REVISTA DE
Biología Tropical

Insect galls from Córdoba, Argentina: a case where stem galls predominate

Nicolás Kuzmanich*, Melisa A. Giorgis & Adriana Salvo

Instituto Multidisciplinario de Biología Vegetal-CONICET, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Av. Vélez Sarsfield 1611, X5016GCA Córdoba, Argentina; nicolaskuzmanich@gmail.com, mgiorgis@imbiv.unc.edu.ar, asalvo@unc.edu.ar

* Correspondence

Received 03-IV-2018. Corrected 29-V-2018. Accepted 28-VI-2018.

Abstract: Galls are structures produced by plants in response to the activity of several types of organisms. Gall-inducing species have a close relationship with their host plant, as their habitat is largely restricted to the gall and the plant organ in which it develops. All plant organs are susceptible to gall induction by insects, the leaves being the most vulnerable. Knowledge about interactions between gall-inducing insects and plants is fragmented and incomplete in Argentina. In this study, we completed an inventory of galls induced by insects on plants in Córdoba (central Argentina) using information from field surveys and a review of the literature. We also focused on the frequency of plant-insect taxonomic associations and plant organs most commonly attacked by gall-inducing insects. Field surveys were performed systematically in 26 sites of Chaco Serrano, which were visited five times in two consecutive years, and in 17 sites of the province, which were sampled one or two times each. A comprehensive literature search of electronic and conventional databases was also conducted to complete the inventory. A total of 99 gall morphospecies on 58 plant species (21 families and 44 genera) were recorded through both field surveys and a literature review, enlarging the list of species available for the region by almost 50 %. Asteraceae and Fabaceae were the plant families most attacked by galling insects, in partial concordance with the most species-rich plant families in the region. Diptera, particularly the family Cecidomyiidae, was the most species-rich group in the community of galling insects, which is in agreement with different studies across the globe. *Baccharis* was the genus displaying the highest number of gall morphotypes, followed by *Acacia*, *Condalia*, *Geoffroea*, *Prosopis* and *Schinus*. Almost 60 % of the morphotypes were stem galls, a pattern uncommon in the literature. Fusiform and globoid-shaped galls were predominant. Our study highlights the scarce knowledge there is about the interactions between plants and gall-inducing insects in Argentina, particularly those involving species of Cecidomyiidae, with more than 30 undescribed species. Possible mechanisms involved in the predominance of stem galls in central Argentina are discussed. Rev. Biol. Trop. 66(3): 1135-1148. Epub 2018 September 01.

Key words: Asteraceae; Cecidomyiidae; cecidogenous insects; insect-plant interactions; species inventory.

Galls are structures produced by plants in response to the activity of several types of organisms, such as nematodes, mites, bacteria, fungi and mainly insects (Mani, 1964; Shorthouse, Wool, & Raman, 2005). Among the latter, the orders Diptera and Hymenoptera contain the highest number of gall-inducing species (Espírito-Santo & Fernandes, 2007; Mani, 1964).

Plant galls arise mostly by hypertrophy (overgrowth) and hyperplasia (overproliferation) of vegetal cells, and usually by the formation of tissues that are absent in ungalled host plants (Mani, 1964; Raman, 2011). Galls display great complexity and an incredible variety of forms, allowing insects to take nutrients and shelter simultaneously (Shorthouse et al., 2005). All plant organs are susceptible to gall induction by insects, the leaves being the most frequently attacked. This pattern has arisen in different localities and vegetation types at a global scale (Felt, 1940; Mani, 1964; Shorthouse & Rohfritsch, 1992; Blanche & Ludwig, 2001; Nieves-Aldrey, Ibáñez, & Medianero, 2008; Kuzmanich, Altamirano, & Salvo, 2015; Mendonça & Stiling, 2017). A few studies have reported stems as the most affected organs (Veldtman & McGeoch, 2003; Carneiro, Borges, Araújo, & Fernandes, 2009; Coelho, Carneiro, Branco, Borges, & Fernandes, 2013; Fernandes et al., 2002; Toma & Mendonça, 2013). The resultant galls have been classified according to their shapes, the organs they affect and other features, in a high number of morphological types (Isaias, Carneiro, Oliveira, & Santos, 2013; Arriola, Melo, & Isaias, 2015).

Some local and regional patterns have been observed in the distribution of insect galls on host plant families and galled plant organs. Regarding the taxonomy of the host plant, some local features of vegetation such as species composition, plant density and richness, together with historical factors, such as the number of species of each plant family occurring in the region, may have contributed to the richness and radiation patterns of the galling insects observed (Gonçalves-Alvim & Fernandes, 2001; Araújo, Scareli-Santos, Guilherme, & Cuevas-Reyes, 2013; Araújo, 2017; Bergamini, Bergamini, Santos, & Araújo, 2017; Mendonça & Stiling, 2017). Thus, in different regions of the world, different families of plants have been mentioned as the most attacked by gall inducing insect species. For example in North America and Europe, the dominant family of galled plants is Fagaceae (Mani, 1964), while in South America, the most attacked plant families are Asteraceae and Fabaceae (Fernandes & Santos, 2014; Mani, 1964).

In the Southern part of the Neotropical region, knowledge of insect gall communities is rather poor. In Argentina, most of the taxonomic studies were performed in the early twentieth century (Kieffer & Jörgensen, 1910; Tavares, 1915; Brèthes, 1916; Jörgensen, 1917; Houard, 1933). Nonetheless, the number of studies dealing with taxonomic and ecological aspects of galling insects in Argentina is growing (Fernandes et al., 2002; Carabajal De Belluomini, Castresana, Salim, & Notario, 2009; Martinez, Altamirano, & Salvo, 2011; Quintero, Garibaldi, Grez, Polidori, & Nieves-Aldrey, 2014; Kuzmanich et al., 2015; Malcom, Oggero, Arana, Tordable, & Boito, 2015; Altamirano, Valladares, Kuzmanich, & Salvo, 2016). In spite of these advances, the information is still fragmented and incomplete. In this context, the goals of the present study were to advance the inventory of galls induced by insects on plants in Córdoba (central Argentina) and to analyze some taxonomic and ecological aspects of these plant-insect interactions. We particularly focused on the frequency of plant-insect taxonomic associations and on the plant organs most commonly attacked by gall-inducing insects, using information from field surveys and a literature review.

MATERIALS AND METHODS

Study Area: The study area includes the province of Córdoba (Argentina), (31˚ 25’ S & 64˚ 10’ W), which covers ca. 161 000 km^2 and comprises three major biogeographical units. The Pampa, located in the Southeast extreme, is dominated by grasslands, whereas the Espinal and Chaco biogeographical provinces cover most of the province and are dominated by seasonally dry forests (Cabrera, 1976). The Pampa grasslands, the Espinal forests and the Eastern lowland area of Chaco are now reduced to small and isolated patches increasingly surrounded by a matrix of soybean, while the Chaco in the Western lowland area of Córdoba is, in general, covered by closed and open forests and shrublands in different successional stages (Hoyos et al., 2013; Cabido et al., 2018). Finally, the mountain region of Chaco (commonly named as Chaco Serrano), is composed of a complex matrix of native open and closed woodlands, shrublands and grasslands, including also monospecific stands of exotic woody species (Cingolani, Renison, Zak, &

Cabido, 2004; Giorgis et al., 2017). This area constitutes the main reservoir of biodiversity in Córdoba (Zak & Cabido, 2002).

A highly seasonal subtropical climate with important variation along the latitudinal and altitudinal gradient characterize the studied area (see Tecco et al. 2016 and Cabido et al. 2018 for more details). Precipitation is coupled with temperature to define the growing and flowering season, which mainly occur between October and April (Giorgis, Cingolani, Teich, & Renison, 2010; Giorgis, Cingolani, Gurvich, & Astegiano 2015).

Field surveys and literature review: Two types of field surveys were performed: i) systematic surveys restricted to a region of Chaco Serrano, located approximately 35 km North of Córdoba City (31º 07' S & 64º 23' W), which contains 26 sites that were visited five times each in two consecutive growing seasons (October to April, 2014-2016). In each site and sampling date, all plants in plots of 20 x 20 m were carefully observed to detect gall occurrence; and ii) complementary surveys, which consisted in just one or two visits to 17 sites in the Espinal and Chaco provinces (Fig. 1). In each site and date, the vegetation was searched for insect galls for approximately one hour (Price et al., 1998), totalizing a number of 109 sampling hours. In both systematic and complementary surveys, galls were collected and taken to the laboratory in order to rear adult insects. Part of the material (insects and galls) was kept in alcohol 70 % for dissection and posterior conservation. Voucher specimens of gall morphotypes obtained by field surveys were deposited at the Entomological Collection of the National University of Córdoba.

The identification of the galling insects was done to the lowest possible taxonomic level through identification keys (White &

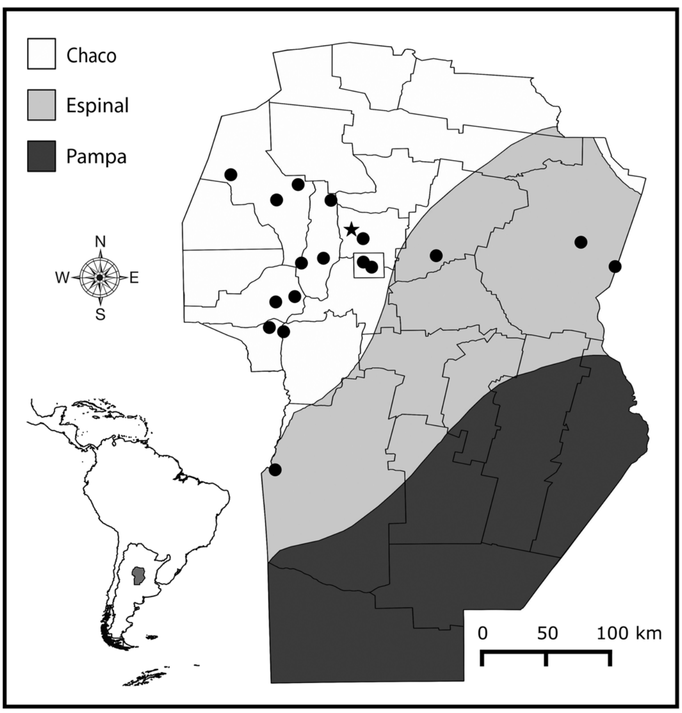

Fig. 1. Cordoba province with area in which 26 sites for systematic samplings (star symbol) and 17 sites for complementary samplings (point symbols) were located. Chaco, Espinal, and Pampa regions are marked with white, light grey and dark grey, respectively.

CC BY

Hodkinson, 1985; Stehr, 1987; Burckhardt & Basset, 2000; Nieves-Aldrey & Blas, 2015) and in comparison with reference material, using compound (Olympus CX31) and stereoscopic (Zeiss, Stemi dV4) microscopes. Gall morphotypes were classified in one of the following categories: clavate, conical, cylindrical, fusiform, globoid, lenticular, rosette, bivalveshaped, hornshaped, leaf fold, marginal roll and pocket shaped, according to Isaias et al. (2013). Other categories were proposed when necessary. A comprehensive literature search of electronic databases (Scopus, Scielo and Google Scholar) was conducted, searching all published papers containing simultaneously the phrases "insect gall" and "Córdoba, Argentina", in the period from 1980 to 2017. Additionally, the largest entomological libraries of the country (located at La Plata and Bernardino Rivadavia Museums and Darwinion Botanic Institute) were visited to get access to unavailable digital resources, particularly those published at the beginning of the century. Species names were updated following several taxonomic databases available on the internet (http://www.floraargentina.edu.ar, https://www.hemiptera-databases.org/psyl-list/, http://eol.org/).

RESULTS

In the Córdoba province, a total of 99 gall morphotypes on 58 plants species belonging to 21 families and 44 genera were recorded through both field surveys and a literature review (Table 1). From all gall records, 55 % were registered for the first time in Cordoba province and 49 % constitute new records for Argentina (Table 1). Sixteen of the morphotypes registered through field surveys were previously mentioned in the literature for the province, whereas 28 % of the interactions were recorded as literature citations, not corroborated by field observations. A total of 18 published studies provided information useful to the inventory.

The botanical families most frequently involved in interactions with galling insects were Asteraceae (27 morphotypes on 17 plant species), Fabaceae (22 morphotypes on six plant species) and Anacardiaceae (eight morphotypes on two plants species), whereas the rest of the families had fewer than seven morphotypes each (Table 2). *Baccharis* was the genus displaying the highest number of gall morphotypes (16), with seven species acting as hosts. Other plant genera frequently attacked by galling insects were *Acacia*, *Condalia*, *Geoffroea*, *Prosopis* and *Schinus*, which had seven morphotypes each, in three or fewer host plant species. Three plant species may be considered as superhosts (sensu, Veldtman & McGeoch, 2003): *Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkart (Fabaceae) and *Schinus fasciculata* (Griseb.) I. M. Johnst. (Anacardiaceae), which displayed seven gall morphotypes each; and *Baccharis salicifolia* (Ruiz & Pav.) Pers., with six galling-insect species. For the first time, the plant genera *Nassella* (Poaceae) and *Angelphytum* (Asteraceae) were reported as hosting gall-inducing insects.

Galls occurring in Cordoba were classified into 11 morphotypes (Table 1), the most common shapes being fusiform (35 % of total gall morphotypes registered) and globoid (34 %) (Table 1). Other forms were represented by 6 % or less of the total gall morphotypes.

Stems were the most affected plant organs, accounting for 58.6 % of the gall morphotypes, whereas a noticeably lower representation was observed for leaf (19.1 %) and bud (14.1 %) galls. Other organs like thorns, petioles, flowers and spines were less affected. Only a very small fraction of galling-insect species was found developing in two different organs (Table 3).

Regarding the insects, 41.4 % of the gall-inducing species were Diptera, 11.1 % Hemiptera, 7 % Lepidoptera and 6 % Hymenoptera. Cecidomyiidae was the family with the highest number of galling species (38.3 %) whereas Cynipidae, Tephritidae, Aphididae, Calophyidae and other families were less-well represented. The absence or very low number of insects reared from more than 75 % of the gall morphotypes prevented the taxonomic identification of the insect inductor. Seven percent

TABLE 1
Insect galls from central Argentina

Host plant	Host plant family	Inducer insect	Organ	Gall shape[1]	Sources[2]
Dicliptera squarrosa Nees	Acanthaceae	Diptera, Cecidomyiidae	Stem	Globoid	*
Iresine diffusa Humb. & Bonpl. ex Willd.	Amaranthaceae	Diptera, Cecidomyiidae	Stem	Globoid	*
Lithraea molleoides (Vell.) Engl.	Anacardiaceae	Hemiptera, *Calophya clavuligera* Burckhardt & Basset	Leaf	Lenticular	4[X]
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	Hemiptera, *Tainarys sordida* Burckhardt	Leaf	Marginal roll	4; 14[$]
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	*Calophya catillicola* Burckhardt & Basset	Leaf	Pocket	4; 14[$]
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	*Calophya duvauae* (Scott) Burckhardt	Leaf	Conical	14[X]
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	Lepidoptera, *Cecidoses eremita* Curt.	Stem	Globoid	3; 10; 11; 12; 14; 17[$]
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	Lepidoptera, *Dicranoses congregatella* Brèthes	Stem	Cylindrical	14; 17[$]
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	Unknown	Bud	Cylindrical	*
Schinus fasciculata (Griseb.) I. M. Johnst.	Anacardiaceae	Unknown	Stem	Amorphous	*
Aspidosperma quebracho-blanco Schltdl.	Apocynaceae	Diptera, *Anasphodiplosis aspidospermae* (Blanch.)	Bud	Cylindrical	2; 9; 10; 17[X]
Ambrosia elatior L.	Asteraceae	“Prob. Aphididae”	Leaf	Marginal roll	10; 17[$]
Angelphytum aspilioides (Griseb.) H. Rob.	Asteraceae	Diptera, Cecidomyiidae	Stem	Fusiform	*
Baccharis aliena (Spreng.) Joch.Müll.	Asteraceae	Lepidoptera	Stem	Fusiform	10; 17[X]
Baccharis articulata (Lam.) Pers.	Asteraceae	Unknown	Stem	Fusiform	*
Baccharis coridifolia DC.	Asteraceae	Diptera, *Baccharomyia cordobensis* (Kieff. & Jörgen.)	Stem	Fusiform	9; 10; 11; 12[X]
Baccharis coridifolia DC.	Asteraceae	Diptera, Cecidomyiidae	Stem	Fusiform	*
Baccharis flabellata Hook. & Arn.	Asteraceae	Unknown	Stem	Globoid to fusiform[#]	*
Baccharis pingraea DC.	Asteraceae	Unknown	Leaf	Lenticular	*
Baccharis rufescens Spreng.	Asteraceae	Diptera, Tephritidae	Stem	Fusiform	*
Baccharis rufescens Spreng.	Asteraceae	Lepidoptera	Stem	Fusiform	*
Baccharis rufescens Spreng.	Asteraceae	Unknown	Stem	Globoid	*
Baccharis rufescens Spreng.	Asteraceae	Unknown	Stem	Rosette	*
Baccharis salicifolia (Ruiz & Pav.) Pers.	Asteraceae	*Baccharomyia ornaticornis* (Kieff. & Jörgen.)	Stem	Fusiform	9; 10; 11; 12; 17[$]
Baccharis salicifolia (Ruiz & Pav.) Pers.	Asteraceae	Diptera, *Geraldesia* sp.	Leaf	Fusiform	8[X]
Baccharis salicifolia (Ruiz & Pav.) Pers.	Asteraceae	Diptera, *Rhoasphondylia crassipalpis* (Kieff. & Jörgen.)	Stem	Globoid	9; 10; 11; 12; 17[X]
Baccharis salicifolia (Ruiz & Pav.) Pers.	Asteraceae	Hemiptera, *Trioza* cf. *steinbachi* (Com. Pers. Burckhardt D.)	Leaf	Marginal roll	10; 13; 17[X]
Baccharis salicifolia (Ruiz & Pav.) Pers.	Asteraceae	Unknown	Stem	Globoid	*
Baccharis salicifolia (Ruiz & Pav.) Pers.	Asteraceae	Unknown	Stem	Rosette	*

TABLE 1 (Continued)

Host plant	Host plant family	Inducer insect	Organ	Gall shape[1]	Sources[2]
Chromolaena arnottiana (Griseb.) R.M. King & H. Rob.	Asteraceae	Diptera, *Cecidochares* sp.	Stem	Cylindrical	*
Conyza sumatrensis (Retz.) E. Walker	Asteraceae	Diptera, Cecidomyiidae	Stem	Fusiform	*
Gnaphalium cabrerae S. E. Freire	Asteraceae	Unknown	Stem	Globoid	*
Porophyllum ruderale (Jacq.) Cass.	Asteraceae	Diptera, Cecidomyiidae	Stem	Globoid	*
Pseudognaphalium cheiranthifolium (Lam.) Hilliard & B.L. Burtt	Asteraceae	Diptera, Tephritidae	Bud	Fusiform	10; 17[$]
Senecio pampeanus Cabrera	Asteraceae	Unknown	Stem	Globoid	*
Vernonia mollissima D. Don ex Hook. et Arn.	Asteraceae	Diptera, Cecidomyiidae	Stem	Fusiform	*
Zexmenia buphtalmiflora (Lorentz) Ariza	Asteraceae	Unknown	Stem	Globoid	*
Zexmenia buphtalmiflora (Lorentz) Ariza	Asteraceae	Unknown	Bud	Globoid	*
Berberis ruscifolia Lam.	Berberidaceae	Hemiptera, Psylloidea	Leaf	Globoid	10; 17 [X]
Wahlenbergia linarioides (Lam.) A. DC.	Campanulaceae	Diptera, Cecidomyiidae	Stem	Globoid to fusiform [#]	*
Celtis ehrenbergiana (Klotzch) Liebm.	Celtidaceae	Diptera, Cecidomyiidae	Stem	Globoid	*; 7 [X]
Celtis ehrenbergiana (Klotzch) Liebm.	Celtidaceae	Diptera, Cecidomyiidae	Leaf	Globoid	*
Celtis ehrenbergiana (Klotzch) Liebm.	Celtidaceae	Diptera, Cecidomyiidae	Stem	Fusiform	*; 7 [X]
Croton argentinus Müll. Arg.	Euphorbiaceae	Diptera, Cecidomyiidae	Leaf	Fusiform	10; 17[$]
Croton lachnostachyus Baill	Euphorbiaceae	Unknown	Leaf	Pocket	*
Tragia dodecandra Griseb.	Euphorbiaceae	Diptera, Cecidomyiidae	Bud	N/A	10; 17[$]
Acacia aromo Gillies ex Hook. & Arn.	Fabaceae	Hymenoptera, *Eschatocerus acaciae* Mayr.	Stem	Globoid	6; 16[$]
Acacia aromo Gillies ex Hook. & Arn.	Fabaceae	Unknown	Thorn	Fusiform	*
Acacia caven (Molina) Molina	Fabaceae	*Eschatocerus acaciae* Mayr.	Stem	Globoid	6; 16[$]
Acacia caven (Molina) Molina	Fabaceae	Diptera, Cecidomyiidae	Leaf	Globoid	*
Acacia caven (Molina) Molina	Fabaceae	Unknown	Thorn	Fusiform	*
Acacia caven (Molina) Molina	Fabaceae	Unknown	Stem	Fusiform	*
Acacia caven (Molina) Molina	Fabaceae	Unknown	Stem	Globoid	*, 13 [X]
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Diptera, *Allodiplosis crassa* Kieff. & Jörgen.	Bud	Globoid	9; 10; 12; 17 [X]
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Diptera, Cecidomyiidae	Stem	Globoid	10; 17[$]
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Diptera, Cecidomyiidae	Bud	Globoid	10; 17[$]

TABLE 1 (Continued)

Host plant	Host plant family	Inducer insect	Organ	Gall shape[1]	Sources[2]
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Lepidoptera	Stem	Fusiform	10; 17[$]
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Lepidoptera	Stem	Fusiform	10; 17[$]
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Unknown	Stem	Globoid	*
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart	Fabaceae	Unknown	Stem	Fusiform	10; 17[$]
Prosopis alba Griseb.	Fabaceae	*Eschatocerus acaciae* Mayr.	Stem	Globoid	5; 16[X]
Prosopis alba Griseb.	Fabaceae	Diptera, Cecidomyiidae	Leaf	Globoid	*; 5[X]
Prosopis alba Griseb.	Fabaceae	Diptera, Cecidomyiidae	Stem	Globoid	*
Prosopis alba Griseb.	Fabaceae	Diptera, Cecidomyiidae	Stem	Fusiform	*; 5[X]
Prosopis alba Griseb.	Fabaceae	Unknown	Petiole	Fusiform	*
Prosopis alba Griseb.	Fabaceae	Unknown	Bud	Globoid	*
Prosopis chilensis (Mol.) Stuntz.	Fabaceae	*Eschatocerus acaciae* Mayr.	Stem	Globoid	6; 16[$]
Prosopis nigra (Griseb) Hieron.	Fabaceae	*Eschatocerus acaciae* Mayr.	Stem	Globoid	6; 16[$]
Lepechinia floribunda (Benth.) Epling	Lamiaceae	Unknown	Stem	Fusiform	*
Minthostachys verticillata (Griseb.) Epling	Lamiaceae	Diptera, Cecidomyiidae	Stem and Petiole	Globoid	18[X]
Heimia salicifolia (Kunth) Link	Lythraceae	Unknown	Stem	Fusiform	*
Nassella neesiana (Trin. & Rupr.) Barkworth	Poaceae	Unknown	Stem	Cylindrical	*
Monnina dictyocarpa Griseb.	Polygonaceae	Diptera, Cecidomyiidae	Flower	N/A	10; 17[$]
Monnina dictyocarpa Griseb.	Polygonaceae	Diptera, Cecidomyiidae	Leaf	N/A	10; 17[$]
Ruprechtia apetala Wedd.	Polygonaceae	Diptera, Cecidomyiidae	Stem	Globoid to fusiform [#]	*
Condalia buxifolia Reissek	Rhamnaceae	Unknown	Stem	Fusiform	*
Condalia microphylla Cav.	Rhamnaceae	Diptera, Cecidomyiidae	Leaf	Fusiform	10; 17[$]
Condalia microphylla Cav.	Rhamnaceae	Diptera, Cecidomyiidae	Bud	Fusiform	10; 17[$]
Condalia microphylla Cav.	Rhamnaceae	Lepidoptera	Bud	Fusiform	10; 12; 17[$]
Condalia montana A. Cast.	Rhamnaceae	Unknown	Stem	Fusiform	*
Condalia montana A. Cast.	Rhamnaceae	Unknown	Bud	Fusiform	*
Condalia montana A. Cast.	Rhamnaceae	Unknown	Bud	Globoid	*
Malus domestica Borkh.	Rosaceae	Hemiptera,*Eriosoma lanigerum* Hausm.	Stem	N/A	10; 17[$]

cc BY

TABLE 1 (Continued)

Host plant	Host plant family	Inducer insect	Organ	Gall shape[1]	Sources[2]
Prunus persica Stokes	Rosaceae	Hemiptera,*Myzus persicae persicae* (Sulzer, 1776)	Leaf	N/A	10; 17$^{\$}$
Populus deltoides subsp. *monilifera* (Aiton) Eckenw.	Salicaceae	Hemiptera,*Pemphigus populitransversus* Riley	Petiole	Globoid	10; 17$^{\$}$
Jodina rhombifolia Hook. & Arn.	Santalaceae	"Insecta"	Stem	Amorphous	10; 17^{X}
Lycium cestroides Schltdl.	Solanaceae	Hymenoptera, *Allorhogas cordobensis* Martínez	Stem	Cylindrical	15^{X}
Lycium ciliatum Schltdl.	Solanaceae	Unknown	Stem	Fusiform	*
Lycium elongatum X cestroides Hieronymus	Solanaceae	Diptera, Cecidomyiidae	Bud	Globoid	10; 17$^{\$}$
Physalis viscosa L.	Solanaceae	Diptera,*Neolasioptera argentata* (Brèthes)	Stem	Fusiform	*; 9; 11; 12^{X}
Solanum argentinum Bitter & Lillo	Solanaceae	Diptera, Cecidomyiidae	Stem	Fusiform to tubular #	1; 7^{X}
Aloysia gratissima (Gillies & Hook. ex Hook.) Tronc.	Verbenaceae	Unknown	Leaf	Lenticular	*
Lantana megapotamica (Spreng.) Tronc.	Verbenaceae	Diptera, Cecidomyiidae	Stem	Globoid	*
Lantana megapotamica (Spreng.) Tronc.	Verbenaceae	Unknown	Leaf	Globoid	*
Lantana grisebachii Seckt var. grisebachii	Verbenaceae	Unknown	Stem	Fusiform	*
Lippia turbinata Griseb.	Verbenaceae	Diptera, Cecidomyiidae	Bud	Fusiform	10; 17$^{\$}$
Lippia turbinata Griseb.	Verbenaceae	Diptera, Cecidomyiidae	Leaf and Stem	Conical	10; 17$^{\$}$
Verbena citrodora (Paláu) Cav.	Verbenaceae	Hemiptera, Psylloidea	Leaf	Pocket	*
Larrea divaricata Cav.	Zygophyllaceae	Unknown	Stem	Fusiform	*

1. Gall shapes were taken from Isaias et al. (2013); "#" indicates a shape proposed by the authors and "N/A" indicates that information about gall shape was not available.
2. Sources on interactions records: "*" indicates new record of each interaction for Córdoba, "$" indicates interactions mentioned in the bibliography, "X" indicates interactions registered in field samplings and also in literature. References are given in numbers (1) Altamirano et al. (2016), (2) Blanchard (1938), (3) Bréthes (1916), (4) Burckhardt & Basset (2000), (5) Carabajal de Belluomini et al. (2009), (6) Díaz (1980), (7) Fernandes et al. (2002), (8) Gagné (1994), (9) Gagné & Jaschhof (2017), (10) Houard (1933), (11) Jörgensen (1917), (12) Kieffer & Jörgensen (1910), (13) Kuzmanich et al. (2015), (14) Malcolm et al. (2015), (15) Martínez et al. (2011), (16) Nieves Aldrey & Blas (2015), (17) Tavares (1915), (18) Valladares, Zapata, Zygaldo, & Banchio (2002).

TABLE 2
Number of plant host species and number of gall morphotypes per plant families in Córdoba (central Argentina)

Botanical family	Number of gall morphotypes (%)	Plant host species (%)	Number of plant species[1]
Asteraceae	27 (27.27)	17 (29.31)	269
Fabaceae	22 (22.22)	6 (10.34)	107
Anacardiaceae	8 (8.08)	2 (3.45)	-
Rhamnaceae	7 (7.07)	3 (5.17)	-
Verbenaceae	7 (7.07)	5 (8.62)	-
Solanaceae	5 (5.05)	5 (8.62)	58
Celtidaceae	3 (3.03)	1 (1.72)	-
Euphorbiaceae	3 (3.03)	3 (5.17)	65
Polygonaceae	3 (3.03)	2 (3.45)	-
Lamiaceae	2 (2.02)	2 (3.45)	-
Rosaceae	2 (2.02)	2 (3.45)	-
Acanthaceae	1 (1.01)	1 (1.72)	-
Amaranthaceae	1 (1.01)	1 (1.72)	-
Apocynaceae	1 (1.01)	1 (1.72)	-
Berberidaceae	1 (1.01)	1 (1.72)	-
Campanulaceae	1 (1.01)	1 (1.72)	-
Lythraceae	1 (1.01)	1 (1.72)	-
Poaceae	1 (1.01)	1 (1.72)	308
Salicaceae	1 (1.01)	1 (1.72)	-
Santalaceae	1 (1.01)	1 (1.72)	-
Zygophyllaceae	1 (1.01)	1 (1.72)	-
Malvaceae	-	-	39
Caryophyllaceae	-	-	33
Brassicaceae	-	-	36
Cactaceae	-	-	36
Cyperaceae	-	-	72
TOTAL	99 (100)	58 (100)	

[1] Number of species for the ten most abundant plant families in the region, taken from Zuloaga et al. (1999).

TABLE 3
Plant organs in which galls are induced by insects, in Córdoba (central Argentina)

Organs	Number of morphotypes	Relative frequency (%)
Stem	58	58.6
Leaf	20	20.2
Bud	14	14.1
Thorn	2	2
Petiole	2	2
Flower	1	1
Leaf and stem	1	1
Stem and petiole	1	1

of the other 25 % of the interactions (in which the insect inductor was identified), belonged to Cecidomyiidae. From these figures, it is evident that there is a need of an increased sampling effort to obtain adults of unidentified species, in order to attain a better knowledge of gall inducing insects in the region.

DISCUSSION

On the basis of the results obtained from field surveys and a literature review, our study provides a list of 99 interactions between species of plants and gall-inducing insects in the Córdoba province. It is interesting to note that more than half of these records constitute new citations for Cordoba, and 49 % are reported for the first time in Argentina, which highlights the scarce knowledge there is about these interactions in the region. The number of galls reported here is rather high in comparison with the ones reported in the few studies available on gall-inducing insects in Argentina, which covered different geographic areas and employed different sampling efforts (Fernandes et al., 2002; Quintero etal., 2014; Kuzmanich et al., 2015).

Our results identify Diptera, particularly the family Cecidomyiidae, as the most species-rich group, which is in agreement with different studies from across the globe (Mani, 1964; Fernandes et al., 2002; Espírito-Santo & Fernandes, 2007; Quintero et al., 2014; Gagné & Jaschhof, 2017; Urso-Guimarães, Castello, Kataoka, & Kochk, 2017). Specific identification of gall midges is very difficult given the scarce knowledge there is about the group in South America (Maia, 2012). In Córdoba, only seven out of 38 gall morphotypes induced by Cecidomyiidae are species properly described, the rest being unknown, even at the generic level.

The plant families hosting the highest number of galls were Asteraceae (27.2 % of interactions) and Fabaceae (22.2 %). Several studies conducted in the Neotropical region reported Asteraceae (Carneiro et al., 2009; Coelho et al., 2013; Arriola et al., 2015; Kuzmanich et al., 2015) and Fabaceae (Fernandes et al., 2002; Coelho et al., 2009; Carvalho-Fernandes, Silva De Almeida-Cortez, & Ferreira, 2012; Urso-Guimarães et al., 2017) as the families most frequently attacked by galling insects. In Córdoba, the families best represented in the vegetation are Poaceae, Asteraceae and Fabaceae, in that order (Zuloaga, Morrone, & Rodriguez, 1999; Giorgis et al., 2011); the predominance of the last two plant families in our records is partially concordant with the "plant family size hypothesis", which predicts a positive correlation between the high number of plant species and the number of associated gall morphotypes (Fernandes, 1992). It is notable, however, that just one association was recorded between a gall-inducing insect and a species of Poaceae. Similar disproportionate low numbers of gall morphotypes in Poaceae, in spite of a high availability of species in the flora, were observed in Brazil (Maia, 2001; Arriola & Ferreira, 2016). Among Asteraceae, the genus *Baccharis* had the highest number of species (7) associated with galling insects and displayed the highest number of gall morphotypes (16). The vulnerability of this genus to galling insects has previously been reported in the Neotropical region, and it has been observed particularly for Cecidomyiidae inducers (Fernandes et al., 2014; Gagné, 1994).

Surprisingly, stems were the organs most frequently affected by galling insects in Cordoba. This result disagrees with the general trend of leaves being the preferred organ for galling insects (Mani, 1964; Shorthouse & Rohfritsch, 1992; Quintero et al., 2014; Arriola et al., 2015; Kuzmanich et al., 2015; Maia & Carvalho-Fernandes, 2016). Just a few studies have reported a greater number of galls on plant stems (Fernandes et al., 2002; Veldtman & McGeoch, 2003; Carneiro et al., 2009; Coelho et al., 2013;), and in some of these cases, they were restricted to a single insect taxon, such as Coleoptera (Maia & Oliveira, 2004). Even when some studies explored the mechanisms of gall induction (see Stuart, Chen, Shukle, & Harris, 2012; Giron, Huguet, Stone, & Body, 2016), to our knowledge, no studies to date have explored the mechanisms by which galls tend to be induced in leaves, stems or other plant organs. It is known that young and undifferentiated tissues are necessary for plant gall induction (Rohfritsch, 1992; Weis, 1988). In tropical latitudes, being climate and resources favorable to a continuous growth of the plant, the active meristematic tissues tend to be more available in leaves than in stems throughout the year, and this may be the reason explaining the usually reported predominance of foliar over stem galls (Shorthouse & Rohfritsch, 1992). The opposite tendency could be expected at higher latitudes, where most of the plants display a seasonal foliage loss and regrowth, thus caulinar meristematic tissues became a more stable resource available for gall-inducing insects. However, the scarce studies in which stem galls predominate were conducted at both, tropical (Carneiro et al., 2009; Coelho et al., 2013) and subtropical (Fernandes et al., 2002; Veldtman & McGeoch, 2003; Toma & Mendonça, 2013) localities. It could be also possible that foliar galls are exposed to early leaf-abscission, which may be incremented by hydric stress (Veldtman & McGeoch, 2003) under arid and semiarid climates, as in central Argentina. Moreover, more stable temperatures (Carneiro et al., 2009) and hydric conditions in stems than in leaves could be favoring the induction of galls in stems. Evidence supporting this idea was observed for one species of Erioccoccidae, whose adults normally induce leaf galls, but before leaf fall, they induce a second gall morphotype in stems to undergo dormancy throughout the dry season (Gonçalves, Gilson, & Isaias 2009).

Our study highlights the scarce knowledge that exists about plants and gall-inducing insects in Argentina, especially regarding interactions between plants and gall-inducing Cecidomyiidae, with more than 30 undescribed species noted in our study. The galling insect community deserves further taxonomic and biological studies, especially considering the speed of deforestation of native forests in central Argentina (Hoyos et al., 2013; Cabido et al. 2018). Finally, in our opinion, understanding the mechanisms by which galls tend to predominate in leaves or stems in a given region is certainly a future challenge.

ACKNOWLEDGMENTS

We are very grateful to the five reviewers, whose valuable comments have allowed us to improve our manuscript, and to Julia Tavela, María Rosa Rossetti, Laura Bernaschini y Luciano Cagnolo for their collaboration in the field sample. NK is a doctoral fellow from CONICET and MG and AS are researchers from CONICET and professors at the National University of Córdoba.

RESUMEN

Agallas de insectos en Córdoba, Argentina: un caso en el que predominan las agallas caulinares. Las agallas son estructuras producidas por las plantas en respuesta a la actividad de diversos tipos de organismos, los cuales establecen una estrecha relación con sus especies hospedantes, ya que su hábitat está restringido en gran medida a la agalla y al órgano vegetal donde la agalla se desarrolla. Todos los órganos vegetales son susceptibles a la inducción de agallas por insectos, siendo las hojas los más frecuentemente atacados. En Argentina, el conocimiento de estas interacciones es fragmentando e incompleto. En el presente estudio, se realizó un inventario de agallas inducidas por insectos utilizando información obtenida de muestreos a campo y revisión bibliográfica. También nos enfocamos en las asociaciones taxonómicas insecto-planta más frecuentes y en los órganos vegetales más atacados por los insectos cecidógenos. Se realizaron muestreos a campo en 26 sitios localizados en el Chaco Serrano, que fueron visitados cinco veces en dos años consecutivos y en otros 17 sitios, distribuidos en la provincia de Córdoba, que fueron visitados una o dos veces. Además se realizó una exhaustiva revisión bibliográfica en bases de datos electrónicas (disponibles en internet) y convencionales. Un total de 99 agallas en 58 especies vegetales (21 familias y 44 géneros) fueron registradas a través de los muestreos en el campo y la revisión bibliográfica, ampliando el número de interacciones previamente conocidas en al menos un 50 %. Las familias vegetales más atacadas fueron Asteraceae y Fabaceae, coincidiendo con las familias vegetales más diversas de la región. La familia Cecidomyiidae (Diptera) presentó el mayor número de especies, en concordancia con diversos estudios alrededor del mundo. *Baccharis* fue el género vegetal que mayor número de morfotipos de agallas albergó, seguido por *Acacia*, *Condalia*, *Geoffroea*, *Prosopis* y *Schinus*. Al menos el 60 % de morfotipos registrados se presentaron en tallos, un patrón poco común en la bibliografía. Las formas predominantes fueron fusiforme y globoide. Nuestra investigación revela el escaso conocimiento sobre la comunidad de insectos cecidógenos y sus agallas en Argentina, particularmente de las inducidas por especies de la familia Cecidomyiidae, con más de 30 especies aún no descritas. Se discuten posibles mecanismos involucrados en la predominancia de agallas caulinares en el centro de Argentina.

Palabras clave: Asteraceae; Cecidomyiidae; interacción insecto-planta; insectos cecidógenos; inventario.

REFERENCES

Altamirano, A., Valladares, G., Kuzmanich, N., & Salvo, A. (2016). Galling insects in a fragmented forest: incidence of habitat loss, edge effects and plant availability. *Journal of Insect Conservation*, *20*(1), 119-127.

Araújo, W. S. (2017). Plant species richness mediates the effects of vegetation structure, but not soil fertility, on insect gall richness in a savanna in Brazil. *Journal of Tropical Ecology*, *33*, 197-204.

Araújo, W. S. de, Scareli-Santos, C., Guilherme, F. A. G., & Cuevas-Reyes, P. (2013). Comparing galling insect richness among Neotropical savannas: Effects of plant richness, vegetation structure and superhost presence. *Biodiversity and Conservation*, *22*(4), 1083-1094.

Arriola, A., & Ferreira, C. (2016). Richness of insect galls on shrub-tree restinga of a coastal plain of Southern Brazil. *Acta Biológica Catarinense*, *3*(2), 121-137.

Arriola, Í. A., Melo, J. C. F., & Isaias, R. M. S. (2015). Questioning the environmental stress hypothesis for gall diversity of restinga vegetation on dunes. *Revista de Biología Tropical*, *63*, 959-970.

Bergamini, B. A. R., Bergamini, L. L., Santos, B. B. dos, & Araújo, W. S. de. (2017). Occurrence and characterization of insect galls in the Floresta Nacional de Silvânia, Brazil. *Papéis Avulsos de Zoologia (São Paulo)*, *57*(32), 413-431.

Blanchard E. (1938). Descripción del cecidómiido productor de la agalla del Quebracho blanco. *Revista Chilena de Historia Natural, 42*, 173-176.

Blanche, K. R., & Ludwig, J. A. (2001). Species richness of gall-inducing insects and host plants along an altitudinal gradient in Big Bend National Park, Texas. *The American Midland Naturalist*, *145*(2), 219-232.

Brèthes, J. (1916). Estudio fito-zoológico sobre algunos Lepidópteros Argentinos productores de agallas. *Anales de la Sociedad Científica Argentina*, *82*, 113-118.

Burckhardt, D., & Basset, Y. (2000). The jumping plant-lice (Hemiptera, Psylloidea) associated with *Schinus* (Anacardiaceae): systematics, biogeography and host plant relationships. *Journal of Natural History*, *34*(1), 57-155.

Cabido, M., Zeballos, S. R., Zak, M., Carranza, M. L., Giorgis, M. A., Cantero, J. J., & Acosta, A. T. (2018). Native woody vegetation in central Argentina: Classification of Chaco and Espinal forests. *Applied Vegetation Science*. doi: 10.1111/avsc.12369

Cabrera, Á. L. (1976). Regiones fitogeográficas argentinas. *Enciclopedia Argentina de Agricultura y Jardinería*, *2*, 1-85.

Carabajal De Belluomini, M. V, Castresana, L., Salim, V., & Notario, A. (2009). The diversity of galls and their occurrence in productive forest systems of *Prosopis alba* (Griseb.) in Santiago del Estero, Argentina. *Boletín de Sanidad Vegeal Plagas*, *35*, 255-265.

Carneiro, M. A. A., Borges, R. A. X., Araújo, A. P. A., & Fernandes, G. W. (2009). Insetos indutores de galhas da porção sul da Cadeia do Espinhaço, Minas Gerais, Brasil. *Revista Brasileira de Entomologia*, *53*(4), 570-592.

Carvalho-Fernandes, S. P., Silva De Almeida-Cortez, J., & Ferreira, A. L. N. (2012). Riqueza de galhas entomógenas em áreas antropizadas e preservadas de caatinga. *Revista Árvore*, *36*(2), 269-277.

Cingolani, A. M., Renison, D., Zak, M. R., & Cabido, M. R. (2004). Mapping vegetation in a heterogeneous mountain rangeland using Landsat data: an alternative method to define and classify land-cover units. *Remote Sensing of Environment*, *92*(1), 84-97.

Coelho, M. S., Almada, E. D., Fernandes, G. W., Carneiro, M. A. A., Santos, R. M., Quintino, A. V., & Sanchez-Azofeifa, A. (2009). Gall inducing arthropods from a seasonally dry tropical forest in Serra do Cipó, Brazil. *Revista Brasileira de Entomologia*, *53*(3), 404-414.

Coelho, M. S., Carneiro, M. A. A., Branco, C., Borges, R. A. X., & Fernandes, G. W. (2013). Gall-inducing insects from Campos de Altitude, Brazil. *Biota Neotropica*, *13*(4), 139-151.

Díaz, N. B. (1980) Cinipoideos galígenos e inquilinos de la república Argentina. *Revista la Sociedad Entomólogica Argentina, 39*, 221-226.

Espírito-Santo, M. M., & Fernandes, G. W. (2007). How many species of gall-inducing insects are there on earth, and where are they? *Annals of the Entomological Society of America*, *100*(2), 95-99.

Felt, P. E. (1940). *Plant galls and gall makers*. *Annals of the Entomological Society of America*. Orange Street, London: Constable And Company Ltd 10.

Fernandes, G. W. (1992). Plant family size and age effects on insular species richness. *Global Ecology and Biogeography Letters*, *2*(3), 71-74.

Fernandes, G. W., & Santos, J. C. (2014). *Neotropical Insect Galls*. Dordrecht: Springer Netherlands.

Fernandes, G. W., Silva, J. O., Espírito-Santo, M. M., Fagundes, M., Oki, Y., & Carneiro, M. A. A. (2014). *Baccharis: A Neotropical Model System to Study Insect Plant Interactions*. In G. W. Fernandes & J. C. Santos (Eds.), *Neotropical Insect Galls* (pp. 193-219). Netherlands: Springer.

Fernandes, G. W., Varela, O., Bucher, E. H., Chani, J. M., Echevarría, A. L., Espírito Santo, M. M., … Lima, J. (2002). Gall-forming insects on woody and herbaceous plant species of the semi-arid chaco forest, Argentina. *Lundiana*, *3*(1), 61-66.

Gagné, R. J. (1994). *The gall midges of the Neotropical region*. New York: Cornell University Press, Ithaca.

Gagné, R. J., & Jaschhof, M. (2017). *A Catalog of the Cecidomyiidae (Diptera) of the World*. Digital.

Giorgis, M. A., Cingolani, A. M., Chiarini, F., Chiapella, J., Barboza, G., Ariza Espinar, L., … Cabido, M. (2011). Composición florística del Bosque Chaqueño Serrano de la provincia de Córdoba, Argentina. *Kurtziana*, *36*(1), 9-43.

Giorgis, M. A., Cingolani, A. M., Gurvich, D. E., & Astegiano, J. (2015). Flowering phenology, fruit set and seed mass and number of five coexisting *Gymnocalycium* (Cactaceae) species from Córdoba mountain, Argentina. *Journal of the Torrey Botanical Society*, *142*(3), 220-230.

Giorgis, M. A., Cingolani, A. M., Gurvich, D. E., Tecco, P. A., Chiapella, J., Chiarini, F., & Cabido, M. (2017). Changes in floristic composition and physiognomy are decoupled along elevation gradients in central Argentina. *Applied Vegetation Science*. doi:10.1111/avsc.12324

Giorgis, M. A., Cingolani, A. M., Teich, I., & Renison, R. (2010). Do *Polylepis australis* trees tolerate herbivory? Seasonal patterns of biomass production and its consumption by livestock. *Plant Ecology, 207*, 307-319.

Gonçalves-Alvim, S. J., & Fernandes, G. W. (2001). Biodiversity of galling insects: Historical, community and habitat effects in four neotropical savannas. *Biodiversity and Conservation*, *10*(1), 79-98.

Gonçalves, S. J. M. R., Gilson, R. P. M., & Isaias, R. M. S. (2009). A unique seasonal cycle in a leaf gall-inducing insect: The formation of stem galls for dormancy. *Journal of Natural History, 43*, 843-854.

Giron, D., Huguet, E., Stone, G. N., & Body, M. M. (2016). Insect-induced effects on plants and possible effectors used by galling and leaf-mining insects to manipulate their host-plant. *Journal of Insect Physiology*, *84*, 70-89.

Houard, C. (1933). *Les zoocécidies des plantes de l'Amérique sud et de l'Amérique centrale*. Paris: Hermann et Cie.

Hoyos, L. E., Cingolani, A. M., Zak, M. R., Vaieretti, M. V., Gorla, D. E., & Cabido, M. R. (2013). Deforestation and precipitation patterns in the arid Chaco forests of central Argentina. *Applied Vegetation Science*, *16*(2), 260-271.

Isaias, R. M. S., Carneiro, R. G. S., Oliveira, D. C., & Santos, J. C. (2013). Illustrated and Annotated Checklist of Brazilian Gall Morphotypes. *Neotropical Entomology*, *42*(3), 230-239.

Jörgensen, P. (1917). Zoocecidios argentinos. *Physis*, *3,* 1-29.

Kieffer, J. J., & Jörgensen, P. (1910). Gallen und gallentiere aus Argentinien. *Parasitenkunde und Infektionskrankheiten, 27*, 362-444.

Kuzmanich, N., Altamirano, A., & Salvo, A. (2015). Agallas de insectos de la región Rioplatense, Buenos Aires, Argentina. *Revista de La Sociedad Entomológica Argentina*, *74*, 47-56.

Maia, V. C. (2001). The gall midges (Diptera, Cecidomyiidae) from three restingas of Rio de Janeiro State, Brazil. *Revista Brasileira de Zoologia*, *18*, 583-629.

Maia, V. C. (2012). Coleopterous galls from the Neotropical region. *Papéis Avulsos de Zoologia (São Paulo)*, *52*, 175-184.

Maia, V. C., & Carvalho-Fernandes, S. P. (2016). Insect galls of a protected remnant of the Atlantic Forest tableland from Rio de Janeiro State (Brazil). *Revista Brasileira de Entomologia*, *60*(1), 40-56.

Maia, V. C., & Oliveira, J. C. D. E. (2004). Coleoptera Associated With Galls From South America With New Records. *America*, *62*(2), 179-184.

Malcolm, M., Oggero, A. J., Arana, M., Tordable, M. C., & Boito, G. T. (2015). Los insectos galícolas en *Schinus fasciculata* (Anacardiaceae) en el Espinal del centro de Argentina. *Iheringia, Série Zoologia*, *106*(1), 133-139.

Mani, M. S. (1964). *Ecology of Plant Galls*. Netherlands: Dr. W. Junk Publishers, the Hague.

Martínez, J. J., Altamirano, A., & Salvo, A. (2011). New species of *Allorhogas* Gahan (Hymenoptera: Braconidae) reared from galls on *Lycium cestroides* Schltdl. (Solanaceae) in Argentina. *Entomological Science*, *14*(3), 304-308.

Mendonça, M. D. S., & Stiling, P. (2017). Subtropical interactions: comparing galling insect and host plant diversity in Southern Brazil and Florida. *Neotropical Entomology*. doi: 10.1007/s1374

Nieves-Aldrey, J. L., & Blas, G. S. (2015). Revision of the neotropical genus *Eschatocerus* Mayr (Hymenoptera, Cynipidae, Eschatocerini) with biological notes and the first description of the terminal larva. *Zootaxa*, *4012*(1), 135-155.

Nieves-Aldrey, J. L., Ibáñez, A., & Medianero, E. (2008). Richness and composition of gall-inducing arthropods at Coiba National Park, Panama. *Revista de Biología Tropical*, *56*(3), 1269-1286.

Price, P. W., Fernandes, G. W., Lara, A. C. F., Brawn, J., Barrios, H., Wright, M. G., … Rothcliff, N. (1998). Global patterns in local numbert of insects galling species. *Journal of Biogeography*, *25*, 581-591.

Quintero, C., Garibaldi, L. A., Grez, A., Polidori, C., & Nieves-Aldrey, J. L. (2014). Galls of the Temperate Forest of Southern South America: Argentina and Chile. In G. W. Fernandes & J. C. Santos (Eds.), *Neotropical Insect Galls* (pp. 429-263). Dordrecht: Springer Netherlands.

Raman, A. (2011). Morphogenesis of insect-induced plant galls: Facts and questions. *Flora: Morphology, Distribution, Functional Ecology of Plants*, *206*(6), 517-533.

Rohfritsch, O. (1992). Patterns in gall development. In J. D. Shorthouse & O. Rohfritsch (Eds.), *Biology of insect-induced galls* (pp. 60-86). New York: Oxford University Press.

Shorthouse, J. D., & Rohfritsch, O. (1992). *Biology of insect-induced galls*. New York: Oxford University Press.

Shorthouse, J. D., Wool, D., & Raman, A. (2005). Gall-inducing insects - Nature's most sophisticated herbivores. *Basic and Applied Ecology*, *6*(5), 407-411.

Stehr, F. W. (1987). *Immature Insects* (Vol. 1). Michigan: Kendall.

Stuart, J. J., Chen, M. S., Shukle, R., & Harris, M. O. (2012). Gall Midges (Hessian Flies) as Plant Pathogens. *Annual Review of Phytopathology*, *50*(1), 339-357.

Tavares, J. S. (1915). Cécidologie argentine. *Brotéria, Série Zoológica*, *13*, 88-126.

Tecco, P. A., Pais Bosch, A. I., Funes, G., Marcora, P., Zeballos, S. R., Cabido, M., & Urcelay, C. (2016). Mountain invasions on the way: are there climatic constraints for the expansion of alien woody species along an elevation gradient in Argentina? *Journal of Plant Ecology, 9*, 380-392.

Toma, T. S. P., & Mendonça, M. D. S. (2013). Gall-inducing insects of an Araucaria Forest in Southern Brazil. *Revista Brasileira de Entomologia*, *57*(2), 225-233.

Urso-Guimarães, M. V., Castello, A. C. D., Kataoka, E. Y., & Koch, I. (2017). Characterization of entomogen galls from Mato Grosso do Sul, Brazil. *Revista Brasileira de Entomologia*, *61*(1), 25-42.

Valladares, G., Zapata, A., Zygaldo, J., & Banchio, E. (2002) Phytochemical induction by herbivores could affect quality of essential oils from aromatic plants. *Journal of Agricultural Food Chemistry*, *50*, 4059-4061.

Veldtman, R., & McGeoch, M. A. (2003). Gall-forming insect species richness along a non-scleromorphic vegetation rainfall gradient in South Africa: The importance of plant community composition. *Austral Ecology*, *28*(1), 1-13.

Weis, A. (1988). Reactive plant tissue sites and the population biology of gall makers. *Annual Review of Entomology*, *33*(1), 467-486.

White, I. M., & Hodkinson, I. D. (1985). Nymphal taxonomy and systematics of the Psylloidea (Homoptera). *Bulletin of the British Museum (Natural History) Entomology*, *50*(2), 153-301.

Zak, M. R., & Cabido, M. (2002). Spatial patterns of the Chaco vegetation of central Argentina: Integration of remote sensing and phytosociology. *Applied Vegetation Science*, *5*(2), 213-226.

Zuloaga, F. O., Morrone, O., & Rodriguez, D. (1999). Análisis de la biodiversidad en plantas vasculares de la Argentina. *Kurtziana*, *27*(1), 17-167.