

Diversity of gall-inducing insects in the high altitude wetland forests in Pernambuco, Northeastern Brazil

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Received 18 June, 2009 – Accepted 17 August, 2009 – Distributed February 28, 2011

(With 2 figures)

Abstract

We report on the richness of galling insects in the altitudinal wetland forests of Pernambuco State, Northeastern Brazil. We found 80 distinct types of insect galls on 49 species of host plants belonging to 28 families and 35 genera. Most of the galled plant species belong to Nyctaginaceae, Fabaceae, Meliaceae, Sapindaceae and Myrtaceae. The most common gall were spheroid and globoid; most galls were glabrous, predominantly green and with one chamber, and on the leaves. Most galls were induced by Cecidomyiidae (Diptera). The results of this study contribute to existing knowledge richness of galling insects and host-plant diversity in the altitudinal wetland forests of Northeastern Brazil.

Keywords: insect galls, species richness, Cecidomyiidae, insect herbivory, host plants.

Diversidade de insetos indutores de galhas em brejos de altitude de Pernambuco, Nordeste do Brasil

Resumo

Este artigo reporta sobre a riqueza de insetos galhadores em brejos de altitude de Pernambuco, Brasil. Foram encontrados 80 morfotipos de galhas sobre 49 espécies de plantas hospedeiras pertencentes a 28 famílias e 35 gêneros. Muitas das plantas galhadas pertencem a Nyctaginaceae, Fabaceae, Meliaceae, Myrtaceae e Sapindaceae. Os tipos morfológicos de galhas mais comuns foram esferoide e globoide, glabro, predominantemente verde e com uma câmara, e sobre as folhas. Muitas galhas foram induzidas por Cecidomyiidae (Diptera). Os resultados deste estudo contribuem para o conhecimento da riqueza de insetos galhadores e da diversidade de plantas hospedeiras em brejos de altitude do nordeste do Brasil.

Palavras-chave: galhas entomógenas, riqueza de espécies, Cecidomyiidae, insetos herbívoros, plantas hospedeiras.

1. Introduction

The tropical altitudinal wet forests of Northeastern Brazil, locally known as “brejos de altitude”, are enclaves of the Atlantic forest in altitudes above 500 m, forming “islands” of wet forest surrounded by semi-arid vegetation (caatinga) (Tabarelli and Santos, 2004). These forest islands are important for the maintenance of biological diversity for two main reasons: 1) many species are endemic, and they represent an important endemism centre; and 2) the altitudinal wet forests share several species with both the Atlantic rain forest and the Amazon rain forest; making this ecosystem singular (see Pôrto et al., 2004a).

Despite its great biological importance, there are exceedingly few ecological studies on insects in the altitudinal

wet forests. In the latest review on altitudinal wet forests (see Pôrto et al., 2004a), only some termites (Isoptera) (Bandeira and Vasconcellos, 2004), bees (Hymenoptera) (Locatelli et al., 2004) and butterflies (Lepidoptera) (Gusmão-Creão and Duarte, 2004) were studied. Contrarily, the studies of some insect guilds are increasing in the Atlantic rain forests, as in galling insects. For instance, Fernandes et al. (2001) reported the galling insect richness and their host plants in the Rio Doce Valley, Minas Gerais, while Dalbem and Mendonça (2006) and Mendonça (2007) the diversity of galling arthropods and host plants in a subtropical forest of Southern Brazil; Fernandes and Negreiros (2006) and Moreira et al. (2007) provided information on galling insect

community in a disturbed area; and Maia (2005) reported the diversity of the cecidomyiids (95 species) in the state of Rio de Janeiro. To our knowledge there is no study on galling insects in the altitudinal wet forests. Hence, for the first time, we report on the richness of galling insects in the altitudinal wet forests of Pernambuco in an attempt to broaden our knowledge of galling species diversity in the Atlantic forest and northeastern Brazil.

2. Material and Methods

2.1. Study area

This study was conducted in seven altitudinal wet forests of Pernambuco State, Brazil: Reserva Municipal de Bonito - Brejo de Bonito (Bonito municipality), Brejo de Bituri Grande - Brejo da Madre de Deus (Brejo Madre de Deus municipality), Reserva Biológica de Serra Negra - Brejo de Serra Negra (Bezerras municipality), Brejo de Taquaritinga do Norte (Taquaritinga do Norte municipality), Brejo de Triunfo (Trunfo municipality), Parque Municipal João Vasconcelos Sobrinho - Brejo dos Cavalos e Brejo da Serra Água Doce (Caruaru municipality). These areas were chosen arbitrarily to cover the maximum of forest variability in the State of Pernambuco and to avoid pseudo-replication between the areas (Figure 1).

2.2. Sampling galling insects richness

The altitudinal wet forests were investigated for galls over a period of seven months from January to September of 2008. In each site, galling insect richness was sampled by two people following the adapted methodology of random walking (see Julião et al., 2002; Fernandes and Negreiros, 2006), where instead of an hour-long survey, we spent three hours in each area. To maximise the sampling of richness, a distance of at least 500 m was established among the sites sampled inside the areas (Fernandes and Price, 1988). All plant organs were investigated, and each gall and host plant (up to 3 m in height) found were collected, placed in plastic bags, and then taken to a laboratory for photographic registration and description of the gall external morphology. Host plants were classified into morphospecies in the field, and later at the species level in the Herbarium UFPE (Universidade Federal de Pernambuco). The classification of species of host plants followed the system proposed by Angiosperm Phylogeny Group II (APG II, 2003), and the authors and scientific host plant names were checked on the Missouri Botanical Garden website "<http://mobot.mobot.org/W3T/Search/classicvast.html>". In general, 95% species of insect induce a gall on a specific tissue of a certain plant species (Carneiro et al., 2009). The use of morphospecies to represent the galling species richness has

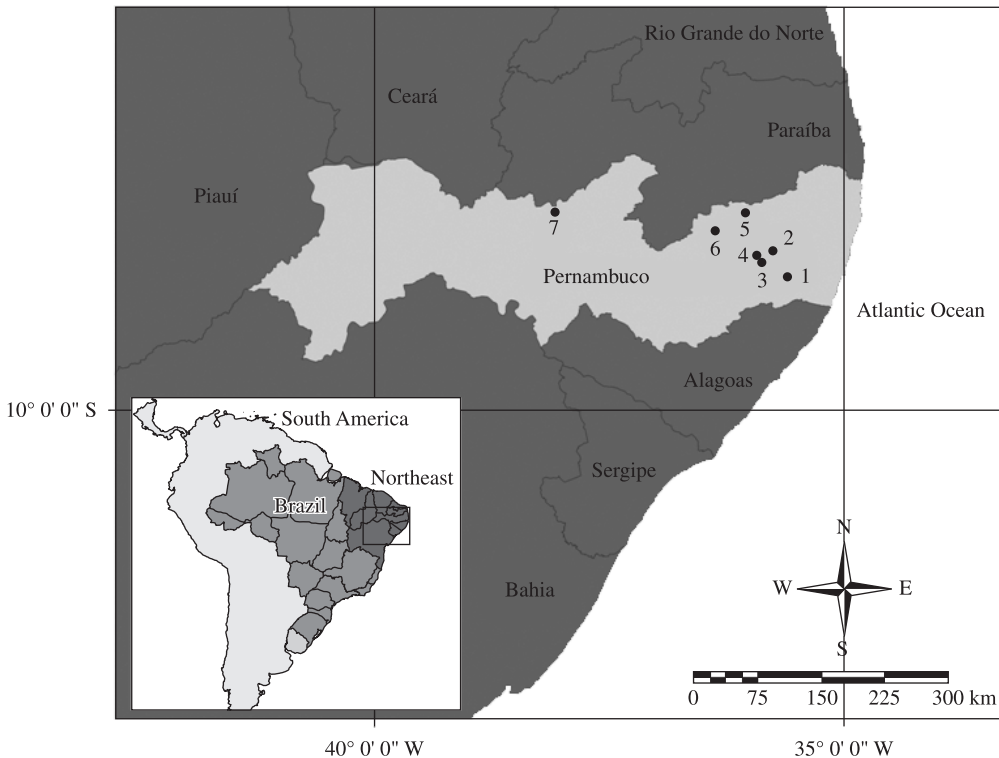


Figure 1. Location of the studied sites (number) in Pernambuco state (detail), northeast region (light grey) of Brazil (dark grey): 1) Brejo de Bonito; 2) Brejo de Serra Negra; 3) Brejo da Serra Água Doce; 4) Brejo dos Cavalos; 5) Brejo de Taquaritinga do Norte; 6) Brejo da Madre de Deus; and 7) Brejo de Triunfo.

Table 1. Gallling insect species and host plants found in the altitudinal wet forests of Pernambuco, Brazil. The host plants and description of gall morphotypes are presented below, with the number of galls found on each host plant, plant organ where the gall was induced, area where the gall was induced on the sheet in the form galls, predominant colour, presence of or no hair, number of chambers (if it is grouped or isolated) and the likely group of the gall inducer. Each gall morphotype of this table is depicted in Figure 1 below.

Host plant family	Host plant species	Galls	Tissue	Side	Shape	Colour	Pubescence	Chambers	Likely gall maker	Figures
Anacardiaceae	<i>Tapirira guianensis</i> Aubl.	1	Leaf	Adaxial	Conical	Brown	No	Isolated	Not identified	2.1
Araliaceae	<i>Schefflera morototoni</i> (Aubl.) Maguire, Steyerl. and Frodin	1	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.2
Asteraceae	<i>Mikania</i> sp. Willd.	1	Leaf	Abaxial	Spherical	Brown	Yes	Isolated	Cecidomyiidae	2.3
Bromeliaceae	Bromeliaceae sp.1	2	Leaf/Stem	-	Elliptical	Green	No	Isolated	Cecidomyiidae	2.4
Combretaceae	<i>Buchenavia capitata</i> (Vahl) Eichler	1	Leaf	Both	Globose	Brown	Yes	Grouped	Not identified	2.5
Elaeocarpaceae	<i>Sloanea</i> sp. L.	1	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.6
Erythroxylaceae	<i>Erythroxylum mucronatum</i> Benth.	1	Leaf	Abaxial	Spherical	Brown	Yes	Isolated	Cecidomyiidae	2.7
Euphorbiaceae	<i>Mabea occidentalis</i> Benth.	2	Leaf	Abaxial	Globose	Brown	No	Isolated	Cecidomyiidae	2.8
Fabaceae	<i>Andira</i> sp. Juss.	1	Leaf/Meristem	-	Amorphous	Green	No	Grouped	Cecidomyiidae	2.11
	<i>Bauhinia</i> cf. <i>outimouta</i> Aubl.	1	Leaf	Both	Elliptical	Green	No	Isolated	Cecidomyiidae	2.12
	<i>Copaifera langsdorffii</i> Desf.	2	Leaf	Adaxial	Discoid	Green	No	Isolated	Cecidomyiidae	2.13
	<i>Derris guilleminiana</i> (Tul.) J.F. Macbr.	1	Leaf	Abaxial	Spherical	Green	No	Isolated	Cecidomyiidae	2.14
	<i>Inga bahiensis</i> Benth.	2	Leaf	Both	Discoid	Brown	Yes	Isolated	Cecidomyiidae	2.15
	<i>Inga edulis</i> Mart.	1	Leaf	Both	Elliptical	Green	No	Isolated	Cecidomyiidae	2.16
	<i>Inga striata</i> Benth.	2	Stem	-	Globose	Green	No	Grouped	Not identified	2.17
	<i>Lonchocarpus guilleminianus</i> Tul. Malmé	1	Leaf	Both	Elliptical	Green	No	Isolated	Not identified	2.18
									<i>Euphalerus</i>	2.19
									<i>ostreoides</i> Crawford,	2.20
									1925 (Homoptera: Psyllidae)	
Flacourtiaceae	<i>Casearia javitensis</i> Kunth	1	Leaf	-	Elliptical	Brown	No	Isolated	Cecidomyiidae	2.21
Lacistemataceae	<i>Lacistema robustum</i> Schmizl.	2	Leaf	-	Elliptical	Green	No	Isolated	Cecidomyiidae	2.22
		1	Meristem	-	Conical	Green	No	Grouped	Cecidomyiidae	2.23

Table 1. Continued ...

Host plant family	Host plant species	Galls	Tissue	Side	Shape	Colour	Pubescence	Chambers	Likely gall maker	Figures
Lauraceae	<i>Ocotea</i> cf. <i>glomerata</i> (Nees) Mez	1	Leaf	Adaxial	Conical	Green	No	Isolated	Heteroptera	2.24
	<i>Lecythis pisonis</i> Cambess.	1	Stem	-	Elliptical	Brown	No	Isolated	Not identified	2.25
	<i>Byrsonima sericea</i> DC.	1	Leaf	Adaxial	Discoid	Yellow	No	Isolated	Heteroptera	2.26
Malpighiaceae		2	Stem	-	Globoid	Green	No	-	Not identified	2.27
	<i>Byrsonima</i> sp. Rich. ex Kunth	1	Leaf	Abaxial	Spherical	Green/Red	No	Isolated	Cecidomyiidae	2.28
	<i>Clidemia</i> sp. D. Don	1	Leaf/Stem	Both	Spherical	Green	Yes	Isolated	Cecidomyiidae	2.29
Melastomataceae	<i>Henriettea succosa</i> (Aubl.) DC.	1	Meristem	-	Rosette	Green	No	Isolated	Lepidoptera	2.30
	<i>Guarea</i> cf. <i>macrophylla</i> Vahl ssp. <i>tuberculata</i> (Vell) T.D. Penn	1	Leaf	Both	Spherical	Green	No	Isolated	Cecidomyiidae	2.31
Meliaceae		2	Leaf	Both	Spherical	Green/Red	Yes	Isolated	Cecidomyiidae	2.32
		3	Leaf	Abaxial	Conical	Green/Brown	Yes	Isolated	Cecidomyiidae	2.33
		4	Leaf	-	Elliptical	Green	No	Isolated	Cecidomyiidae	2.34
Monimiaceae		5	Leaf	-	Amorphous	Green	No	-	Cecidomyiidae	2.35
		6	Leaf	Both	Spherical	Green	No	Isolated	Cecidomyiidae	2.36
	<i>Guarea guidonia</i> (L.) Sleumer	1	Leaf/Stem	Abaxial	Spherical	Green	No	Grouped	Cecidomyiidae	2.37
Myrsinaceae		2	Leaf	-	Elliptical	Green	No	Isolated	Cecidomyiidae	2.38
	<i>Mollinedia dardanoi</i> Peixoto	1	Leaf	Abaxial	Globoid	Green	No	Isolated	Cecidomyiidae	2.39
	<i>Cybianthus</i> sp. Mart.	1	Leaf	Adaxial	Discoid	Green	No	Isolated	Heteroptera	2.40
Myrtaceae	<i>Eugenia</i> sp. L.	1	Leaf	Adaxial	Globoid	Brown	No	Isolated	Not identified	2.41
	<i>Myrcia</i> cf. <i>fallax</i> (Rich.) DC.	1	Leaf/Stem	Both	Globoid	Green	No	Isolated	Cecidomyiidae	2.42
	<i>Myrcia</i> sp. DC. ex Guill.	1	Stem	-	Globoid	Brown	No	Grouped	Cecidomyiidae	2.43
Nyctaginaceae	<i>Myrcia sylvatica</i> (G. Mey.) DC.	1	Meristem	-	Elliptical	Brown	No	Grouped	Cecidomyiidae	2.44
		2	Stem	-	Elliptical	Brown	No	Grouped	Cecidomyiidae	2.45
		3	Leaf	-	Amorphous	Brown	No	Grouped	Not identified	2.46
		4	Leaf/Stem	Both	Globoid	Green/Red	No	Isolated	Cecidomyiidae	2.47
	<i>Guapira laxa</i> (Netto) Furlan	1	Vein	Abaxial	Globoid	Brown	No	Isolated	Cecidomyiidae	2.48
	<i>Guapira</i> sp.1 Aubl.	1	Leaf	Abaxial	Spherical	Green/Red	No	Isolated	Cecidomyiidae	2.49
		2	Leaf	Adaxial	Spherical	Brown	No	Isolated	Cecidomyiidae	2.50
		3	Leaf	Both	Globoid	Green	No	Isolated	Cecidomyiidae	2.51

Table 1. Continued ...

Host plant family	Host plant species	Galls	Tissue	Side	Shape	Colour	Pubescence	Chambers	Likely gall maker	Figures
Ochnaceae	<i>Guapira</i> sp.2 Aubl.	4	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.52
		5	Leaf	Adaxial	Spherical	Vermelho	Yes	Isolated	Cecidomyiidae	2.53
		6	Stem	-	Elliptical	Green/Brown	No	Isolated	Not identified	2.54
		7	Stem	-	Amorphous	Green	No	Grouped	Not identified	2.55
		1	Leaf	Abaxial	Globose	Brown	Yes	Isolated	Cecidomyiidae	2.56
		2	Leaf	Abaxial	Spherical	Green/Brown	Yes	Isolated	Cecidomyiidae	2.57
		3	Leaf	Abaxial	Spherical	Yellow	Yes	Isolated	Cecidomyiidae	2.58
Polygonaceae	<i>Ouratea</i> sp. Aubl.	4	Leaf	Adaxial	Spherical	Brown	No	Isolated	Cecidomyiidae	2.59
		5	Leaf	Adaxial	Conical	Brown	No	Isolated	Cecidomyiidae	2.60
		6	Leaf	Both	Globose	Brown	No	Isolated	Cecidomyiidae	2.61
		7	Leaf	Adaxial	Spherical	Green	Yes	Isolated	Cecidomyiidae	2.62
		1	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.63
		2	Leaf	-	Elliptical	Brown	No	Grouped	Cecidomyiidae	2.64
		1	Leaf	Abaxial	Spherical	Brown	Yes	Isolated	Cecidomyiidae	2.65
Rubiaceae	<i>Coccoloba</i> sp. P. Browne	1	Leaf	Abaxial	Conical	Green	No	Isolated	Cecidomyiidae	2.66
		1	Leaf	Abaxial	Globose	Green	No	Isolated	Cecidomyiidae	2.67
		1	Leaf	Abaxial	Spherical	Green	No	Isolated	Cecidomyiidae	2.68
		1	Leaf	Abaxial	Globose	Brown	No	Isolated	Cecidomyiidae	2.69
		2	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.70
		1	Petiole	-	Spherical	Brown	No	Isolated	Not identified	2.71
		1	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.72
Sapindaceae	<i>Paulinia</i> cf. <i>racemosa</i> Wawra	1	Leaf/Petiole	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.73
		2	Stem/Petiole	-	Elliptical	Brown	No	Grouped	Cecidomyiidae	2.74
		3	Leaf	Both	Conical	Green	No	Isolated	Cecidomyiidae	2.75
		1	Leaf	Both	Discoid	Green	No	Isolated	Cecidomyiidae	2.76
		1	Leaf	Adaxial	Conical	Green	No	Isolated	Cecidomyiidae	2.77
		1	Leaf	Both	Globose	Green	No	Grouped	Cecidomyiidae	2.78
		1	Leaf	Both	Globose	Green	No	Isolated	Cecidomyiidae	2.79
Not identified	Not identified sp.1	1	Stem	-	Spherical	Green	Yes	Isolated	Cecidomyiidae	2.80

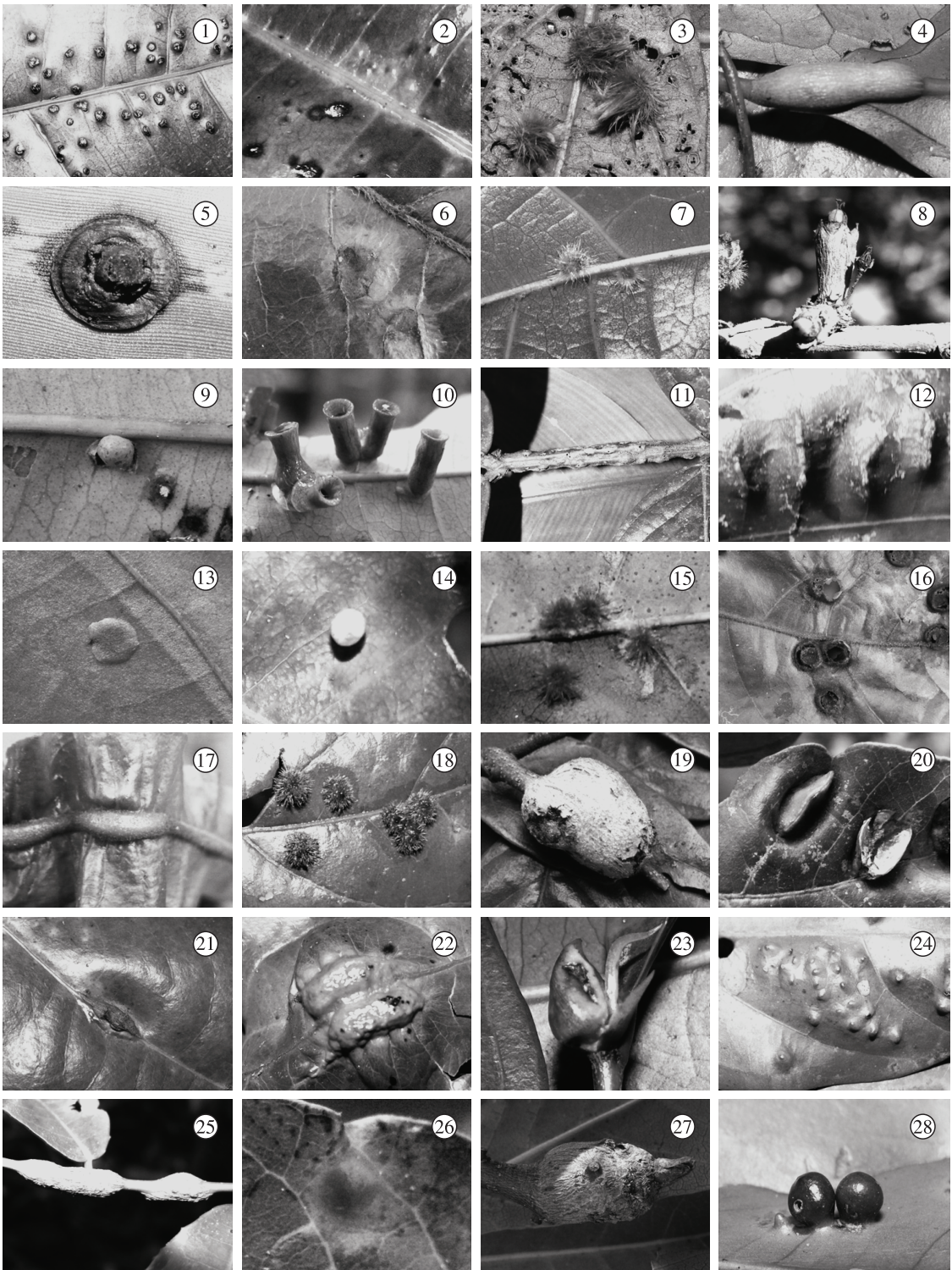


Figure 2. (1-28). Gallling insect morphospecies in altitudinal wet forests of Pernambuco, Brazil. 1) *Tapirira guianensis*; 2) *Schefflera morototoni*; 3-4) *Mikania* sp.; 5) *Bromeliaceae* sp.1; 6) *Buchenavia capitata*; 7) *Sloanea* sp.; 8-9) *Erythroxylum mucronatum*; 10) *Mabea occidentalis*; 11) *Andira* sp.; 12-13) *Bauhinia* cf. *outimouta*; 14) *Copaifera langsdorffii*; 15) *Derris guilleminiana*; 16) *Inga bahiensis*; 17) *Inga edulis*; 18-19) *Inga striata*; 20) *Lonchocarpus guilleminiaus*; 21-22) *Casearia javitensis*; 23) *Lacistema robustum*; 24) *Ocotea* cf. *glomerata*; 25) *Lecythis pisonis*; 26-27) *Byrsonima sericea*; 28) *Byrsonima* sp.;

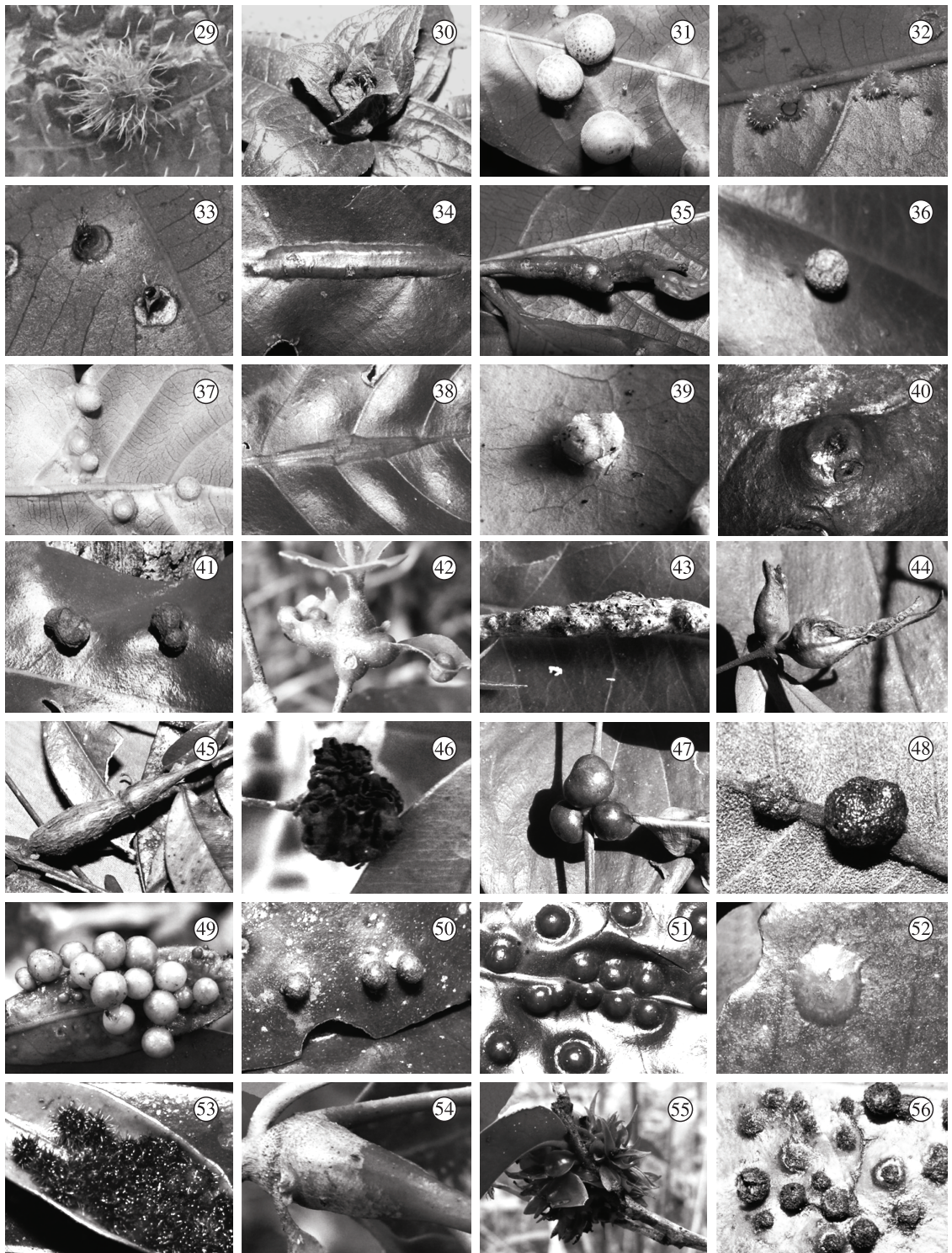


Figure 2. (29-56). Continued... Galling insect morphospecies in altitudinal wet forests of Pernambuco, Brazil. 29) *Clidemia* sp.; 30) *Henriettea succosa*; 31-36) *Guarea* cf. *macrophylla*; 37-38) *Guarea guidonia*; 39) *Mollinedia dardanoi*; 40) *Cybianthus* sp.; 41) *Eugenia* sp.; 42) *Myrcia* cf. *fallax*; 43) *Myrcia* sp.; 44-47) *Myrcia sylvatica*; 48) *Guapira laxa*; 49-55) *Guapira* sp.1; 56) *Guapira* sp.2;



Figure 2. (57-80). Continued... Gallling insect morphospecies in altitudinal wet forests of Pernambuco, Brazil. 57-62) *Guapira* sp.2; 63-64) *Ouratea* sp.; 65) *Coccoloba* sp.; 66) *Psychotria barbiflora*; 67) *Psychotria carthagenensis*; 68) *Psychotria sessilis*; 69-70) *Cupania racemosa*; 71) *Paullinia* cf. *racemosa*; 72) *Paullinia pinnata*; 73-75) *Paullinia trigonia*; 76) *Smilax* cf. *officinalis*; 77) *Celtis membranacea*; 78) *Paypayrola blanchetiana*; 79) *Violaceae* sp.1; 80) Not identified sp.2. For host plant identification and gall morphotypes description, see also Table 1.

been used in several studies in different ecosystems (e.g., Price et al., 1998; Cuevas-Reyes et al., 2004; Fernandes and Negreiros, 2006; Moreira et al., 2007). Galls were characterised as reported by Fernandes and Price (1988): host plant species, number of types of galls by host plant, type of host tissue attacked, shape of galls, colour of galls,

presence or absence of pubescence, and number of chambers in the gall, occurrence on the galled organ: isolated or grouped/coalescent. We chose to present only a list with the probable inducers of gall makers because many galls were naturally damaged, or without the presence of the inducer or with parasited larvae.

3. Results

We found 80 morphologically distinct types of insect galls in the altitudinal wet forests of Pernambuco. These galls were found on 49 species of host plants belonging to 28 families and 35 genera (Table 1, Figure 2). The richness of galling insects was greater in the Brejo dos Cavalos (32 species) followed by Brejo de Bonito (27 species), Brejo da Madre de Deus (15 morphotypes), Brejo de Serra Negra (eight species), Brejo de Taquaritinga do Norte (five species), Brejo de Triunfo (three species), and Brejo da Serra Água Doce with two species. The majority of insect galls were induced by species of the family Cecidomyiidae (81.25%) followed by Heteroptera (5%), Lepidoptera (1.25%), while we could not identify the remaining 12.50% (undetermined). The host plant families that supported the greater number of species of galls were: Nyctaginaceae (18.99%), Fabaceae (12.66%), Meliaceae (10.13%), and Sapindaceae and Myrtaceae with 8.86% each. The genera with the greatest number of species of galls were: *Guapira* (Nyctaginaceae) (15 species), *Guarea* (Meliaceae) (eight species), *Myrcia* (Myrtaceae) (six species), and *Paullinia* (Sapindaceae) with five species. Most galls were induced on the leaves (72.5%), followed by stems (10.0%), simultaneously on leaves and stems (6.25%), and on apical buds (5.0%). The most frequent shape of galls was spheroid (27.50%), followed by globose (21.25%). Eighty-one percent of galls were glabrous; 53.75% were predominantly green, while 81.25% did not form clusters.

4. Discussion

Some studies on insect gall richness conducted in the Atlantic forest are concentrated in the South and Southeast of Brazil and our study represents the first contribution to the understanding on this herbivore guild distribution and diversity in the upland tropical wet forest ecosystems. A comparison with the data from other Brazilian Atlantic rain forests indicates that the richness of the insect galls in the upland forest of Pernambuco (80 species) is comparatively smaller. For instance, Fernandes et al. (2001) reported on 273 galling species in the Atlantic rain forests of the Rio Doce Valley. However, it is important to emphasize that these comparisons between studies should be viewed with caution by differences in methodology, sampling size and time. Many sampled areas of altitudinal wet forests have suffered a strong degradation in their ecosystems; e.g., loss of habitat, hunting, wood extraction, agriculture and fragmentation (see Tabarelli and Santos, 2004). Moreover, these ecosystems are true mountain top islands within the semi-arid vegetation (caatinga), and therefore, they had a smaller spatial area compared to areas of continuous Atlantic rain forests of the coast. All these factors may contribute to a reduction in the richness of insect galls in this ecosystem.

Although the purpose of this study is not to compare the richness of galling insects among sample areas, it is important to emphasize the great richness of insect galls

species in the Brejo dos Cavalos (32 species) and Brejo de Bonito (27 species). This result can be interpreted because these areas have high biological diversity of important groups, such as bryophytes (Pôrto et al., 2004b) and host plants (e.g., Rodal et al., 2005) to both areas, bromeliads to Caruaru (Siqueira Filho, 2004), which indicates a high degree of preservation and conservation of these areas, and therefore a greater diversity of galling insects.

This is the first descriptive study on galling insect richness done in the altitudinal wet forests. However, many other areas of altitudinal wet forests inside the caatinga matrix are to be studied before they are totally degraded, and in order to reach a better understanding of the distribution of galling insects and their host plants along the tropical forests.

Acknowledgements — We thank two anonymous reviewers, Mr. Gilcean for field work, A. Aguiar (Patriota) for figure design, and the financial support was provided by DCR-FACEPE/CNPq (DCR-0087-2.05/06, APQ-0008-2.05/07), CNPq (309633/2007-9) and FAPEMIG (PRI-00121/10).

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