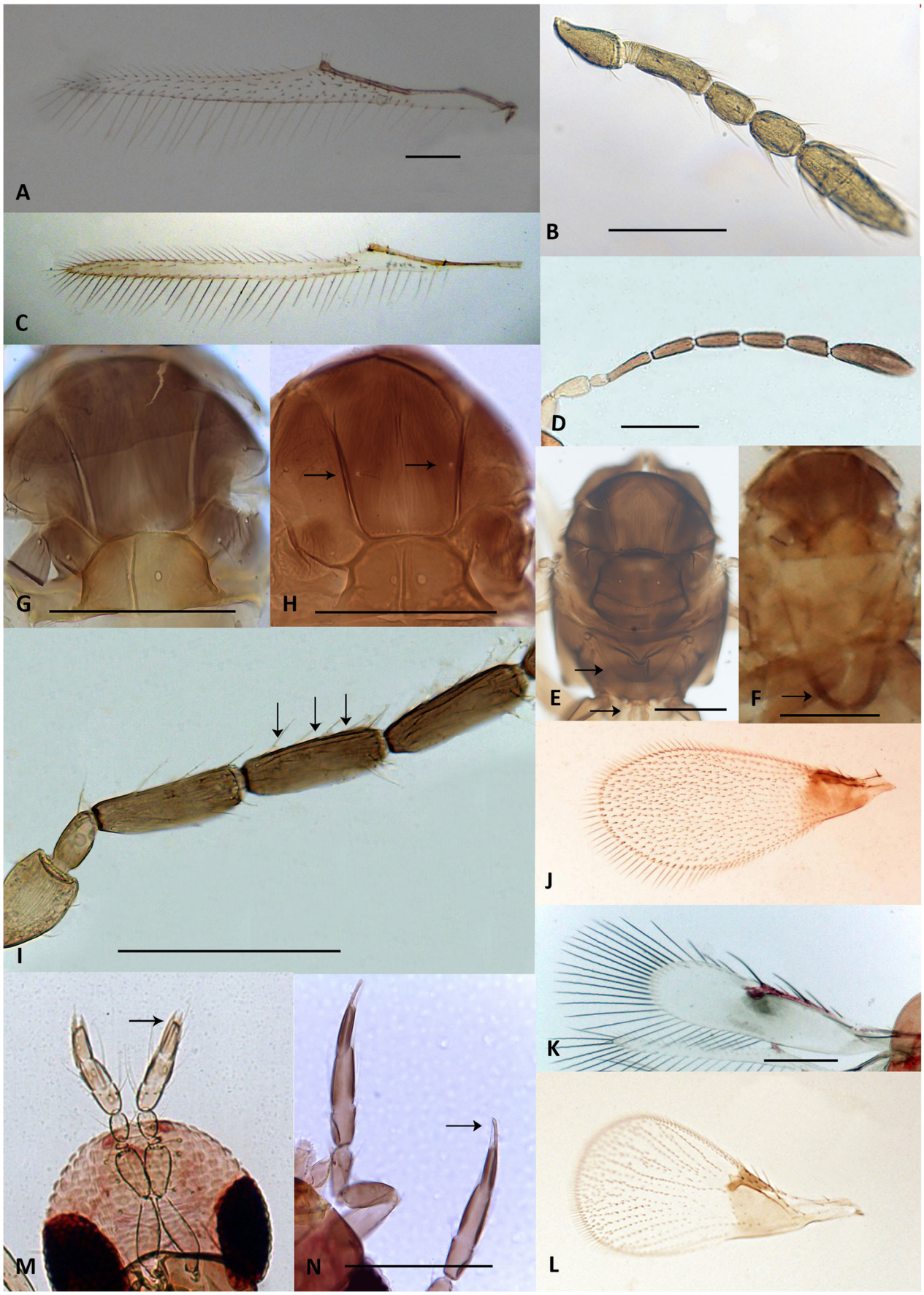
Anagrus nigriventris Girault

Material examined. ARGENTINA. Tucumán: El Manantial, 13-17.i.2005, 10♀♀ 15♂♂; 17-21.i.2005 [3♀♀ 1♂ MLPA]; 21-24.i.2005, 22♀♀ 10♂♂; 24-27.i.2005, 21♀♀ 2♂♂; 3-7.iii.2006 [3♀♀ UCRC]. San Miguel de Tucumán, xi.2004, 4♀♀ 3♂♂; i.2005, 7♀♀ 2♂♂; ii.2005, 2♀♀ 3♂♂; i.2006, 3♀♀.

This species was collected in low numbers from parasitized corn leafhopper eggs in Yunga's forest province and its ecotone with Chaco province.

Anagrus nigriventris is common and widespread in the New World, being recorded from Argentina, Brazil, Canada, Chile, Mexico, Peru, Trinidad and Tobago, and USA; it also occurs in the Hawaiian Islands (Hawaii, USA) (Chiappini *et al* 1996, Luft Albarracin *et al* 2006). Host associations of this species include various leafhopper species and also the mirid bug *Pycnoderes quadrimaculatus* Guérin-Méneville (Triapitsyn & Moratorio 1998). *Anagrus nigriventris* is an important egg parasitoid of the beet leafhopper, *Neoaliturus* (*Circulifer*) *tenellus* (Baker), and *Empoasca* spp. (Triapitsyn

Fig 2 Species of egg parasitoids of *Dalbulus maidis* in Argentina. **A**, *Aprostocetus (Ootetrastichus) infulatus*, hind wing. **B** *Aprostocetus (Ootetrastichus) infulatus* antenna. **C** *Anagrus incarnatus*, hind wing. **D** *Anagrus incarnatus*, antenna. **E** *Polynema* sp. mesosoma and petiole (*arrow*, dorsal view). **F** *Anagrus* sp. mesosoma (mesophragma, *arrow*; dorsal view). **G** *Anagrus incarnatus*, midlobe of mesoscutum (dorsal view). **H** *Anagrus nigriventris*, midlobe of mesoscutum (adnotaular setae, *arrow*). **I** *Anagrus* sp. antenna (F3 with sensory ridge, *arrows*). **J** *Aphelinoidea semifuscipennis*, hind wing. **K** *Oligosita girault*i, hind wing. **L** *Zagella nanula*, hind wing. **M** *Pseudoligosita longifrangiata*, antenna (clava with a terminal spindle-shaped sensillum, *arrow*). **N** *Oligosita girault*i, antenna (clava with a terminal drumstick-shaped sensillum, *arrow*). *Scale lines* 0.1 mm.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& Moratorio 1998). Luft Albarracin *et al* (2006) reported the corn leafhopper as its host in Argentina.

Polynema (Doriclytus) sp. A

Material examined. ARGENTINA. Tucumán: El Mollar, 10-16.ii.2007, 15♀♀ 5♂♂.

The specimens of *Polynema* (*Doriclytus*) sp. A we reared from *D. maidis*, eggs are dark brown. The identity of this species is under investigation and will be dealt with in a separate publication (D.A. Aquino, G.A. Logarzo & E. Luft Albarracin in preparation). Like *A. miriamae*, this species was collected only at El Mollar site (Tucumán Province), located in the Monte province where is one of the most common parasitoids of *D. maidis*, 33.3% of the collected egg parasitoids.

Polynema (Doriclytus) sp. B

Material examined. ARGENTINA. Tucumán: Los Nogales, 18-25.i.2007, 9♀♀ 1♂.

The identity of *Polynema* (*Doriclytus*) sp. B is under investigation and will be dealt with in a separate publication (D.A. Aquino, G.A. Logarzo & E. Luft Albarracin in preparation). This species was collected in the ecotone Yungas-Chaco.

Trichogrammatidae

Aphelinoidea semifuscipennis Girault

Material examined. ARGENTINA. Tucumán: El Manantial, 3-7.iii.2006 [1♀ 1♂ MLPA]; 7-11.iii.2006 [4♀♀ UCRC]; 27.i-2.ii.2006, 2♂♂; 14-21.iii.2005 [1♀ MPLA]; 17-26.iii.2005, 2♂♂. Las Talitas, 18-22.xii.2006, 59♀♀ 20♂♂.

The specimens were collected in the Yungas forest formation and also in the ecotone Yungas-Chaco. Its known hosts were *D. maidis* and *D. elimatus* (Ball) occurring only in Mexico (Moya Raygoza *et al* 2012, 2014).

Burksiella platensis (De Santis)

Material examined. ARGENTINA. Tucumán: El Manantial, 6-9.i.2005, 3♀♀ 1♂; 22-25.ii.2005 [1♀ MPLA]; 2-11.iii.2005, 1♀ 1♂; 9-17.iii.2005 [1♀ 1♂ MLPA]; 4-9.i.2006, 1♀.

All the specimens were obtained only from one locality in the Yungas environment.

This species is known only from South America (Argentina and Brazil), and until now, its only known host was the sharpshooter *Tapajosa rubromarginata* (Signoret) (Triapitsyn 2003). *Dalbulus maidis* is a new host associated for *B. platensis*.

Zagella nanula De Santis

Material examined. ARGENTINA. Santiago del Estero: Pozo Hondo, 20-26.xii.2006, 4♀♀ 1♂. Tucumán: Los Nogales, 8-12.ii.2007 [2♀♀ MPLA]. El Manantial, 23-27.xii.2004, 9♀♀ 14♂♂; 3-6.i.2005, 18♀♀ 5♂♂; 6-9.i.2005, 7♀♀ 1♂; 13-24.i.2005, 35♀♀ 13♂♂; 24.i-2.ii.2005 [6♀♀ 5♂♂ MLPA, 4♀♀ 3♂♂ UCRC]; 15-18.ii.2005, 8♀♀ 5♂♂; 2-11.iii.2005, 14♀♀ 4♂♂; 11-21.iii.2005, 9♀♀ 10♂♂; 14-21.iii.2005, 11♀♀ 6♂♂; 17-26.iii.2005, 7♀♀ 6♂♂; 19-22.xii.2005, 6♀♀ 6♂♂; 26-30.xii.2005, 19♀♀ 14♂♂; 12-23.i.2006, 22♀♀ 9♂♂; 27.i-2.ii.2006, 12♀♀ 8♂♂. San Miguel de Tucumán, xi.2004 [3♀♀ 2♂♂ MPLA]; ii.2005 [2♀♀ UCRC].

This species was described by De Santis (1970) based on a single female from Uruguay. *Zagella nanula* is commonly obtained from *D. maidis* eggs and occurs in Chaco, Yungas, and the ecotone between them.

Paracentrobia tapajosae Viggiani

Material examined. ARGENTINA. Salta: Metán, 11-13.i.2006, 5♀♀. Tucumán: El Manantial, 20-27.xii.2004, 93♀♀ 28♂♂; 27.xii.2004 - 3.i.2005, 19♀♀ 8♂♂; 3-6.i.2005, 9♀♀ 3♂♂; 6-13.i.2005, 67♀♀ 18♂♂; 13-21.i.2005, 175♀♀ 72♂♂ [6♀♀ 2♂♂ UCRC]; 21-27.i.2005, 107♀♀ 32♂♂; 24.i-2.ii.2005, 92♀♀ 26♂♂; 15-25.ii.2005, 80♀♀ 36♂♂; 2-11.iii.2005, 71♀♀ 27♂♂ [3♀♀ 3♂♂ MPLA]; 11-21.iii.2005, 126♀♀ 24♂♂; 21-31.iii.2005, 57♀♀ 42♂♂. Los Nogales, 21-28.xii.2006, 65♀♀ 36♂♂; 18-25.i.2007, 23♀♀ 10♂♂; 8-12.ii.2007, 29♀♀ 14♂♂. San Miguel de Tucumán, iv.2004 [1♀ MPLA]; xii.2004, 15♀♀ 12♂♂ [4♀♀ 3♂♂ MPLA, 2♀♀ 2♂♂ UCRC]; i.2005, 21♀♀ 19♂♂; iii.2005, 54♀♀ 25♂♂; i.2006 [7♀♀ 3♂♂ MPLA]; ii.2006 14♀♀; i.2007, 43♀♀ 25♂♂.

Paracentrobia tapajosae Viggiani is one of the most common egg parasitoids of the corn leafhopper in the sampled localities in the Yungas and the Yungas-Chaco ecotone. It is newly recorded from Salta Province. This recently described species was known to occur only in Tucumán Province (El Manantial and San Miguel de Tucumán) as an egg parasitoid of the leafhoppers *T. rubromarginata* and *Agalliana ensigera* Oman (Virla *et al* 2009b).

Paracentrobia sp. A

Material examined. ARGENTINA. Tucumán: El Manantial, 26-29.xii.2005, 3♀♀.

The occurrence of this egg parasitoid of the corn leafhopper is very occasional. *Paracentrobia* sp. A is easily distinguishable from the two other congeneric species known from Argentina, *P. subflava* (Girault), and *P. tapajosae* Viggiani, by the body coloration, having the pronotum, mesoscutum, axilla, scutellum, and procoxa dark brown, and rest of the body yellow

(the body is completely yellow in *P. subflava* and *P. tapajosae*). It also lacks a dark spot just behind the stigmal vein of the fore wing.

Oligosita desantisi Viggiani

Material examined. ARGENTINA. Tucumán: El Manantial, 11-14.iii.2005, 2♀♀. El Mollar, 17-22.i.2007 [2♀♀ MPLA].

This species was described by Viggiani (1981) based on the specimens collected in Buenos Aires Province (Argentina) and Miranda State (Venezuela). Its known hosts were *Exitianus obscurinervis* (Stål) (Virla 2000) and *D. maidis* (Moya Raygoza *et al* 2012). *Oligosita desantisi* was collected very sporadically and always in low numbers in the sites located in the Yungas and Monte.

Oligosita giraulti Crawford

Material examined. ARGENTINA. Tucumán: El Cadillal, 13-20.x.2005, 3♀♀. El Manantial, 9-17.iii.2005, 10♀♀ 1♂; 21-27.i.2005 [2♀♀ MLPA]; 21-31.iii.2005, 4♀♀ 1♂; 23-30.i.2006, 15♀♀. San Miguel de Tucumán, i.2006 [4♀♀ UCRC]; i.2007, 11♀♀.

This species is widely distributed in the Neotropical region. It was recorded previously from the USA, Costa Rica, Panama, Trinidad and Tobago, Guyana, Brazil, and Argentina (only in Misiones Province). It's previously known hosts belong to Cercopidae (De Santis 1979).

Here, we found it only in Tucumán Province, where it occurs in the Yungas and the ecotone Yungas-Chaco.

Pseudoligosita longifrangiata (Viggiani)

Material examined. ARGENTINA. Catamarca: San José, 10-16.ii.2007, 3♀♀ 3♂♂. Jujuy: Purmamarca, 12-20.i.2007, 1♀ 1♂. Salta: Animaná, 10-16.ii.2007, 6♀♀. El Tunal, 28.xii.2006 - 3.i.2007, 5♀♀ 1♂♂ [2♀♀ 1♂ UCRC]. San Ramón de la Nueva Orán, 11-19.i.2007, 3♀♀ 2♂♂. Tucumán: Colalao del Valle, 10-16.ii.2007 [2♀♀ 2♂♂ MPLA]. El Manantial, 3-6.i.2005, 10♀♀ 4♂♂; 26-29.xii.2005, 18♀♀ 4♂♂; 9-17.iii.2005, 39♀♀ 5♂♂; 21-30.iii.2006, 40♀♀ 32♂♂; 19-22.xii.2005, 7♀♀ 1♂; 9-17.i.2006 [2♀♀ 2♂♂ MPLA]. El Mollar, 8-12.ii.2007 [1♀ MPLA]. Horco Molle, 12-19.iv.2006, 18♀♀ 24♂♂. La Ramada, 13-16.x.2006, 1♀ 1♂. Las Cejas, 13-17.xii.2004 [4♀♀ 1♂ MPLA]. Las Salinas, 13-16.x.2006, 4♀♀ 3♂♂. Las Talitas, 12-14.x.2005, 1♀ 3♂♂. Los Nogales, 21-28.xii.2006, 45♀♀ 16♂♂; 18-25.i.2007, 14♀♀ 20♂♂; 8-12.ii.2007, 97♀♀ 65♂♂. Trancas, 5-8.ix.2006, 1♂. San Miguel de Tucumán, ii.2004, 6♀♀; iv.2004, 17♀♀ 6♂♂; xi.2004 [5♀♀ 1♂ UCRC]; xii.2004, 18♀♀ 7♂♂; i.2005, 56♀♀ 30♂♂; ii.2005, 16♀♀ 10♂♂; i.2006, 88♀♀ 23♂♂; xii.2006, 130♀♀ 44♂♂.

In this study, *P. longifrangiata* was found to be one of the most common parasitoids of *D. maidis* eggs in all biogeographical regions that were surveyed (Table 2). We extend its known distribution range to almost all of northwestern Argentina.

This species was previously known from Uruguay (Curticeiras State) and Argentina (Buenos Aires Province) (Viggiani 1981). Recently, *P. longifrangiata* was registered attacking eggs of Odonata in Brazil (Querino & Hamada 2009).

The record of 16 species of egg parasitoids attacking *D. maidis* eggs in northwestern Argentina reveals that in each locality, there is a complex of such natural enemies of this economically important leafhopper pest, but the rates of parasitism observed in the course of this survey were relatively low compared with such rates reported for this leafhopper in other countries, even considering possible overestimations.

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