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Illustrated and Annotated Checklist of Brazilian Gall Morphotypes

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Abstract
The analysis on nine inventories on the richness and diversity of galling herbivores in Brazil accounted for 806 gall systems occurring in 443 host-plant species from 74 plant families. This checklist of the Brazilian gall morphotypes proposes seven standardized morphotypes and five additional shapes that group the majority of the three-dimensional shapes reported in literature. Criteria are proposed to standardize the terminology, and a critical analysis is provided aiming to avoid possible inconsistencies in order to generate easily comparable data in future inventories. The morphotypes are herein catalogued in alphabetical order, accompanied by a conceptual definition, an illustration, and examples that best represent the shape. It is proposed that the inventories should present at least the (1) host-plant species, (2) galling herbivore species or its identification to the lowest possible taxonomic level, (3) host-plant galled organ and gall position, (4) gall morphotype, (5) gall color and registration of indumentum when present, (6) gall phenological and developmental data, (7) association with other trophic levels, and (8) additional information, such as dimension, and number of chamber(s).

Introduction

Plant galls are structures which may appear in any host-plant organ in response to the feeding activity of a parasite, the galling arthropod, commonly an insect. The relationship between host plants and their galling herbivores is highly specific, and the galls are considered the extended phenotype of their inducing organisms (Abrahamson & Weis 1997). So, although galls are widely diverse, each gall shape, namely a morphotype, is a repetitively induced structure (Raman 2007) which has shown to be very conservative in morphogenetical terms. From this point of view, it seems plausible to consider gall morphotypes as reliable representations of the biodiversity of galling insects in a given area, even if the involved taxa are not scientifically described yet (Carneiro *et al* 2009). This is particularly useful for the Neotropical gall systems where there is still a greatly unexplored and undescribed biodiversity (see Espírito-Santo & Fernandes 2007).

As galls are widely diverse in the Neotropics, many shapes that describe their structures are supposed to be found in the literature. In fact, a brief view on Neotropical galls inventories reveals a large and sometimes confusing terminology, which is used to refer to similar shapes or morphotypes. Many of them present imprecise terminology and even lack some adequate data on the approximated shape, presence or absence of indumentum, color, and precise position of the galls in their host organs. In an effort to standardize this terminology, nine inventories (Maia & Fernandes 2004, Maia *et al* 2008, Carneiro *et al* 2009, Maia & Oliveira 2010, Maia 2012, Santos *et al* 2011a, b, Malves & Frieiro-Costa 2012, Santos *et al* 2012) were used to generate a list of the most common morphotypes currently reported. Our proposal does not cover all Neotropical gall diversity which should continue to be

inventoried. It focuses on clear parameters for the establishment of a standardized gall characterization.

This annotated and illustrated checklist of the Brazilian gall morphotypes also present a critical analysis of the data to point out possible inconsistencies to be avoided in the future. The proposed criteria aim to standardize the terminology to be used in future inventories of gall diversity, thus allowing the construction of comparable data bases for Neotropical flora. The morphotypes are herein catalogued in alphabetical order, accompanied by a conceptual definition, an illustration, and examples that best represent the shapes.

Materials and Methods

Data sampling

Current data were extracted from nine inventories from Brazil which reported lists of galls in different Brazilian biomes (Maia & Fernandes 2004, Maia *et al* 2008, Carneiro *et al* 2009, Maia & Oliveira 2010, Maia 2012, Santos *et al* 2011a, b, Malves & Frieiro-Costa 2012, Santos *et al* 2012), accounting for 806 gall systems induced in several host-plant species. The choice of these inventories was based on the existence of illustrations that permitted the visualization of the real shape of the galls independently of the names given by the authors.

Nomenclature standardization

The information found in the inventories was complemented by aspects observed on their photographs, obeying the criteria of similarity to tridimensional shapes (*sensu* Radford *et al* 1974), and similarity to preexisting forms, whenever impossible to fit a tridimensional shape. The names are presented both in English and in Portuguese (Pt) as some inventories are published in Portuguese.

Results and Discussion

General considerations

The 806 gall systems reported in the nine inventories accounted for 43 different shapes within which the most commonly reported are the elliptical and globoid (Table 1). Seven morphotypes could be grouped and standardized, and other five common shapes were included for their peculiarity and abundance in nature. The list of 43 names for the gall morphotypes results from the use of several names for the same shape or the use of similar names for different shapes. Based on the illustrations, the list of names was reviewed and shortened with the purpose of simplifying the terminology. Synonyms for 26 of the original morphotypes are proposed (Table 1). The current checklist was based on the 94 gall systems identified to any hierarchical level lower than family, and do not represent all of the galls in the Neotropics, which should continue to be inventoried. The seven three-dimensional morphotypes are based on the comparative morphological analyses of the gall systems set for the list, and are herein illustrated and diagnosed. In addition, a gall system which best represents each morphotype was referred.

Checklist of the gall morphotypes

Clavate (Fig 1; Pt="clavada"). Resembles a club. It grows wider from the base to the distal end, so that the apical portion is expanded and round. Carneiro *et al* (2009) has named the fusiform galls in *Aspilia fruticosa* (Asteraceae) and *Baccharis reticularia* (Asteraceae) as clavate, and Santos *et al* (2011b) has named the clavate galls induced by a Cecidomyiidae in *Manihot dichotoma* (Euphorbiaceae) as cylindrical. The clavate shape is best illustrated by the gall induced by a Lepidoptera on *Microlicia fasciculata* (Melastomataceae) (Carneiro *et al* 2009).

Conical (Fig 2; Pt="cônica"). A cone-shaped morphotype with wide round base and acute apical portion to where imaginary convergent lines can be traced. It occurs predominantly in leaves. This shape may be induced by Cecidomyiidae (Carneiro *et al* 2009, Maia & Oliveira 2010, Santos *et al* 2011a, 2012), Hemiptera (Maia & Oliveira 2010) and Heteroptera (Santos *et al* 2011a) in 56 distinct host-plant species from 27 distinct families. This morphotype is best illustrated by the gall induced by *Liodiplosis conica* (Gagné *et al* 2001) on *Mikania* sp. (Asteraceae) (Maia & Oliveira 2010).

Cylindrical (Fig 3; Pt="cilíndrica"). A cylinder-shaped morphotype whose basal and apical portions are proportional and with somewhat similar diameters. Many gall morphotypes induced by Cecidomyiidae in plant species of Asteraceae (Maia & Fernandes 2004, Maia *et al* 2008, Maia & Oliveira 2010), Euphorbiaceae (Santos *et al* 2011b), Asclepiadaceae (Santos *et al* 2012), Apocynaceae (Santos *et al* 2012), Myrtaceae (Maia & Fernandes 2004, Maia & Oliveira 2010), and Melastomataceae (Santos *et al* 2012) were named as cylindrical but do present a distinct shape. The true cylindrical morphotype is best illustrated by the gall induced by a Cecidomyiidae in *Mabea occidentalis* (Euphorbiaceae) (Santos *et al* 2011a), which the authors have equivocally named as conical.

Table 1 Gall morphotypes reported in the nine inventories of the Neotropical diversity of galling herbivores, their occurrence, frequency (in percent), and suggested standard designation.

Morphotypes	Number	Percent	Suggested synonyms	References
Amorphous	20	2.5	–	Maia *et al* (2008), Santos *et al* (2011a, b), and Santos *et al* (2012)
Bipuncta	1	0.1	Fusiform	Maia & Oliveira (2010)
Bivalve shaped	1	0.1	–	Maia & Fernandes (2004)
Blister shaped	1	0.1	Globoid	Maia & Fernandes (2004)
Bulbous	7	0.9	Globoid	Maia (2012)
Circular	19	2.4	Lenticular	Maia & Fernandes (2004), Maia & Oliveira (2010), and Maia (2012)
Clavate	3	0.4	–	Carneiro *et al* (2009)
Coalescent	1	0.1	Globoid	Maia (2012)
Conical	60	7.4	–	Maia & Fernandes (2004), Maia *et al* (2008), Carneiro *et al* (2009), Maia & Oliveira (2010), Maia (2012), Santos *et al* (2011a, b), Malves & Frieiro-Costa (2012), and Santos *et al* (2012)
Cylindrical	10	1.2	–	Maia & Fernandes (2004), Maia *et al* (2008), Maia & Oliveira (2010), Santos *et al* (2011b), and Santos *et al* (2012)
Cylindrical with apical projection	1	0.1	–	Maia & Oliveira (2010)
Discoid	76	9.4	Lenticular	Maia & Fernandes (2004), Maia *et al* (2008), Carneiro *et al* (2009), Maia & Oliveira (2010), Santos *et al* (2011a, b), and Santos *et al* (2012)
Elliptical	178	22.1	Fusiform	Maia & Fernandes (2004), Maia *et al* (2008), Carneiro *et al* (2009), Maia (2012), Santos *et al* (2011a, b), and Santos *et al* (2012)
Elliptical pedunculated	1	0.1	Fusiform	Maia (2012)
Fusiform	12	1.5	–	Maia & Oliveira (2010), Maia (2012), and Malves & Frieiro-Costa (2012)
Globoid	188	23.3	–	Maia & Fernandes (2004), Maia *et al* (2008), Carneiro *et al* (2009), Maia (2012), Santos *et al* (2011a, b), and Santos *et al* (2012)
Globose	18	2.2	Globoid	Maia (2012)
Globose with apical projection	1	0.1	Globoid	Maia (2012)
Globulous	13	1.6	Globoid	Malves & Frieiro-Costa (2012)
Horn shaped	1	0.1	–	Maia & Fernandes (2004)
Lateral swelling	1	0.1	Globoid	Maia (2012)
Leaf fold	3	0.4	–	Maia & Fernandes (2004) and Malves & Frieiro-Costa (2012)
Legume	7	0.9	Leaf fold	Carneiro *et al* (2009)
Lenticular	16	2.0	–	Maia *et al* (2008)
Linear	1	0.1	Globoid	Maia & Oliveira (2010)
Mamiliform	1	0.1		Maia & Fernandes (2004)
Marginal roll	11	1.4	–	Maia & Fernandes (2004), Carneiro *et al* (2009), Maia & Oliveira (2010), and Maia (2012)
Matted	1	0.1	Globoid	Maia & Oliveira (2010)
Ovoid	5	0.6	Globoid	Maia & Fernandes (2004) and Maia (2012)
Parenchymatic	7	0.9	–	Maia (2012)
Pine shaped	1	0.1	Rosette	Maia & Fernandes (2004)
Pocket shaped	1	0.1	–	Maia *et al* (2008)
Rosette	3	0.4	–	Maia & Fernandes (2004), Santos *et al* (2011a), and Santos *et al* (2012)
Spheral	48	6.0	Globoid	Santos *et al* (2011a), Santos *et al* (2011b), and Santos *et al* (2012)
Spherical	18	2.2	Globoid	Maia & Oliveira (2010) and Malves & Frieiro-Costa (2012)
Spheroid	13	1.6	Globoid	Maia & Fernandes (2004) and Maia & Oliveira (2010)
Spot	1	0.1	Lenticular	Maia & Fernandes (2004)
Star	1	0.1	Star shaped	Santos *et al* (2012)
Suculent	1	0.1	–	Maia & Fernandes (2004)
Swelling	47	5.8	Globoid/fusiform	Maia & Fernandes (2004), Carneiro *et al* (2009), and Maia (2012)

Table 1 (continued)

Morphotypes	Number	Percent	Suggested synonyms	References
Triangular	2	0.2	Conical	Maia & Fernandes (2004) and Maia & Oliveira (2010)
Tubular	2	0.2	Cylindrical	Maia & Fernandes (2004)
Unilateral swelling	1	0.1	Globoid	Maia (2012)
Not reported	2	0.2	–	Maia *et al* (2008)
Total	806	100		

Fusiform (Fig 4; Pt="fusiforme"). This shape resembles two cones connected by their bases, with both extremities narrower than the median portion. It is common in stems and petioles but may also occur along midribs or in extralaminar position on leaves. It may be induced by Lepidoptera and Cecidomyiidae on eight host-plant families (Maia & Oliveira 2010, Maia 2012, Malves & Frieiro-Costa 2012). This morphotype may also be induced in leaves (especially along midribs and petioles), and may be illustrated by the gall of *Asphondylia* sp. (Cecidomyiidae) on *Aureliana fasciculata* (Solanaceae) (Maia *et al* 2008). This morphotype is commonly referred as "elliptical" and "swelling."

Globoid (Fig 5; Pt="globóide"). It includes round shapes ranging from ellipsoids to spheroids. It may be induced in all vegetative and reproductive host-plant organs by several taxa of Cecidomyiidae. It may be intralaminar or extralaminar, which can be illustrated by the leaf galls of Cecidomyiidae on *Eugenia uniflora* (Myrtaceae) (Maia *et al* 2008) and on *Schefflera morototoni* (Araliaceae) (Santos *et al* 2011a), respectively. This is believed to be the most common gall morphotype and has been referred in the inventories as "spherical," "spheroid," "globose," "globular," and "ovoid" among others.

Lenticular (Figs 6–7; Pt="lenticular"). Morphotype commonly forming a circular halo on the leaf lamina. It resembles either biconvex or biconcave lenses. Sometimes it can be flattened in distinct degrees in one or both surfaces and may be intralaminar or extralaminar. It has been referred as "discoid," for example in the galls induced by Cecidomyiidae on *Pogonophora schomburgkiana* (Peraceae) (Santos *et al* 2012) and by an unidentified gall inducer on *Zygia racemosa* (Fabaceae) (Maia 2012). When it is small, it has been nominated as a "spot" gall (Maia & Fernandes 2004) and differs from the globoid and fusiform morphotypes because of its dorsiventral flattening in relation to leaf lamina.

Rosette (Fig 8; Pt="em roseta"). This morphotype is a consequence of the shortening of the internodes so that several leaves depart from the same point or very near from each other. It is commonly induced on buds and has been registered as induced by Lepidoptera in distinct host-plant species of Melastomataceae (Maia & Fernandes 2004, Santos *et al* 2011a, 2012). Maia & Fernandes (2004) have named an elongated rosette gall as "pine like." This morphotype is best illustrated by the bud gall in *Henriettea succosa* (Melastomataceae) (Santos *et al* 2011b).

Other common shapes found in nature

Bivalve shaped (Fig 9; Pt="em concha"). It resembles the shell of a bivalve Mollusca and was named for the gall induced by *Myrciariamya* n. sp. (Cecidomyiidae) in *Myrciaria tenella* (Myrtaceae) (Maia & Fernandes 2004). The galls induced by *Euphalerus ostreoides* (Crawford 1925) in *Lonchocarpus muhelbergianus* (Fabaceae) is also a typical bivalve-shaped gall (Isaias *et al* 2011) which has been mistakenly named (Santos *et al* 2012) as elliptical.

Horn shaped (Fig 10; Pt="em chifre"). Similar to the horns of a bull on the apical position. It is exemplified by one of the most common morphotypes found in *Copaifera langsdorffii* (Fabaceae) (Oliveira *et al* 2008) and was correctly named by Maia & Fernandes (2004). This name is also used for a gall induced by Coleoptera in an undetermined Fabaceae by these same authors.

Leaf fold (Fig 11; Pt="de dobramento"). Formed by the folding of the whole leaf lamina along the midrib. Although not directly associated with a peculiar shape, this term successfully describes this morphotype due to the evident developmental process through which the host leaf passes towards gall formation. Sometimes it may resemble a legume fruit, which has led them to be improperly designated as "legume" (*cf*. Carneiro *et al* 2009).

Marginal roll (Fig 12; Pt="enrolamento"). Formed by the rolling movement of one or both leaf margins. As for "leaf fold" galls, the peculiar developmental process of such galls

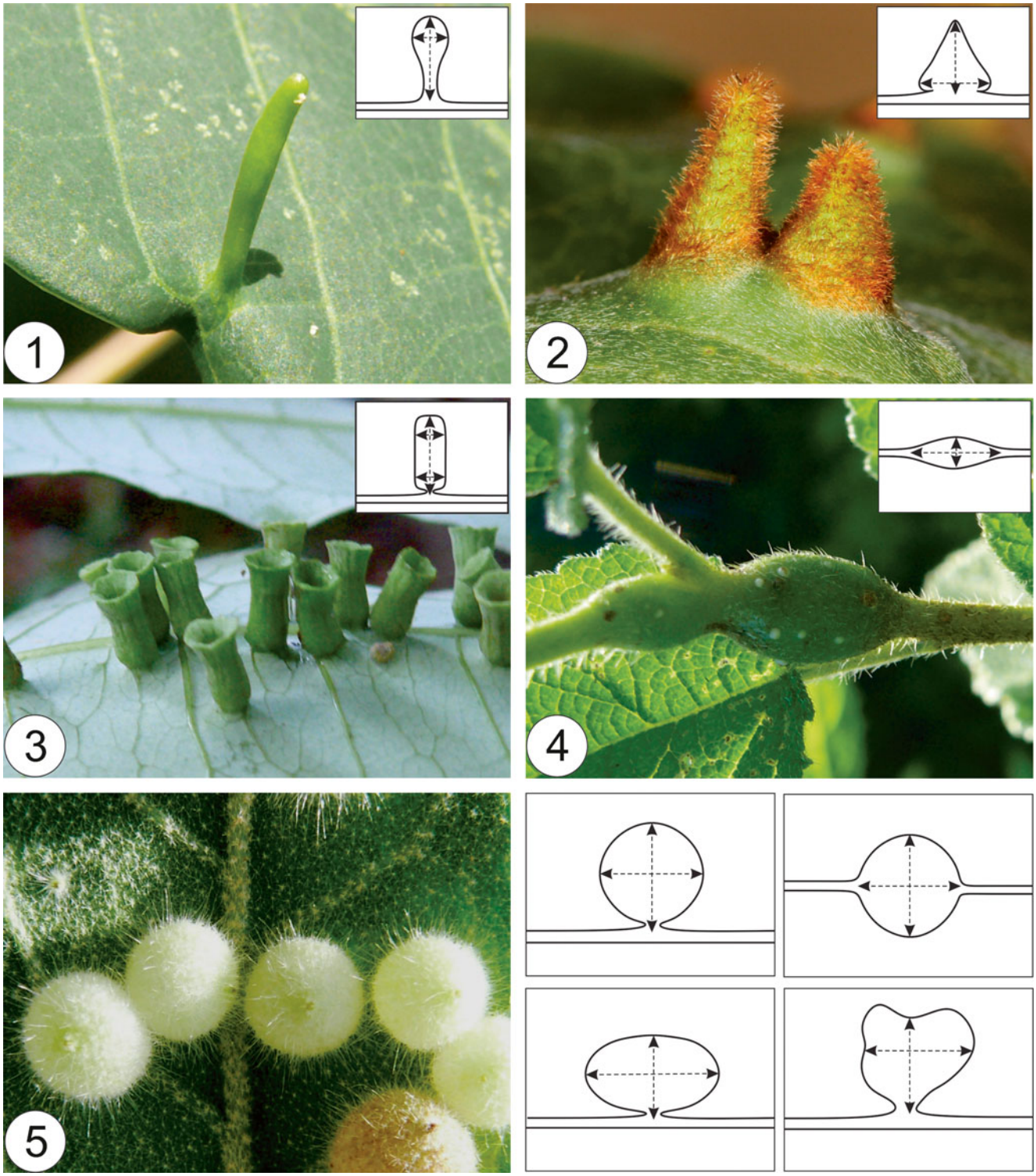

Fig 1–5 Gall morphotypes. *1*, Clavate gall induced on the adaxial surface of the leaves of *Manihot dicothoma* (Euphorbiaceae). *2*, Conical galls induced on the adaxial surface of the leaves of *Roupala montana* (Proteaceae). *3*, Cylindrical galls induced on the adaxial surface of the leaves of *Mabea occidentalis* (Euphorbiaceae). *4*, Fusiform galls induced on stems of *Cordia leucocephala* (Boraginaceae). *5*, Globoid galls induced on the abaxial leaf surface of *Croton echoides* (Euphorbiaceae).

is believed to best describe their morphotype. It has appeared under the label of "legume" (Carneiro *et al* 2009) and "elliptical" galls (Santos *et al* 2011a, b).

Pocket shaped (Fig 13; Pt="em bolso") It is formed by the folding of the leaf lamina over the site of oviposition, and is characteristically open on the host organ surface. It is best

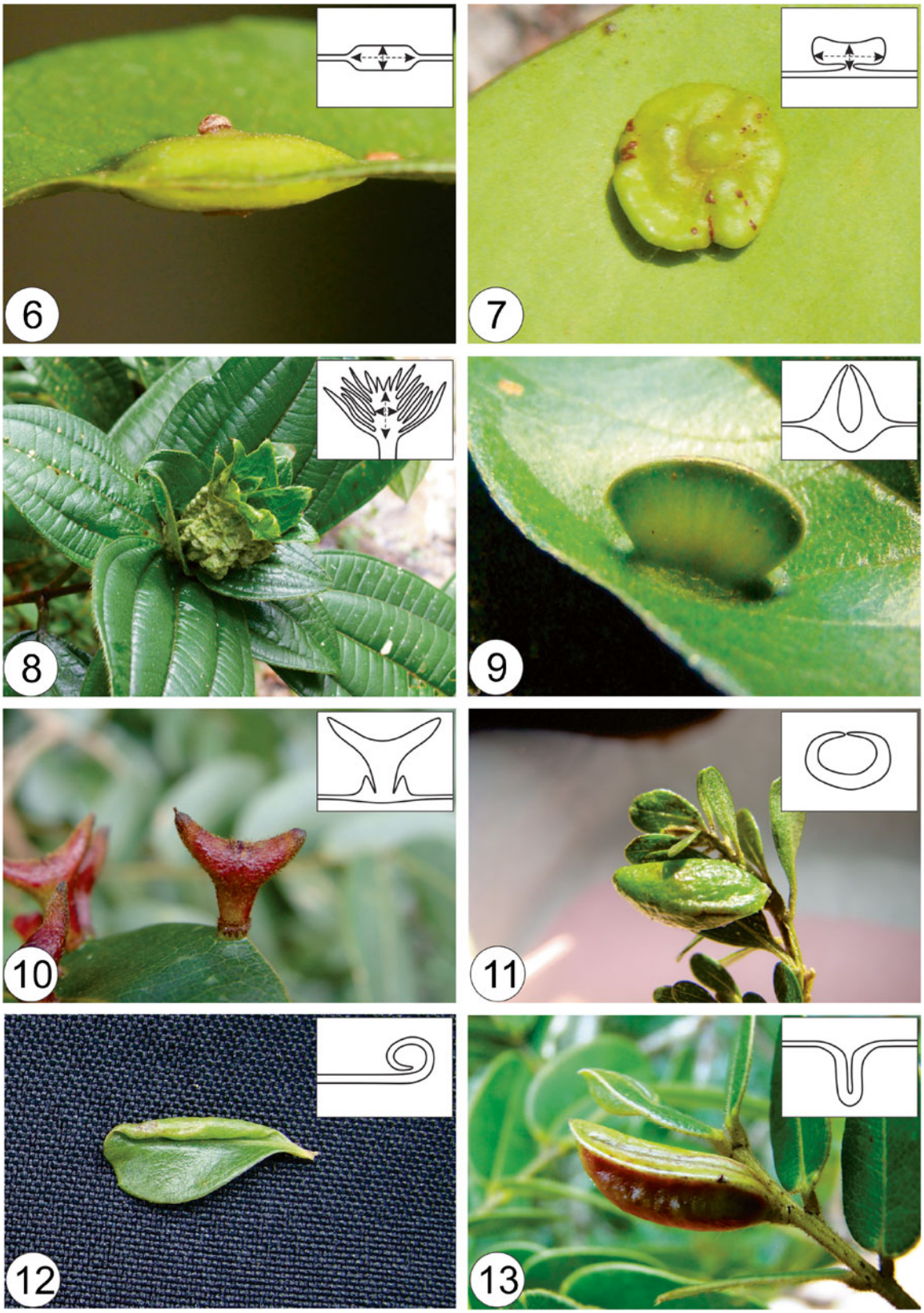

Fig 6–13 Gall morphotypes. *6*, Intralaminar lenticular gall on leaves of Sapindaceae. *7*, Extralaminar lenticular gall on leaves of *Clusia nemorosa* (Clusiaceae). *8*, Rosette gall on stem apex of *Henriettea succosa* (Melastomataceae). *9*, Bivalve-shaped gall on leaflet of *Lonchocarpus muhelbergianus* (Fabaceae); 10, horn-shaped galls on leaflets of *Copaifera langsdorffii* (Fabaceae). *11*, Fold gall on leaves of *Baccharis reticularia* (Asteraceae). *12*, Leaf rolling gall on a leaf of *B. reticularia*. *13*, Pocket gall on the midrib of the leaflet of *Copaifera langsdorffii.*

Table 2 Distribution of the 43 morphotypes in their host organs, occurrence, and frequency, according to the nine analyzed inventories.

Morphotypes	Leaf		Stem		Meristems		Reproductive organs		Roots		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Amorphous	13	2.7	1	0.4	4	5.8	2	25.0		–	20	2.5
Bipuncta	1	0.2		–		–		–		–	1	0.1
Bivalve shaped		–		–	1	1.4		–		–	1	0.1
Blister shaped	1	0.2		–		–		–		–	1	0.1
Bulbous	2	0.4	5	2.0		–		–		–	7	0.9
Circular	19	4.0		–		–		–		–	19	2.4
Clavate		–	3	1.2		–		–		–	3	0.4
Coalescent	1	0.2		–		–		–		–	1	0.1
Conical	53	11.1	2	0.8	5	7.2		–		–	60	7.4
Cylindrical	8	1.7		–	1	1.4	1	12.5		–	10	1.2
Cylindrical with apical projection	1	0.2		–		–		–		–	1	0.1
Discoid	74	15.5		–	2	2.9		–		–	76	9.4
Elliptical	53	11.1	109	43.3	15	21.7		–	1	100	178	22.1
Elliptical pedunculated	1	0.2		–		–		–		–	1	0.1
Fusiform	3	0.6	9	3.6		–		–		–	12	1.5
Globoid	86	18.1	76	30.2	23	33.3	3	37.5		–	188	23.3
Globose	15	3.2	3	1.2		–		–		–	18	2.2
Globose with apical projection	1	0.2		–		–		–		–	1	0.1
Globulous	6	1.3	6	2.4		–	1	12.5		–	13	1.6
Horn shaped	1	0.2		–		–		–		–	1	0.1
Lateral swelling	1	0.2		–		–		–		–	1	0.1
Leaf fold	3	0.6		–		–		–		–	3	0.4
Legume	7	1.5		–		–		–		–	7	0.9
Lenticular	16	3.4		–		–		–		–	16	2.0
Linear	1	0.2		–		–		–		–	1	0.1
Mamiliform	1	0.2		–		–		–		–	1	0.1
Marginal roll	11	2.3		–		–		–		–	11	1.4
Matted		–		–	1	1.4		–		–	1	0.1
Ovoid	3	0.6		–	2	2.9		–		–	5	0.6
Parenchymatic	7	1.5		–		–		–		–	7	0.9
Pine shaped		–		–	1	1.4		–		–	1	0.1
Pocket shaped	1	0.2		–		–		–		–	1	0.1
Rosette		–		–	3	4.3		–		–	3	0.4
Spheral	46	9.7	2	0.8		–		–		–	48	6.0
Spherical	13	2.7	4	1.6	1	1.4		–		–	18	2.2
Spheroid	7	1.5	3	1.2	3	4.3		–		–	13	1.6
Spot	1	0.2		–		–		–		–	1	0.1
Star	1	0.2		–		–		–		–	1	0.1
Suculent		–	1	0.4		–		–		–	1	0.1
Swelling	14	2.9	26	10.3	6	8.7	1	12.5		–	47	5.8
Triangular	2	0.4		–		–		–		–	2	0.2
Tubular	1	0.2		–	1	1.4		–		–	2	0.2
Unilateral swelling		–	1	0.4		–		–		–	1	0.1
Not reported	1	0.2	1	0.4		–		–		–	2	0.2
Total	476	100	252	100	69	100	8	100	1	100	806	100

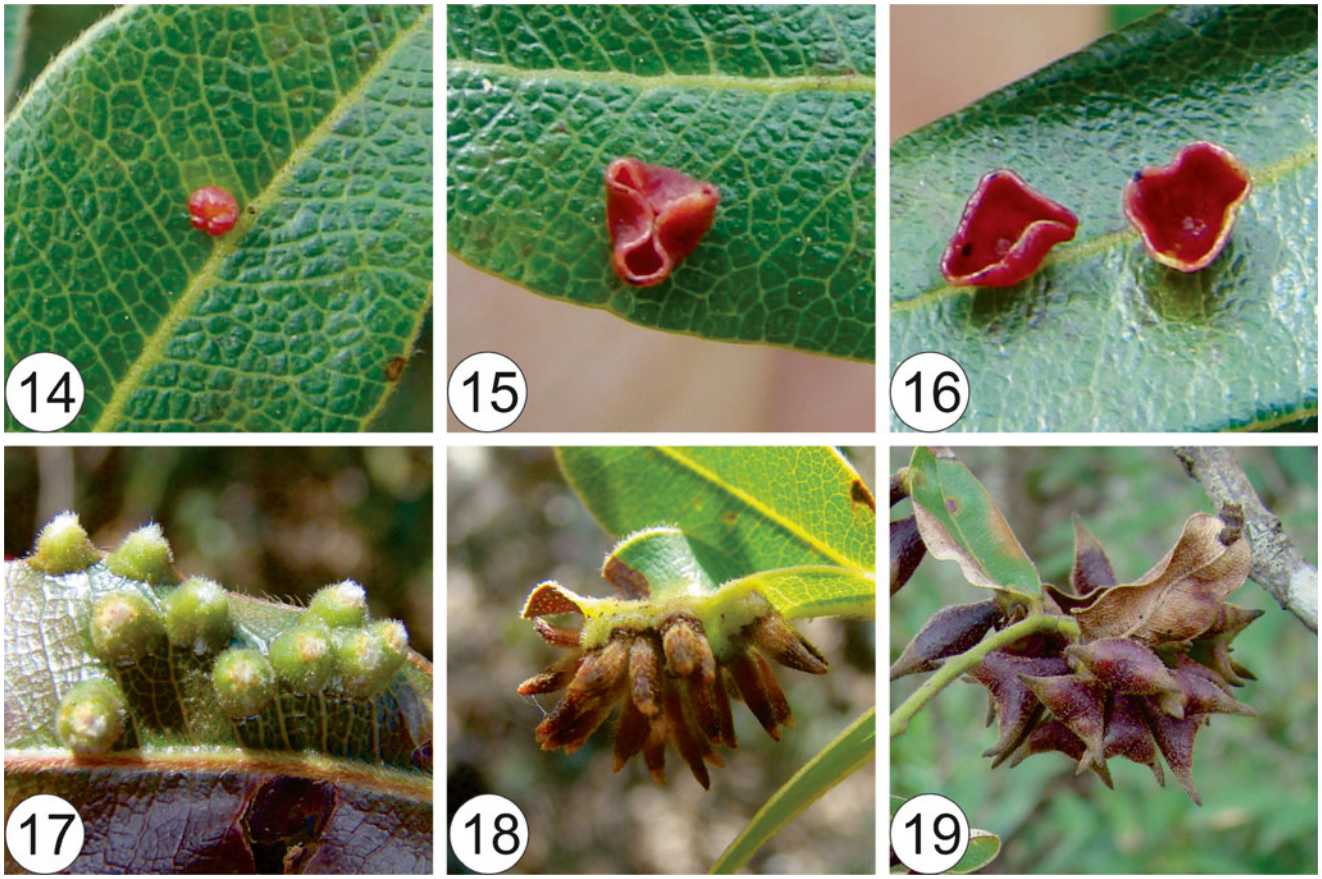

Fig 14–19 Alterations in shape due to the developmental stages of galls on *Copaifera langsdorffii* (Fabaceae). *14–16*, The cup-shaped gall. *17–19*, The horn-shaped gall.

illustrated by the galls induced by Cecidomyiidae along the midrib of *C. langsdorffii* (Fabaceae) leaflets (Oliveira & Isaias 2009).

Confusing terminology

Some of the terminology found in the inventories was considered inadequate for several reasons. Terms such as "circular" and "spot" could not represent the gall structure since they are basically two-dimensional forms, being in discordance with the true three-dimensional nature of the galls (Raman 2007). On the other hand, the terms "swelling" and "succulent" fail on giving a precise definition of the gall shape, being thus inadequate.

In other cases, the terms had to be contracted into one that best fitted the concept of the true form of the described galls (*sensu* Radford *et al* 1974). That was the case for the "mamiliform" galls which are conical, and of the "elliptical" galls which fit better as fusiform. The most common of the gall morphotypes generated in several host-plant galling herbivore systems is the globoid. This morphotype was reported as "blister shaped," "bulbous," "globose," "globulous," "spheral," "spheroid," "spherical," and "ovoid" in the inventories. The terms "discoid" and "lenticular" were grouped as lenticular and included all the round-shaped, flattened, and intralaminar or extralaminar galls because of their similarity in shape.

Amorphous vs. grouped galls

Raman (2007) has proposed that insect galls, the true galls, are symmetrical structures. However, we have accounted for 20 galls that did not present any symmetry. A careful examination of the illustrations indicated that they are coalescent galls, with variation in indumentum or internode shortening. When grouped, gall tissues may fuse, generating an amorphous structure which does not represent the isolated shape of each gall. The absence of shape was registered in 2.5% of the gall morphotypes reported in the nine inventories, and were induced by Cecidomyiidae (Maia *et al* 2008, Santos *et al* 2011a, b), Heteroptera (Santos *et al* 2011b), and Thysanoptera (Maia *et al* 2008) in 11 host-plant species from 12 distinct families. It may occur on leaves, stems or vegetative or reproductive buds. This seems to be the case of the "linear" Cecidomyiidae gall induced on an unidentified

species of Fabaceae (Maia & Oliveira 2010), in which there is a certain number of globoid grouped galls. If isolated, they should obey Raman's (2007) conceptual proposal as the lack of symmetrical shape is a consequence of tissue fusion.

Galls vs. host organs

Leaves are the most affected host organs referred in the Neotropical inventories, bearing 428 host-plant galling herbivore systems. Also, as they are the most plastic host organs, leaf galls accounted for 35 different shapes out of the 42 reported on the inventories. On the other hand, stems present a considerable amount of galls (252 galls), but fewer variations in shape. Only 14 different shapes were attributed to stem galls on the inventories (Table 2). This is believed to be due to the constraints imposed by the host organ over the morphogenesis of the gall, since stems are considered to be less plastic organs when compared to leaves (Valladares *et al* 2006). Galls on meristems and reproductive organs are more difficult to be accounted since these organs are not always present or active in the plant body. Even though they are poorly reported as host organs (only 77 records out of 806), they still present a considerable amount of morphotypes (16 morphotypes in the inventories), which is probably due to the great morphogenetic potentialities of the meristematic tissues. Root galls seem to be the most difficult to be registered (only one system was reported), probably due to their underground localization, which constitutes a barrier to the majority of galling insects, or even because they are hidden and make their direct observation much more complicated.

Changes in color

The set of colors observed in gall structures is a consequence of changes in the accumulation of plant pigments, and may change during gall development, especially from green to red (Inbar *et al* 2010). Even though it is an easy trait to be registered, the color of 28.7% of the gall morphotypes was not reported in the inventories (Maia & Fernandes 2004, Maia *et al* 2008, Carneiro *et al* 2009, Maia & Oliveira 2010, Maia 2012, Santos *et al* 2011ab, 2012, Malves & Frieiro-Costa 2012). The great majority is referred as greenish (39.4%), with 21.3% being reported as brownish, 6.6% as yellowish, 2.5% as reddish, 1% as whitish, and only 0.5% is equally distributed as black and pinkish. The inventories, in general, do not register the alterations in color observed in the same gall morphotypes, even when 2-year cycles were followed.

The age of the galls may influence the variation in color. During senescence, chlorophylls are degraded and the carotenoids and anthocianins are not masked anymore (Dias *et al* 2013). This phenomenon is believed to be common in the developmental cycle of some gall morphotypes. On the other hand, chlorophyll concentration may increase with gall age, as the plant tissues fully differentiate functional chloroplast, commonly turning from red to green. Sometimes, the color of the same gall morphotype may vary from dark to yellowish green, reaching the red and even the brown colors depending on the stimuli from the galling insect and from environmental conditions such as light exposure.

As it is seen, although very important for gall morphotypes diagnoses, the color is subjected to a great amount of variables that directly affects its expression. So, special care is necessary on the description of such characteristic, taking into account the environmental conditions to which host plants are subjected, the gall developmental stage, and even the presence of other trophic levels that affect the stimuli from the galling herbivore to maintain the gall structure.

The superhosts of galling herbivores

The presence of superhosts increases the richness of galling herbivores in specific areas (Veldtman & McGeoch 2003), and when morphotypes are used to estimate this richness, attention to specific variables should avoid overestimations. Variables such as the developmental stage of the gall, the age of the host organ by the time of oviposition (Oliveira & Isaias 2009), as well as the morphological variations related to sex of the gall inducers (Gonçalves *et al* 2009) may be difficult to be visualized during isolated field sampling. In many of these cases, the phenological and anatomical analyses are essential to avoid misinterpretations.

Gall shapes may vary during their development, which could lead to the accounting of the same gall as different morphotypes. Within the nine inventories, 143 superhosts were reported, but some of them may be the same gall system with distinct shapes due to optional sites of oviposition. This may be the case of the stem galls on *B. reticularia* (Asteraceae), *B. salzmanii*, and *Lessigianthus pychnostachius* (Asteraceae) reported in Carneiro *et al* (2009), which vary from fusiform to globoid the closer they are to the stem apex.

The gall developmental stage is also responsible for the gall shape. Costa *et al* (2010) reported 23 distinct gall morphotypes in the superhost *C. langsdorffii* (Fabaceae). One of these morphotypes, the cup-shaped gall, may occur either on the abaxial or adaxial leaflet surface, and has a membranous texture. The larval chamber is located at the basal portion of the gall which is monotalamous (Oliveira *et al* 2008). The developmental process lasts 2–3 days, when the gall changes from light green to red. Its shape also turns from globose to cup shaped, when it elongates axially

and opens in its apical portion along linear preexisting scars (Figs 14–16). The alterations in color and shape could lead to the registering of three distinct morphotypes if the temporal variable is not evaluated. Another example of change in shape on the same host plant is the horn-shaped gall. It occurs either on the abaxial or the adaxial leaflet surface, is pedunculated, and varies from green to red when mature. The development of this gall morphotype lasts about 1 year. At the very beginning, the gall is conical, with a large amount of trichomes emerging from its tip center. Later on, two hairy projections protrude from the conical structure, forming the gall body, and the basal portion originates the peduncle (Figs 17–19). These two morphotypes illustrate the importance of periodic field observation to follow the phenotypical changes along gall development.

Standardization of gall diagnosis

In order to standardize gall morphotype nomenclature and to create a comparable data base of Neotropical galls, we hereby propose steps for a complete gall diagnosis in which field information as well as laboratory data should be included. This is an effort to collect as much information as possible so that the knowledge on such Neotropical diversity remains available and retrievable for future comparable investigations.

Plants and galling herbivores identification must always be conducted to the lowest possible taxonomic level. As galling herbivores are poorly known on the taxonomic basis, gall morphotype designation must be at least accompanied by plant species name and enough information that allows it to be distinguished from other plant galls. The basic information that should allow the individualization of a gall morphotype is: (1) host-plant species, (2) galling herbivore species or its identification to the lowest possible taxonomic level, (3) host-plant galled organ and gall position, (4) gall morphotype, (5) gall color and registration of indumentum when present, (6) gall phenological and developmental data, (7) association with other trophic levels, and (8) additional information, such as dimension and number of chamber(s).

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