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Characterization of entomogenic galls in areas of seasonal deciduous forest in Southwestern Bahia, Brazil

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Abstract. Galls are small structures induced mostly by insects in different plant organs, and have different shapes and colorations. Knowledge on galls is still sparse in the semiarid region of Bahia. Therefore, the goal of this study was to characterize galls in fragments of seasonal deciduous forest. Sampling was performed in the Bahia municipalities of Boa Nova, Jequié, Poções and Vitória da Conquista. In each site, one fragment was chosen, and in each fragment, plots were established to survey galls on vegetation. We sampled 158 gall morphotypes, representing 49 (morpho) species distributed across 15 families of host plants. Myrtaceae and Malphigiaceae had the highest numbers of gall morphotypes. Most galls were collected from leaves, whereas the most common gall morphotypes were globoid and fusiform.

Keywords: Biodiversity; Fragments; Malphigiaceae; Myrtaceae; Plant-Insect Interaction.

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Galls are abnormal alterations of cells, resulting from hypertrophy (increase in cell volume) and/or hyperplasy (increase in cell number) which occurs when plant tissue or organs respond to feeding by various groups of organisms, especially fungi, bacteria, viruses, mites, nematodes and insects (Rohfritsch & Shorthouse 1982; Dreger-Jauffret & Shorthouse 1992; Raman 2007).

Organisms that form galls are very specific regarding their host. Generally, each species induces the formation of galls in a particular site of the plant (Hanson & Gauld 2006). Galls can be found on leaves and branches (among other plant organs), with different shapes and colors (Carneiro *et al.* 2009; Costa *et al.* 2014a; Costa *et al.* 2014b).

A recent functionality which stresses the importance of this type of study is the utilization of insect galls as indicators of environmental quality (Julião *et al.* 2005). Environmental disturbances that change vegetation composition can cause local extinction of many galling insects by the disappearance of their respective host plants (Carvalho-Fernandes *et al.* 2012).

Galling insects can be used as indicators of habitat diversity and quality given some of their features: they are taxonomically and ecologically diverse, have a high ecological specificity, are sedentary in their larval stage, are abundant, respond predictably to environmental variation and are associated to particular species and resources (Mani 1964; MacArthur *et al.* 1979; Fernandes & Price 1988, 1991, 1992; Fernandes *et al.* 1989; Gagné 1989; Price *et al.* 1998; Fernandes 1992; Floate *et al.* 1996).

The Southwestern region of Bahia has dry and subhumid climate, with plain relief, Latossolo soil type and vegetation of the Seasonal Deciduous and Semideciduous Forest type, featuring the transition between Atlantic Forest and Caatinga (locally known as "Mata de Cipó"). This type of phytophysiognomy has tree species typical of Atlantic Forest as well as Caatinga species (Novaes & José 1992).

Studies of gall characterization concentrated on the Cerrado and Atlantic Forest environments, although some studies have been performed in other biomes. Among those, we can highlight some of greater relevance regarding gall characterization: Araújo *et al.* (2014), Carneiro *et al.* (2009), Fernandes *et al.* (2016), Maia (2001), Maia & Fernandes (2004) and Moreira *et al.* (2007).

In the state of Bahia, surveys of galls of a particular biome concentrate on the transition between Caatinga and Cerrado (Costa *et al.* 2014a), between Campo Rupestre and Cerrado (Vieira *et al.* 2018), with one study performed in Caatinga of Bahia but also encompassing the states of Alagoas and Sergipe (Carvalho-Fernandes *et al.* 2012).

Therefore, the goal of this study was to characterize galls and to identify their host plants in fragments of seasonal deciduous forest of Southwest Bahia.

MATERIAL AND METHODS

Research was performed in fragments of seasonal deciduous forest with similar conservation state and located in four municipalities of Bahia: Boa Nova (14º23'S/40º8'W, Parque Nacional de Boa Nova, 820 m a.s.l.), Jequié (13º51'S/40º4'W, Serra do Castanhão, 770 m a.s.l.), Poções (14º31'S/40º21'W, Serra do Arrepio, 1005 m a.s.l.) and Vitória da Conquista (14º51'S/40º50'W, Povoado Lagoa das Flores, 916 m a.s.l.).

Sampling was performed monthly between March 2017 and May 2018. One fragment was sampled in each municipality; in each of the four fragments, 32 plots were established (2×5 m, 10 m²), for a total of 128 plots. Plots were placed randomly and, in each survey, two plots are placed at the border of the fragment and two plots were placed within the fragment with a minimum distance of 20 m between them. All vegetation within transect was surveyed up to a height of two m.

Galls were sampled manually, put into plastic bags and transported to the Laboratory of Insect Biology (LABI), where they were put into transparent plastic bags containing moistened cotton wads. Sampled galls were kept in the laboratory for two months, and were surveys each two days for the presence of adult insects, after this period the galls were dissected. Part of the botanical material sampled from host plants was sent for taxonomic identification at the herbarium of State University of Southwest Bahia, *campus* Jequié.

Galls were sorted under a stereoscopic microscope according to gall morphotypes, that were defined following their morphological traits or those of their host species (Santos & Ribeiro 2015). We adopted a stringent criterion of specificity while separating morphotypes, as similar galls from different host species were considered as different gall morphotypes (Carneiro *et al.* 2009). Gall morphotypes related to the plant organ where they occur in acceptable as a surrogate for species identification in galling insects, due to their specificity regarding the host plant and the organ in which they occur (Price *et al.* 1998; Carneiro *et al.* 2009).

Galls were photographed and we recorded several variables: quantity, clustering, organ, leaf surface (adaxial or abaxial), shape, color, pilosity and quantity of chambers (Santos *et al.* 2010). To standardize the recorded information and to allow comparison and analysis, we followed the classification used by Isaias *et al.* (2013) to group the different gall patterns.

RESULTS

We sampled 158 morphotypes of galls across 49 morphospecies of host plants, representing 15 botanical families. The most common host plants were Myrtaceae with 64 morphotypes of galls (40.5%), encompassing 27 host species; Malpighiaceae with 28 morphotypes (17.7%) encompassing one host species; and Rutaceae with 24 morphotypes (15.2%) encompassing two host species (Table 1). Family Erythroxylaceae was the one with the highest number of gall host species, more precisely five species and with 11 morphotypes of galls. We also highlight the family Euphorbiaceae, which had four species and with 14 morphotypes of galls.

Species *Metrodorea maracasana* Kaastra (Rutaceae) was the host plant with highest diversity of gall morphotypes, with 21 morphotypes, followed by species *Actinostemon* sp.1 (Euphorbiaceae), with 11 morphotypes. We can also highlight *Myrcia* sp.2 (Myrtaceae) with eight morphotypes and Myrtacea sp.1 (Myrtaceae) with seven morphotypes (Table 3).

Galls were collected from two organs, with predominance of leaves (91.1%) over stems (8.9%). There was much variation in gall coloration: brown was most common color (39.9%), followed by green (33.6%) and black (12.7%). Other recorded colors were yellow (8.2%), red (2.5%), grey (1.9%), white (0.6%) and peach (0.6%). The number of galls collected on the abaxial surface of the leaves was higher (46.8%) than on the adaxial surface (38.6%). We also recorded galls on both leaf sides (3.2%), and in 11.4% of the galls we could not discriminate between leaf sides because of the form of gall induction (classified as leaf fold), which deformed leaf architecture.

Of the 13 morphotypes suggested by Isaias *et al.* (2013), eight were found in this study, with predominance of globoid (26.6%), fusiform (16.4%), and lenticular intralaminate and leaf fold forms (12.0%) (Table 2). We highlight the low percentage of galls with trichomes (12.8%). Unilocular galls represented 85.4% of the total sampled, while multilocular galls represented 14.6%.

The species with highest quantity of associated gall morphotypes was *M. maracasana* (Rutaceae), with 21 morphotypes, followed by *Actinostemon* sp.1 (Euphorbiaceae), with 11 morphotypes. The distribution of galls among

Table 1. Richness of insect galls by host family, genus and species in a seasonal deciduous forest in Southwestern Bahia, Brazil.

Family	Number of genera	Number of species	Number of gall morphotypes
Anacardiaceae	01	01	01
Annonaceae	01	01	04
Apocynaceae	01	02	02
Araceae	01	01	01
Celastraceae	01	01	01
Erythroxylaceae	01	05	11
Euphorbiaceae	02	04	14
Fabaceae	00	01	01
Malpighiaceae	00	00	28
Myrtaceae	02	27	64
Nyctaginaceae	01	01	02
Phyllantaceae	01	01	02
Rubiaceae	01	01	01
Rutaceae	02	02	24
Smilacaceae	01	01	02
Total	**16**	**49**	**158**

botanical families was not homogeneous, with a pattern of single records for most families (Maia 2011). In contrast, only Euphorbiaceae and Myrtaceae had host plant representatives in all four fragments. Rutaceae occurred in three of the four fragments, represented by species *M. maracasana* (except for the Jequié fragment).

DISCUSSION

The four families with highest diversity of gall morphotypes (Myrtaceae, Malpighiaceae, Rutaceae and Euphorbiaceae) accounted for 82.3% of host plants, indicating their importance for the composition of the entomogenic gall fauna of Seasonal Deciduous Forest.

Corroborating results from other studies, Family Myrtaceae is among those with highest diversity of entomogenic galls (Maia & Fernandes 2004; Maia 2013), whereas family Malpighiaceae can be highlighted regarding its importance for the diversity of plants in the studied region.

Considering that the current study is a first for the Southwestern region of Bahia, we cannot compare our data on gall morphotype richness with those of other studies. However, we can make an inference about species richness in this environment in light of other studies. In Caatinga and Cerrado, 21 and 49 gall morphotypes were found, respectively (Nogueira *et al.* 2016), whereas the current study found 158 morphotypes, significantly increasing the known diversity of galls in the region and in the state of Bahia.

Galls were induced mainly on leaves, but also occurred on stems. This result is in accordance with the global pattern indicated by other studies, which have reported higher variability of leaf gall forms (Maia 2011; Nogueira *et al.* 2016). Fernandes *et al.* (1988) highlighted that this pattern is due to some factors such as the facility that galling insects may have in finding leaves, given their higher quantity and conspicuousness relative to other organs. These results are similar to those found in diverse Brazilian ecosystems (Maia & Fernandes 2004 [Cerrado]; Carneiro *et al.* 2009 [Cerrado]; Santos & Ribeiro 2015 [Mata Atlântica]; Brito *et al.* 2018 [Caatinga]).

Table 2. Gall morphotypes collected in a seasonal deciduous forest in Southwestern Bahia, Brazil.

Gall morphotype	Gall number	Percentage
Globoid	42	26.6%
Fusiform	26	16.4%
Lenticular intralaminate	19	12.0%
Leaf fold	19	12,0%
Conic	18	11.4%
Cylindrical	14	8.9%
Amorphous	14	8.9%
Clavate	06	3.8%
Total	**158**	**100%**

A low number of galls with hairiness was found, representing 12.8% of the total sampled, as in the surveys carried out by Lima & Calado 2018 and Silva *et al.* 2018. This fact contradicts literature data, as trichomes function to avoid excessive loss of moisture as well as to provide defense against natural enemies (Costa *et al.* 2014a; Stone & Schonrogge 2003).

Most recorded galls had a single chamber (85.4%), corroborating the literature (Nogueira *et al.* 2016). This finding could be explained by the hypothesis proposed by Fernandes *et al.* (1988), according to which isolated galls would be favored because the pressure exerted by parasitoids would be minimized given the longer search time imposed by gall isolation. Galls with many chambers (14.6%) were significantly common when compared to other studies (Costa *et al.* 2014a; Nogueira *et al.* 2016).

There is single gall for which the galling insect could be identified, which was associated to *Tapirira guianensis* Aubl. (Anacardiaceae). The low rate of emergence of galling insects was very different from that reported by the majority of surveys (Santos *et al.* 2011a, 2011b; Costa *et al.* 2014a; Santos & Ribeiro 2015), with a distinction from Araújo *et al.* (2014) who recorded a relatively low rate compared to the pattern recorded regarding inducing insects. Gall dissection revealed that most were empty. Another remarkable fact was the larger number of galls with signs of predation, in some cases with vestiges of the structure.

The low quantity of galling insects can reflect the conservation status of Mata do Cipó. Disturbances are possibly modifying ecological interactions among galling insects and plants. However, as there were no studies prior to the current one, we cannot infer a specific scenario, and this is a justification for future studies in this environment.

One perspective that arises from this research is the study of galling insects and their responses to environmental change in Mata do Cipó, as these animals are totally dependent on plant species (Carvalho-Fernandes *et al.* 2012). Some hypotheses aim at explaining the distribution of gall-inducing insects, such as plant species richness (Carvalho-Fernandes *et al.* 2012), and Fernandes & Price (1988) show that plant richness influences the richness of insect galls.

This is the first study on galls induced by insects in areas of seasonal deciduous forest in Southwestern Bahia. This survey contributes to increase knowledge on the diversity of galls and their host plants, considering the few surveys carried out so far in the area (Santos *et al.* 2011a, 2011b; Carvalho-Fernandes *et al.* 2012; Costa *et al.* 2014a). However, additional studies on the characterization of galls should be performed in this environment, focusing on obtaining more information on arthropod biodiversity, especially on galling insects. This will provide a broader picture on the pattern of association between this group and their host plants.

Table 3. Occurrence and characterization of insect galls on host plants in a seasonal deciduous forest in Southwestern Bahia, Brazil. Legend: BN: Boa Nova; JQ: Jequié; PO: Poções; VC: Vitória da Conquista.

Family	Specie	Organ	Grouped	Foliar surface	Morphotype	Color	Trichome	Chambers	Site
Anacardiaceae	*Tapirira guianensis* Aubl.	Stem	No	-	Globoid	Brown	Glabrous	Unilocular	BN
Annonaceae	*Hornschucia* sp.	Leaf	Yes	Abaxial	Conic	Green	Glabrous	Unilocular	VC
		Leaf	No	Adaxial	Fusiform	Yellow	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Globoid	Brown	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Lenticular Intralaminate	Yellow	Glabrous	Unilocular	BN
Apocynaceae	*Aspidosperma* sp.	Leaf	Yes	Adaxial	Globoid	Yellow	Glabrous	Unilocular	JQ
	Apocynaceae sp.	Leaf	No	Adaxial	Globoid	Green	Pubescent	Unilocular	JQ
Araceae	*Anthurium pentaphyllum* G. Don	Leaf	No	Adaxial	Clavate	Green	Glabrous	Unilocular	JQ
Celastraceae	Celastraceae sp.	Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	BN
Erythroxylaceae	*Erythroxylum distortum* Mart.	Leaf	Yes	Abaxial	Amorphous	Black	Glabrous	Unilocular	JQ
	Erythroxylum macrocalyx Mart.	Leaf	No	Abaxial	Amorphous	Brown	Glabrous	Unilocular	PO
		Leaf	No	Abaxial	Cylindrical	Brown	Glabrous	Unilocular	PO
		Leaf	No	Abaxial	Globoid	Black	Glabrous	Unilocular	PO
		Leaf	No	Abaxial	Lenticular Intralaminate	Brown	Glabrous	Unilocular	PO
	Erythroxylum macrochoetum Miq.	Leaf	Yes	Adaxial	Amorphous	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	JQ
		Stem	No	-	Fusiform	Brown	Glabrous	Unilocular	JQ
	Erythroxylum polygonoides Mart.	Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	PO
		Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	PO
	Erythroxylum sp.	Leaf	No	Abaxial	Globoid	Brown	Glabrous	Unilocular	PO
Euphorbiaceae	*Actinostemon concolor* (Spreng.) Müll.Arg.	Leaf	No	Abaxial	Fusiform	Brown	Glabrous	Unilocular	JQ
	Actinostemon klotzschii Pax	Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	VC
	Actinostemon sp.1	Leaf	No	Abaxial	Fusiform	Green	Glabrous	Unilocular	JQ
		Leaf	No	Abaxial	Fusiform	Brown	Glabrous	Unilocular	JQ
		Leaf	Yes	Abaxial	Globoid	Brown	Pubescent	Unilocular	PO
		Leaf	No	Abaxial	Globoid	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Conic	Brown	Glabrous	Unilocular	PO
		Leaf	No	Adaxial	Fusiform	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Fusiform	Green	Glabrous	Unilocular	BN-JQ
		Leaf	No	Adaxial	Leaf fold	Brown	Glabrous	Unilocular	JQ
		Leaf	No	-	Fusiform	Green	Glabrous	Unilocular	JQ
		Leaf	No	-	Fusiform	Brown	Glabrous	Unilocular	JQ
		Stem	No	-	Globoid	Brown	Glabrous	Unilocular	BN
	Maprounea sp.	Leaf	No	Abaxial	Cylindrical	Black	Glabrous	Unilocular	JQ
Fabaceae	*Machaerium* sp.	Leaf	No	Adaxial	Clavate	Green	Glabrous	Unilocular	JQ
Malpighiaceae		Leaf	No	Abaxial	Amorphous	Brown	Glabrous	Unilocular	VC
		Leaf	Yes	Abaxial	Conic	Green	Glabrous	Unilocular	BN-VC
		Leaf	No	Abaxial	Conic	Black	Pubescent	Unilocular	BN
		Leaf	No	Abaxial	Conic	Black	Glabrous	Unilocular	BN
		Leaf	No	Abaxial	Conic	Brown	Glabrous	Unilocular	VC
		Leaf	No	Abaxial	Cylindrical	Brown	Glabrous	Multilocular	VC
		Leaf	No	Abaxial	Cylindrical	Brown	Glabrous	Unilocular	BN-VC
		Leaf	No	Abaxial	Cylindrical	Brown	Glabrous	Multilocular	VC
		Leaf	No	Abaxial	Cylindrical	Black	Glabrous	Multilocular	BN
		Leaf	No	Abaxial	Cylindrical	Black	Glabrous	Unilocular	BN
		Leaf	No	Abaxial	Leaf fold	Green	Glabrous	Unilocular	BN

to be continued...

Table 3. Continue...

Family	Specie	Organ	Grouped	Foliar surface	Morphotype	Color	Trichome	Chambers	Site
Malpighiaceae		Leaf	No	Abaxial	Globoid	Yellow	Pubescent	Unilocular	BN-VC
		Leaf	No	Abaxial	Globoid	Yellow	Pubescent	Multilocular	BN-VC
		Leaf	No	Abaxial	Globoid	Yellow	Pubescent	Multilocular	BN
		Leaf	No	Adaxial	Globoid	Yellow	Pubescent	Multilocular	VC
		Leaf	No	Abaxial	Globoid	Yellow	Pubescent	Multilocular	VC
		Leaf	No	Abaxial	Globoid	Brown	Glabrous	Multilocular	VC
		Leaf	No	Abaxial	Globoid	Brown	Pubescent	Multilocular	BN
		Leaf	No	Abaxial	Fusiform	Brown	Glabrous	Unilocular	BN-VC
		Leaf	No	Abaxial	Fusiform	Green	Glabrous	Unilocular	VC
		Leaf	No	Abaxial	Lenticular Intralaminate	Brown	Glabrous	Unilocular	BN-VC
		Leaf	Yes	Abaxial	Lenticular Intralaminate	Brown	Glabrous	Multilocular	VC
		Leaf	No	Abaxial	Lenticular Intralaminate	Brown	Glabrous	Multilocular	VC
		Leaf	No	Adaxial	Amorphous	Green	Glabrous	Unilocular	VC
		Leaf	No	Adaxial	Conic	Green	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Cylindrical	Brown	Glabrous	Unilocular	BN-VC
		Leaf	Yes	Adaxial	Cylindrical	Brown	Glabrous	Multilocular	VC
		Leaf	No	Adaxial	Cylindrical	Brown	Glabrous	Multilocular	VC
Myrtaceae	*Eugenia* sp.1	Leaf	No	Adaxial	Lenticular Intralaminate	Brown	Glabrous	Unilocular	BN
	Eugenia sp.2	Leaf	No	Abaxial	Conic	Green	Glabrous	Unilocular	VC
		Leaf	Yes	Adaxial	Conic	Green	Glabrous	Unilocular	VC
		Leaf	No	Abaxial	Leaf fold	Green	Glabrous	Unilocular	VC
	Myrcia sp.1	Leaf	No	Abaxial	Amorphous	Peach	Glabrous	Unilocular	VC
		Leaf	No	Abaxial	Leaf fold	Green	Glabrous	Unilocular	VC
		Leaf	No	Abaxial	Fusiform	Brown	Pubescent	Unilocular	VC
		Leaf	Yes	Abaxial	Fusiform	Brown	Glabrous	Unilocular	VC
		Leaf	Yes	Adaxial	Globoid	Brown	Glabrous	Unilocular	VC
		Leaf	No	Both	Cylindrical	Black	Glabrous	Unilocular	VC
		Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	VC
		Stem	No	-	Globoid	Brown	Glabrous	Multilocular	VC
	Myrcia sp.2	Leaf	No	Adaxial	Amorphous	Green	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Amorphous	Green	Glabrous	Unilocular	JQ
	Myrcia sp.3	Leaf	No	Abaxial	Leaf fold	Green	Glabrous	Unilocular	VC
	Myrcia sp.4	Leaf	Yes	Abaxial	Conic	Brown	Glabrous	Unilocular	VC
		Leaf	No	Abaxial	Globoid	Yellow	Pubescent	Unilocular	VC
		Leaf	No	Abaxial	Globoid	Red	Pubescent	Unilocular	VC
		Leaf	Yes	Abaxial	Globoid	Brown	Pubescent	Unilocular	VC
		Leaf	Yes	Adaxial	Globoid	Grey	Glabrous	Unilocular	VC
		Leaf	No	Both	Cylindrical	Black	Glabrous	Unilocular	VC
	Myrcia sp.5	Leaf	No	Adaxial	Lenticular Intralaminate	Brown	Glabrous	Multilocular	BN
		Leaf	No	Adaxial	Lenticular Intralaminate	Brown	Glabrous	Unilocular	BN
		Leaf	Yes	Abaxial	Globoid	Red	Pubescent	Unilocular	PO
	Myrcia sp.6	Stem	No	-	Fusiform	Grey	Glabrous	Multilocular	PO
		Leaf	No	Abaxial	Conic	Brown	Glabrous	Unilocular	PO
	Myrcia sp.7	Leaf	No	Both	Globoid	Brown	Glabrous	Unilocular	PO
	Myrcia sp.8	Leaf	Yes	Abaxial	Globoid	Black	Glabrous	Unilocular	PO
		Leaf	No	Abaxial	Globoid	Black	Pubescent	Unilocular	PO
		Leaf	No	Abaxial	Globoid	Black	Pubescent	Unilocular	PO
		Leaf	Yes	Abaxial	Conic	Black	Glabrous	Unilocular	PO
		Leaf	Yes	Adaxial	Globoid	Black	Pubescent	Unilocular	PO

to be continued...

Table 3. Continue...

Family	Specie	Organ	Grouped	Foliar surface	Morphotype	Color	Trichome	Chambers	Site
		Leaf	Yes	Abaxial	Lenticular Iintralaminate	Brown	Glabrous	Unilocular	PO
	Myrtaceae sp.1	Leaf	No	Abaxial	Globoid	Yellow	Glabrous	Unilocular	JQ
		Leaf	Yes	Adaxial	Conic	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Fusiform	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	JQ
		Leaf	No	-	Fusiform	Green	Glabrous	Unilocular	JQ
		Stem	No	-	Fusiform	Brown	Glabrous	Unilocular	JQ
	Myrtaceae sp.2	Leaf	No	Adaxial	Conic	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Both	Fusiform	Black	Glabrous	Unilocular	JQ
	Myrtaceae sp.3	Leaf	Yes	Adaxial	Globoid	Brown	Pubescent	Unilocular	JQ
	Myrtaceae sp.4	Leaf	No	Abaxial	Globoid	Brown	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Fusiform	Green	Glabrous	Unilocular	JQ
	Myrtaceae sp.5	Stem	Yes	-	Globoid	Brown	Glabrous	Multilocular	JQ
	Myrtaceae sp.6	Leaf	No	Adaxial	Amorphous	Green	Glabrous	Unilocular	JQ
	Myrtaceae sp.7	Leaf	No	Abaxial	Amorphous	Green	Glabrous	Unilocular	VC
	Myrtaceae sp.8	Leaf	Yes	Abaxial	Globoid	Black	Glabrous	Unilocular	PO
Myrtaceae		Leaf	No	Abaxial	Cylindrical	Black	Glabrous	Unilocular	PO
	Myrtaceae sp.9	Leaf	Yes	Adaxial	Lenticular Intralaminate	Brown	Glabrous	Multilocular	JQ
	Myrtaceae sp.10	Leaf	No	Adaxial	Amorphous	Green	Glabrous	Unilocular	JQ
		Stem	Yes	-	Globoid	Brown	Glabrous	Multilocular	JQ
		Stem	No	-	Fusiform	Brown	Glabrous	Unilocular	JQ
	Myrtaceae sp.11	Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	JQ
		Leaf	No	Adaxial	Lenticular Intralaminate	Brown	Glabrous	Multilocular	JQ
	Myrtaceae sp.12	Leaf	No	Abaxial	Globoid	Brown	Glabrous	Multilocular	JQ
		Leaf	No	Abaxial	Globoid	Black	Glabrous	Multilocular	JQ
	Myrtaceae sp.13	Leaf	Yes	Adaxial	Lenticular Intralaminate	Brown	Glabrous	Unilocular	
	Myrtaceae sp.14	Leaf	No	Adaxial	Clavate	Red	Pubescent	Unilocular	VC
	Myrtaceae sp.15	Leaf	No	Abaxial	Lenticular Intralaminate	Brown	Glabrous	Unilocular	VC
	Myrtaceae sp.16	Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	JQ
	Psidium brownianum Mart. ex DC	Leaf	Yes	Abaxial	Globoid	Red	Pubescent	Unilocular	PO
		Leaf	No	Abaxial	Globoid	Black	Glabrous	Unilocular	PO
Nyctaginaceae	*Guapira graciliflora* (Mart. ex Schmidt) Lundell	Leaf	Yes	Adaxial	Lenticular Intralaminate	Black	Glabrous	Unilocular	PO
		Stem	No	-	Globoid	Brown	Glabrous	Unilocular	PO
Phyllantaceae	*Savia* sp.	Leaf	Yes	Abaxial	Clavate	Green	Glabrous	Unilocular	JQ
		Leaf	Yes	Abaxial	Amorphous	Green	Glabrous	Unilocular	PO
Rubiaceae	*Psychotria* sp.	Stem	No	-	Fusiform	Grey	Glabrous	Unilocular	PO
	Metrodorea maracasana Kaastra	Leaf	No	Abaxial	Amorphous	Green	Glabrous	Unilocular	BN
		Leaf	No	Abaxial	Leaf fold	Green	Glabrous	Unilocular	PO
		Leaf	Yes	Abaxial	Conic	Green	Glabrous	Unilocular	BN
		Leaf	No	Abaxial	Leaf fold	Green	Glabrous	Unilocular	BN
		Leaf	No	Abaxial	Fusiform	Green	Glabrous	Unilocular	VC
Rutaceae		Leaf	Yes	Abaxial	Lenticular Intralaminate	Yellow	Glabrous	Unilocular	BN-PO
		Leaf	No	Abaxial	Lenticular Intralaminate	Green	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Amorphous	Yellow	Glabrous	Unilocular	VC
		Leaf	No	Adaxial	Cylindrical	Green	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Clavate	Brown	Glabrous	Unilocular	PO

to be continued...

Table 3. Continue...

Family	Specie	Organ	Grouped	Foliar surface	Morphotype	Color	Trichome	Chambers	Site
Rutaceae		Leaf	No	Adaxial	Clavate	Green	Glabrous	Unilocular	PO
		Leaf	No	Adaxial	Conic	Green	Glabrous	Unilocular	BN-VC
		Leaf	Yes	Adaxial	Leaf fold	Green	Glabrous	Unilocular	BN-PO-VC
		Leaf	Yes	Adaxial	Lenticular Intralaminate	Green	Glabrous	Unilocular	VC
		Leaf	Yes	Adaxial	Lenticular Intralaminate	Yellow	Glabrous	Unilocular	PO-VC
		Leaf	Yes	Adaxial	Lenticular Intralaminate	Green	Glabrous	Unilocular	PO
		Leaf	Yes	Both	Conic	Green	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Leaf fold	Green	Glabrous	Unilocular	BN-VC
		Leaf	No	-	Fusiform	Green	Glabrous	Unilocular	PO
		Stem	No	-	Fusiform	Brown	Glabrous	Unilocular	BN
		Stem	Yes	-	Globoid	White	Glabrous	Unilocular	BN
	Pilocarpus spicatus A.St.-Hil.	Leaf	No	-	Globoid	Brown	Glabrous	Multilocular	BN
		Leaf	No	Abaxial	Conic	Green	Glabrous	Unilocular	VC
		Stem	No	Abaxial	Fusiform	Green	Glabrous	Unilocular	BN
Smilacaceae	Smilacaceae sp.	Leaf	No	Adaxial	Globoid	Brown	Glabrous	Unilocular	BN
		Leaf	No	Adaxial	Fusiform	Brown	Glabrous	Unilocular	BN

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