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Contribution to the knowledge of the Rubiaceae of the Lesser Antilles: Martinique's case.

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ABSTRACT

The Rubiaceae represent one of the world's five largest families of flowering plants. This family is diversified in terms of number of species, genera, physiognomic types or chemical spectra. Within their flora the Lesser Antilles (part of one of the world's biodiversity hot spots) accommodate part of this diversity, originating from tropical America. In order to enrich our knowledge of the Rubiaceae of the West Indies, we carried out a study in forest ecology in Martinique. The aim was to determine the chorology of the Rubiaceae species and their functions as well as to identify their various ethnobotanical uses. The place of the Rubiaceae in Martinique's plant dynamics, the factorial conditions that favour their settlement and distribution have thus been defined using data from the world scientific literature, regional floras and field surveys. It is clear that this family occupies a wide range of habitats. The Rubiaceae are present in all bioclimates (dry to wet), in various plant formations at various stages of evolution. We recorded 89 Rubiaceae species divided in 41 genera. All forms of life are represented ranging from trees to grasses, through lianas and epiphytes. The Rubiaceae are an essential component of our region's flora; nevertheless their diversity is weakened by a strong degree of anthropisation characterised by environmental damage.

Keywords

Lesser Antilles, Martinique, Rubiaceae, chorology, ecology.

Academic Discipline

Ecology, Botany, Biogeography, Natural Geography.

SUBJECT CLASSIFICATION

Ecology

TYPE (METHOD/APPROACH)

Experimental

INTRODUCTION

The Rubiaceae represent one of the largest families of flowering plants (angiosperms) in the world. There are currently approximately 611 genera and more than 13,100 species of Rubiaceae in the world [1-4]. On a global scale as well as on the scale of tropical America, the Rubiaceae rank in fourth position after the Orchidaceae, Asteraceae, Fabaceae and Poaceae (Tables 1 and 2), [3, 5-7].

On average since the 1970s, more than sixty species have been discovered and circa four genera are described each year [4]. A worldwide list of all Rubiaceae known to date can be consulted on the Internet and is updated regularly [3]. The result is an important and constant work in terms of taxonomic classification [8-10].

Table 1: Ranking of the five largest families of angiosperms in the world [4].

Rank	Family	Number of species	Number of genera
1	Orchidaceae	25158	830
2	Asteraceae	>23000	1535-1700
3	Fabaceae	19350	727
4	Rubiaceae	13143	611
5	Poaceae	11591	700

Table 2: Ranking of the five largest families of angiosperms in tropical America [7].

Rank	Family	Number of species
1	Asteraceae	8000
2	Orchidaceae	7000

3	Fabaceae	6700
4	Rubiaceae	5000
5	Poaceae	3300

The Rubiaceae are cosmopolitan. There are some representatives in Antarctica: the *Coprosma, Galium, Nertera and Sherardia* genera. In temperate regions it is the genus Rubieae which is the most distributed [11-13]. Most of these species are nevertheless located in tropical and subtropical regions. There are many "hot spots" in Central America, South America and the Caribbean: more than half of the species and one third of the family's genera [4,7,11].

The Rubiaceae occupy a wide range of habitats. They are found in dry regions, in the mangrove forests in the coastal area and even in alpine locations at over 4000 meters [4,7,13]. They are predominantly found in tropical wet forests with high tree abundance [4]. In the tropics, the Rubiaceae are highly susceptible to environmental disturbances and are rarely found in secondary forests [4]. In South America the Rubiaceae are found in the Amazon basin, in the tropical forests of Brazil, in the Andean cloud forests, in the thorny plant forests of desert biomes, in the subtropical savannahs situated at high altitudes, in the sandy and salty lands close to the sea and covered with herbaceous plants [7].

The Rubiaceae family has a variety of biological forms: some are trees forming part of the canopy of tropical forests (*Chimarrhis)*, others are shrubs, epiphytes, myrmecophytes, annual or perennial grasses, lianas, succulents, and even aquatic life forms [4,11,14]. Table 3 presents the botanical determination keys to recognize the members of the family [1,4,7,11,15,16].

The chemical spectrum of the Rubiaceae is remarkable. They are the source of thousands of bioactive substances with promising pharmacological potential [17-24]. They are also widely used in the world and are recognized numerous properties: anti-inflammatory, analgesic, antibacterial, antiviral, antioxidant ... [17, 25-32]. The current phylogenetic classification of the Rubiaceae[1] is presented in figure 1 [33.34].

Table 3: The main botanical characteristics of the Rubiaceae [1,4,7,11,15,16].

	RUBIACEAE
Leaves	Simple, whole, opposite, opposite decussated, sometimes whorled (3 to 6 leaves per knot) or pseudo-whorled. Leaf blade undivided and leaf margin always entire.
The stipules	Presence of interpetiolar or intrapetiolar stipules
Flowers	Actinomorphs and rarely zygomorphs. Gamopetal corollas. The number of stamens is often equal to the number of corolla lobes. The ovary is located lower.
The fruits	Capsules, berries, drupes or schizocarps.
Other characteristics	Presence of obturators, a Caspari band, and numerous alkaloids.

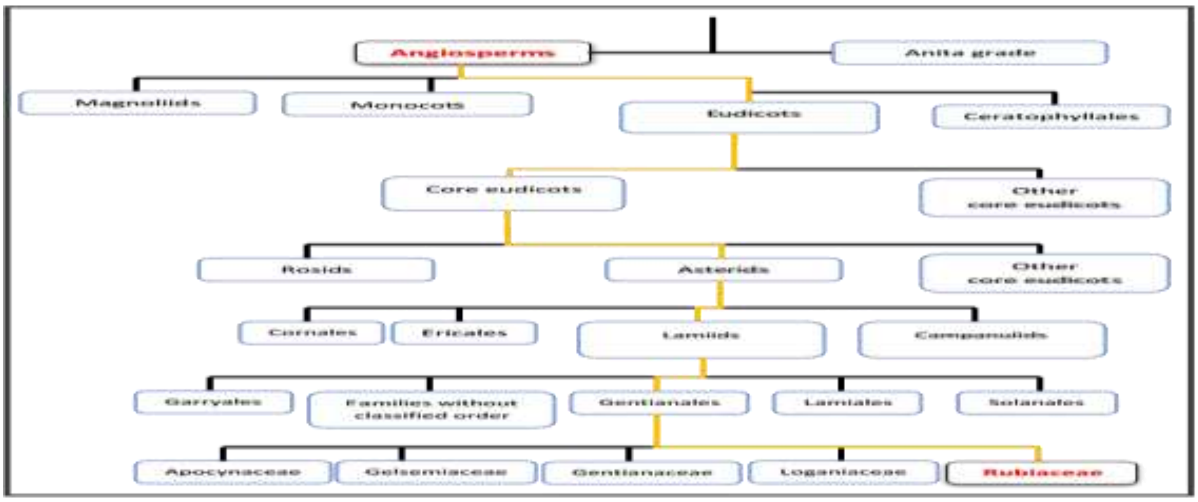

Figure 1: Classification of the Rubiaceae according to APG III [33].

[1] According to the 2009 Angiosperm Phylogeny Group (APG III) [33,34].

The Rubiaceae family consists of three subfamilies: Cinchonoideae, Ixoroideae, Rubioideae [1,2,12,17,35,36]. Some authors propose we retain only two subfamilies, the Cinchonoideae and Rubioideae and form super tribes [37], but this classification contains many genera with unresolved taxonomic positions [7]. Currently, the phylogenetic studies still recognize the existence of the three above mentioned subfamilies and recognize 44 tribes [2,7,12,17,38].

Several assumptions have been made about the origins and the diversification processes of the family, particularly for the tropical America taxa. In fact, there are biogeographic models which correlate their biological evolution with historical physical events [39.40]. Without establishing valid time frames for the divergence of the different family groups, the origin of the Rubiaceae is still unclear [13]. Whatever the flora of the Lesser Antilles, most of it originates from tropical America via the Greater Antilles, where there is strong taxonomic similarity at the level of the families. This fact is linked to the geological formation of the Lesser Antilles. The main dispersal vectors were the wind, water and bird fauna [41]. This flora was nevertheless enriched by African, European as well as Asian contributions.

Scientific research in the forest ecology in the Lesser Antilles and particularly in Martinique has progressed considerably since the twentieth century [41-55]. In fact, our knowledge on sylvatic ecosystems is not better established: in terms of distribution modes, architectures and structures, functioning, phases of evolution, floristic compositions, and ecological profiles of the species. Naturally over time there has been a growing and remarkable enrichment of scientific productions [41-55] resulting in studies which targeted the plant families in particular. We have several objectives in what regards the Rubiaceae in Martinique: to determine their chorologies, their functions and their biodemographic importance within the natural vegetation, and to identify their ethnobotanical uses.

MATERIALS

The study is carried out in Martinique: a French island territory located in the Caribbean (Figure 2). It is a mountainous island of 1128 km2 which occupies a central position in the Lesser Antilles at 14° 40' north latitude and 61° west longitude. This island lies between Dominica in the north and Sainte-Lucie in the south, and is surrounded to the east by the Atlantic Ocean and to the west by the Caribbean Sea.

Figure 2: Martinique's location in the Caribbean.

The Lesser Antilles including Martinique are the result of an intra-oceanic subduction between the North American plate and the Caribbean plate [56,57]. The various volcanic episodes that took place led to the formation of the island and the reliefs thus created were then remodeled by erosion.

Therefore the island's geomorphology is highly contrasted (Figure 3) with a mountainous northern part, composed of the most important and recent volcanic massifs (the Pelée Mountain: 1397 meters, the Pitons du Carbet 1196 m, the Jacob mountain: 800 m), and a less imposing southern part, consisting of hills which do not exceed 500 meters of altitude and the centre of the island characterised by the Lamentin and Riviére Salée plains. From a pedological point of view, Martinique has a remarkable diversity of soil types (Figure 4) [58].

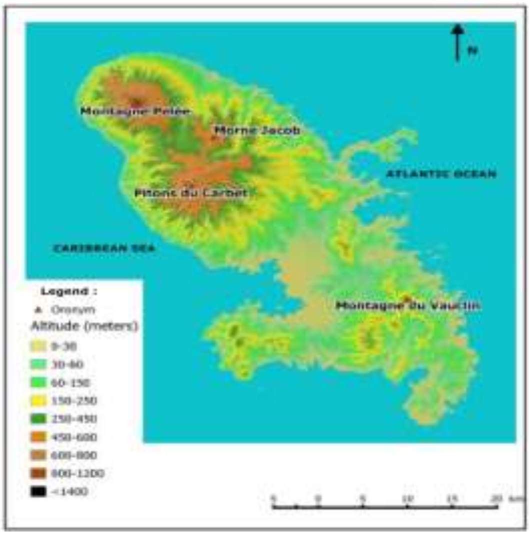

Figure 3: Hypsometric map of Martinique. (Source: IGN[2])

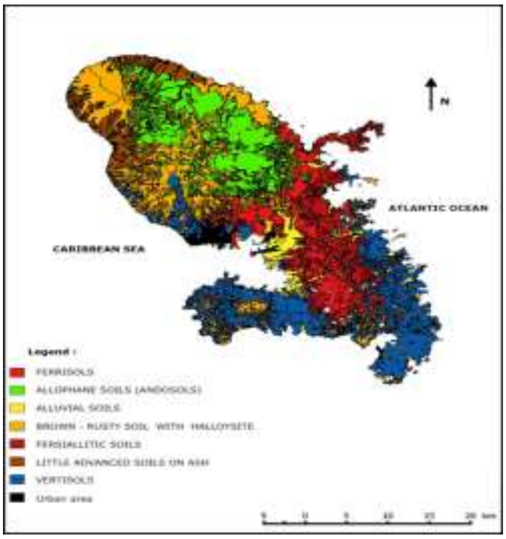

Figure 4: Soil map of Martinique. (Source: IRD[3])

The climate is a wet tropical one with an average annual temperature of 26°C. This island is regularly swept by eastern trade winds [59]. There are two main seasons: the dry season from February to March called "summer" and the rainy season from July to October called "winter". Shorter transition periods with less marked characteristics are added to these two seasons. The hydrological network is dense due to the very abrupt reliefs, in particular in the north (steep slopes and gullies), giving rise to a number of rivers with mainly torrential features.

Martinique is subjected to the same mass of air but its topography generates very contrasting orographic rainfall on the island, leading to the creation of various bioclimates (Figure 5). These various bioclimates result in the stratification of the plant formations [41,50,51].

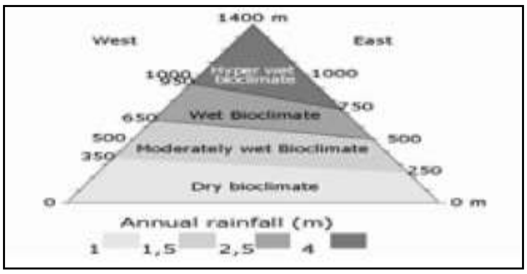

Figure 5: Bioclimatic floors of Martinique [51].

[2] IGN: National Geographic Institute (France).
[3] IRD: Institute for Development Research (France)

In his works JOSEPH P. (2009, 2012) [41,51], described the altitudinal floors of the bioclimates and the associated plant formations (Figure 6). We therefore generally distinguish in ascending order: from 0 to 250 m, a dry bioclimate with annual average rainfall of less than 1500 mm, which is associated with a tropical seasonal evergreen forest of lower horizon and xeric facies (formerly a xerophytic forest); from 250 to 500 m, a moderately humid bioclimate with annual rainfall ranging between 1500 and 2500 mm, associated with a typical tropical seasonal evergreen forest (formerly a mesophilic forest). Then, from 500 to 1300 m, a wet bioclimate with rainfall ranging between 2500 and 4000 mm or more, which is associated with a tropical sub-montane ombrophilous rainforest (formerly a hygrophilous forest) and a tropical montane ombrophilous forest (formerly known as the upper horizon of the hygrophilous forest).

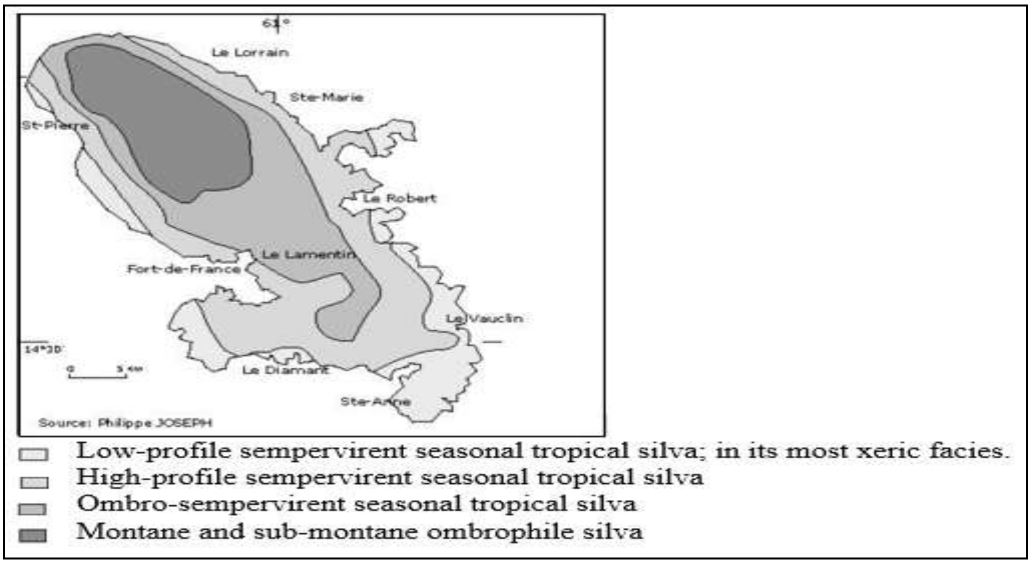

Figure 6: Martinique's vegetation cover in pre-Columbian times [49].

There are a little more than 3000 plant species on the island (pteridophytes, gymnosperms, angiosperms ...) of which circa 1000 are introduced [50]. The present vegetation is a mosaic of various plant formations belonging to very different phases of evolution [41,51]. This phytocenotic diversity[4] is the result of the natural components structuring the island but also of a strong anthropization since the island was taken into possession in 1635 [41].

METHODS

Research in the global scientific literature has been conducted to collect global data on the Rubiaceae such as their botanical descriptions, phylogenetic classifications, geographical distributions, ecologies, and ethnobotanical uses. An additional review has been carried out in the works on the Lesser Antilles flora [60,61] and in international floristic databases [3].

These bibliographic data have been supplemented by field surveys. The surveys were carried out in Martinique in different forest formations corresponding to various bioclimates and different stages of evolution. The surveyed stations were chosen taking into account the floristic units located in a similar climatic context. Each survey consists of a transect subdivided into quadrats (Figure 7). The total areas are variable according to the minimal areas. The length of the transects varies but the quadrats are all the same size [62].

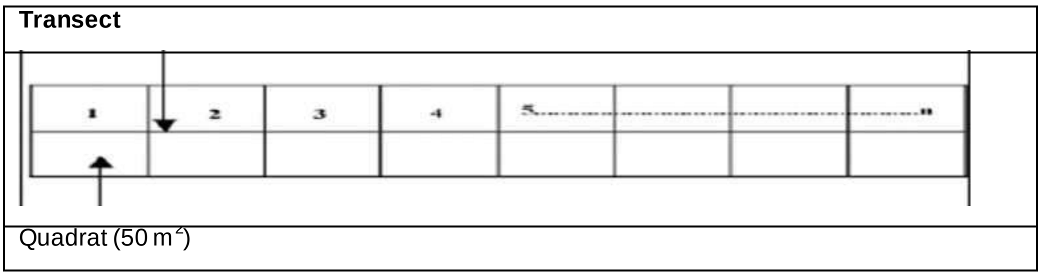

Figure 7: Illustration of the transect [63].

For each survey we record a number of ecological and floristic descriptors. These include the name of the species, the number of individuals from regenerations to mature specimens (biodemographic aspect), diameters (sections measured at 1.33 m from the ground in accordance with the international standards), total heights and the height of the first ramifications [62].

These descriptors allow us to characterize the surveyed forest formations in terms of architecture, structure, and floristic compositions. The very heterogeneous mesological factors combined with the relations between species lead to the

[4] Plant community

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emergence of a grouping of species or the so-called "species population" known as dominant within the stations in terms of number of individuals, distribution in the station and occupied land areas [41,53]. This population is highlighted using indicators already defined and used in forest ecology such as frequency (presence of the species in the different quadrats), density (corresponding to the distribution of species populations in the station), distribution index (corresponding to the density multiplied by the relative frequency and expressing the biodemographic importance of the species) and the index of dominance (corresponding to the distribution index multiplied by the basal area expressing the species' adaptation and expansion capacity within the environment) [53,63].

Therefore the stations surveyed and presented here are located on Figure 8 and described in Table 4. For each bioclimate (from dry to wet) we present two stations that have been surveyed[5]. For all of these stations (4700 m²) we counted 3625 individuals.

Figure 8: Location of the surveyed stations.

The two dry bioclimate stations are composed of plant formations of the xerophytic type in the young secondary forest stage and in the shrub stage (Vauclin, Figure 8, Table 4). Two other stations located in zones normally covered by the dry bioclimate however exhibit a meso-climate of the moderately wet type (Diamant and Marin, Figure 8, Table 4). This is linked to the topography of the site (the bottom of valleys) favouring a flora of mesophilic type. This represents a vegetation inversion phenomenon [41]. These two stations are in the young secondary forest stage. The other two stations influenced by the wet bioclimate in the north of the island (Lorrain, Figure 8) consist of plant forms of hygrophilous type, in the late secondary forest stage (Table 4).

The area-species curve correlates the number of new recorded species in relation to the surveyed surface. At the point of inflection, this curve allows us to estimate the minimal surface area. For Station 1 (Figure 9 (a)), the minimum area required for statistical processing is 600 m². Figure 9 (b), indicates that for station 2 the minimal area would also be 600 m²; however after a slight shift the increase in the number of cumulative species indicates the change to another biocenosis[6]. The minimal area for station 3 is 650m² (Figure 9 (c)), nevertheless the fluctuations in the curve reveal environment disturbances. Station 4 is composed of two biocenoses, the first's limit surface area is 300m² (Figure 9 (d)). Figure 9 (e) shows that the surveyed surface of station 5 corresponds to one part of a biocenosis because it has no inflection. FIG. 9 (f) (station 6) is characteristic of the survey of two contiguous biocenoses: the first having a 600m² area.

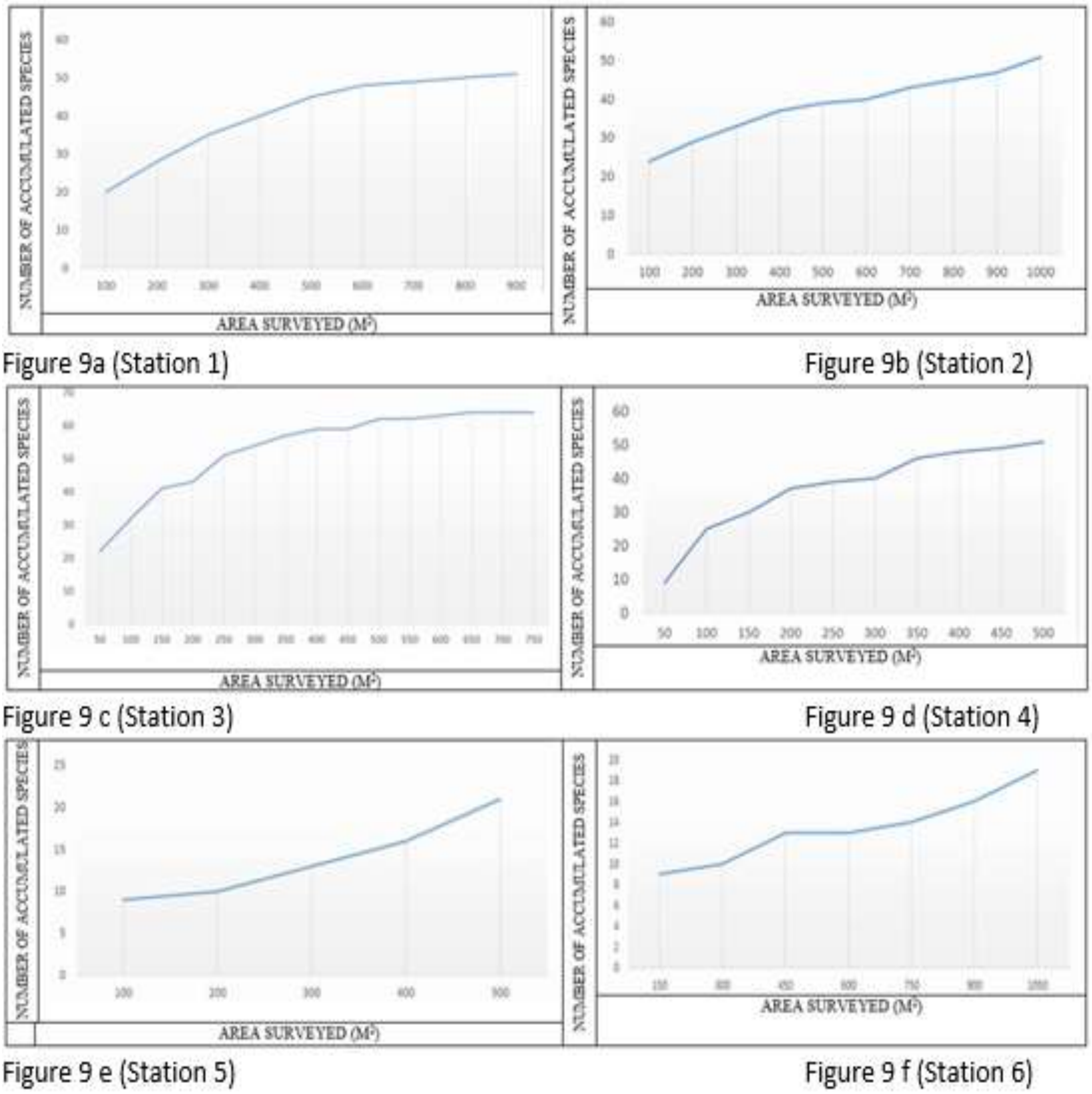
[5] The floristic surveys of the two stations in a medium wet environment were produced and kindly made available by Professor JOSEPH P. (University of the French West Indies, Martinique, France). Thanks to the Bioreca team for data collection in the field: Kévine Baillard, Séverine Ely-Marius, Yelji Abati, Yanis Jean-François.

[6] Plant community

Table 4: Presentation of the surveyed stations.

	Place	Municipality	Bioclimate	Soil type	Dynamic stage	Area (m^2)	Number of families	Number of genera	Number of species	Number of individuals	Density
Station 1	Morne Carrière	Vauclin	dry (1500 mm annual precipitation)	vertisols	early secondary sylvan formation	900	34	48	51	1033	1.15
Station 2	Morne Carrière	Vauclin	dry (1500 mm annual precipitation)	vertisols	shrubby stage	1000	33	45	51	1256	1.26
Station 3	Morne Aca	Marin	moderately humid (1700 mm annual precipitation)	haplic nitisols	early secondary sylvan formation	750	34	53	63	591	0.79
Station 4	Gardier	Diamant	moderately humid (1700 mm annual precipitation)	haplic nitisols	early secondary sylvan formation	500	30	45	52	523	1.05
Station 5	Forêt domaniale de Reculée	Sainte-Marie	humid (3000 mm annual precipitation)	andosols	late secondary sylvan formation	500	20	20	21	58	0.12
Station 6	Forêt domaniale de Reculée	Sainte-Marie	humid (3000 mm annual precipitation)	andosols	late secondary sylvan formation	1050	14	16	19	164	0.16

Figure 9 a, b, c, d, e, f:



Area-species curve by station.

RESULTS

1. Presentation of the Rubiaceae of Lesser Antilles and Martinique

The list of all the Rubiaceae described in the Antilles and Martinique was compiled using the most recent flora [60-61]. The main genera and number of species are presented in Table 5. According to these flores, some twenty plant species are endemic to the Lesser Antilles islands, including two in Martinique: Rondeletia martinicensis and Palicourea martinicensis.

Table 5: Total number of Rubiaceae recorded in the Caribbean and Martinique [60-61].

Rubiaceae recorded in the West Indies				Rubiaceae recorded in Martinique			
Genera	Number of species	Genera	Number of species	Genera	Number of species	Genera	Number of species
Alibertia	1	Macrocnemum	1	Alibertia	1	Leptactina	1
Antirhea	3	Malanea	1	Antirhea	1	Machaonia	1
Catesbaea	1	Manettia	1	Chimarrhis	1	Manettia	1
Chimarrhis	1	Mitracarpus	2	Chiococca	1	Mitracarpus	1
Chiococca	2	Morinda	1	Chione	1	Morinda	1
Chione	1	Mussaenda	7	Coffea	3	Mussaenda	2
Chomelia	1	Neolamarckia	1	Coutarea	1	Neolamarckia	1
Coffea	3	Neolaugeria	1	Diodia	3	Neolaugeria	1
Coutarea	1	Oxyanthus	1	Erithalis	3	Palicourea	2
Diodia	3	Palicourea	3	Exostema	2	Pentas	1
Erithalis	3	Pentas	1	Faramea	1	Portlandia	1
Ernodea	1	Pentodon	1	Gardenia	2	Posoqueria	2
Exostema	2	Portlandia	1	Genipa	1	Psychotria	13
Faramea	1	Posoqueria	2	Geophila	1	Randia	4
Gardenia	2	Psychotria	16	Gonzalagunia	1	Rondeletia	3
Genipa	1	Randia	4	Guettarda	3	Rudgea	1
Geophila	1	Relbunium	1	Hamelia	2	Schradera	1
Gonzalagunia	1	Rondeletia	6	Hedyotis	2	Spermacoce	6
Guettarda	3	Rudgea	3	Hillia	1	Thogsennia	1
Hamelia	2	Sabicea	1	Hoffmannia	1	Vangueria	1
Hedyotis	3	Schradera	1	Ixora	12		
Hillia	1	Serissa	1				
Hoffmannia	2	Sipanea	1				
Isertia	1	Spermacoce	13				
Ixora	12	Strumpfia	1				
Leptactina	1	Thogsennia	1				
Machaonia	1	Vangueria	1				

Total	Lesser Antilles			Martinique		
	Genera	Species	Endemic species in these islands	Genera	Species	Endemic species
	54	129	20	41	89	2

2. Land surveys carried out in Martinique

The surveyed stations are located on Figure 8 and described in Table 4. We present two surveyed stations for each bioclimate. These floristic surveys indicate the Rubiaceae family's position in terms of biodiversity (number of species and individuals) in the vegetal mosaic of Martinique (Tables 6 and 7).

Table 6: Top 10 families ranked by number of species per station.

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
Rang	Family	No. of species	Family	No. of species	Family	No. of species	Family	No. of species	Family	No. of species	Family	No. of species
1	Rubiaceae	6	Capparaceae	4	Myrtaceae	8	Myrtaceae	10	Cyatheaceae	2	Sapotaceae	3
2	Verbenaceae	2	Euphorbiaceae	4	Rubiaceae	7	Rubiaceae	4	Rubiaceae	1	Meliaceae	2
3	Sapindaceae	3	Mimosaceae	4	Lauraceae	4	Sapotaceae	3	Meliaceae	1	Arecaceae	2
4	Mimosaceae	3	Boraginaceae	3	Mimosaceae	3	Polygonaceae	3	Elaocarpaceae	1	Lauraceae	2
5	Rutaceae	2	Nyctaginaceae	2	Malpighiaceae	2	Moraceae	3	Burseraceae	1	Rubiaceae	1
6	Nyctaginaceae	2	Verbenaceae	2	Polygonaceae	2	Mimosaceae	2	Dichapetalaceae	1	Dichapetalaceae	1
7	Piperaceae	2	Apocynaceae	2	Sapindaceae	2	Sapindaceae	2	Clusiaceae	1	Elaocarpaceae	1
8	Boraginaceae	2	Sapindaceae	2	Meliaceae	2	Lauraceae	2	Simaroubaceae	1	Burseraceae	1
9	Capparaceae	2	Fabaceae	2	Poaceae	2	Rutaceae	2	Annonaceae	1	Myrtaceae	1
10	Euphorbiaceae	2	Rutaceae	2	Fabaceae	2	Boraginaceae	1	Araceae	1	Solanaceae	1

No. of species: Number of species

Table 7: Top 10 families ranked by number of individuals per station

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
Rang	Family	No. of ind.	Family	No. of ind.	Family	No. of ind.	Family	No. of ind.	Family	No. of ind.	Family	No. of ind.
1	Rutaceae	189	Capparaceae	292	Myrtaceae	165	Myrtaceae	199	Rubiaceae	13	Sapotaceae	73
2	Verbenaceae	149	Nyctaginaceae	284	Lauraceae	96	Sapotaceae	47	Cyatheaceae	7	Rubiaceae	20
3	Apocynaceae	119	Acanthaceae	164	Rhizophoraceae	61	Rubiaceae	35	Meliaceae	7	Meliaceae	17
4	Sapindaceae	101	Euphorbiaceae	147	Polygonaceae	27	Rutaceae	34	Elaocarpaceae	6	Dichapetalaceae	12
5	Simaroubaceae	76	Lauraceae	64	Mimosaceae	26	Euphorbiaceae	27	Burseraceae	5	Elaocarpaceae	11
6	Rubiaceae	72	Mimosaceae	51	Rubiaceae	24	Lauraceae	24	Dichapetalaceae	4	Arecaceae	9
7	Nyctaginaceae	70	Boraginaceae	45	Meliaceae	19	Polygonaceae	22	Clusiaceae	2	Lauraceae	8
8	Piperaceae	40	Erythroxylaceae	37	Simaroubaceae	19	Meliaceae	17	Simaroubaceae	2	Burseraceae	5
9	Mimosaceae	33	Verbenaceae	24	Nyctaginaceae	17	Nyctaginaceae	17	Annonaceae	1	Myrtaceae	3
10	Boraginaceae	30	Bignoniaceae	23	Poaceae	16	Oleaceae	16	Araceae	1	Solanaceae	2

No. of ind. : Number of individuals

The architecture and structure of the surveyed stations are defined based on the diameters of the living trees, (Figures 10, 12 and 14) and the total heights (Figures 11, 13 and 15) [62]. The dominant species population for each station (in terms of number of individuals, their distributions and occupied land areas) is presented in Tables 8, 9, 10.

a. Architecture and structure of the dry bioclimate stations 1 and 2

Station 1 is in the secondary young forest stage: 60% of the trees have small diameters of 2.5 cm, 2% have diameters exceeding 20 cm and the majority of the trees do not exceed 15 meters in height (Figures 10 (a) and 11 (a)). Three species form the dominant species population for station 1: Citharexylum spinosum (Verbenaceae), Simarouba amara (Simaroubaceae) and Tabernaemontana citrifolia (Apocynaceae). Citharexylum spinosum is the most preponderant in terms of number of individuals (distribution index) and epigeal biomass (basal area), (Table 8 (a)).

Station 2 is in the shrub stage: 95% of the trees have small diameters (2.5 to 5 cm) and the majority of the trees range between 1 and 8 meters in height (Figures 10 (b) and 11 (b)). Pisonia fragrans (Nyctaginaceae), Croton corylifolius (Euphorbiaceae) and Morisonia americana (Capparaceae) are the dominant species (Table 8 (b)).

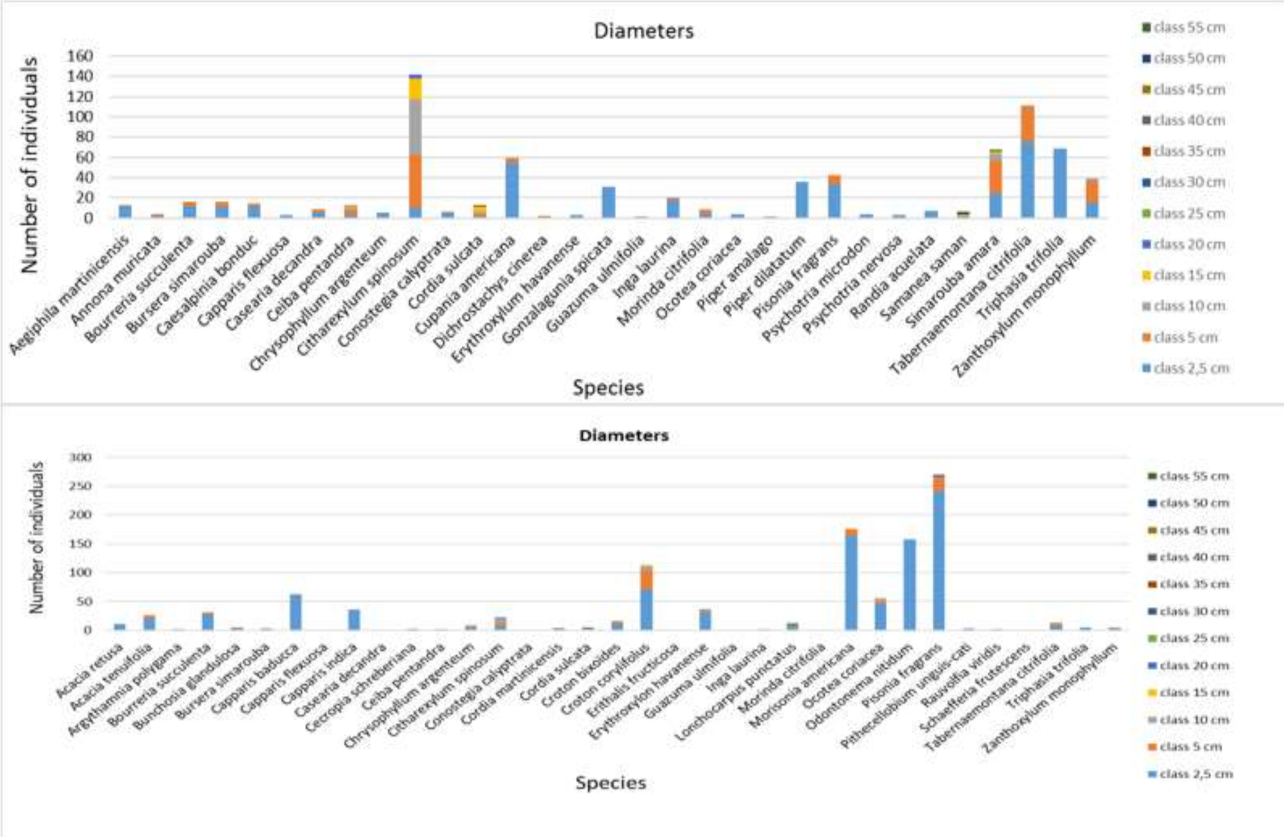


Figure 10: Distribution of live tree diameter classes: station 1 (a), station 2 (b).

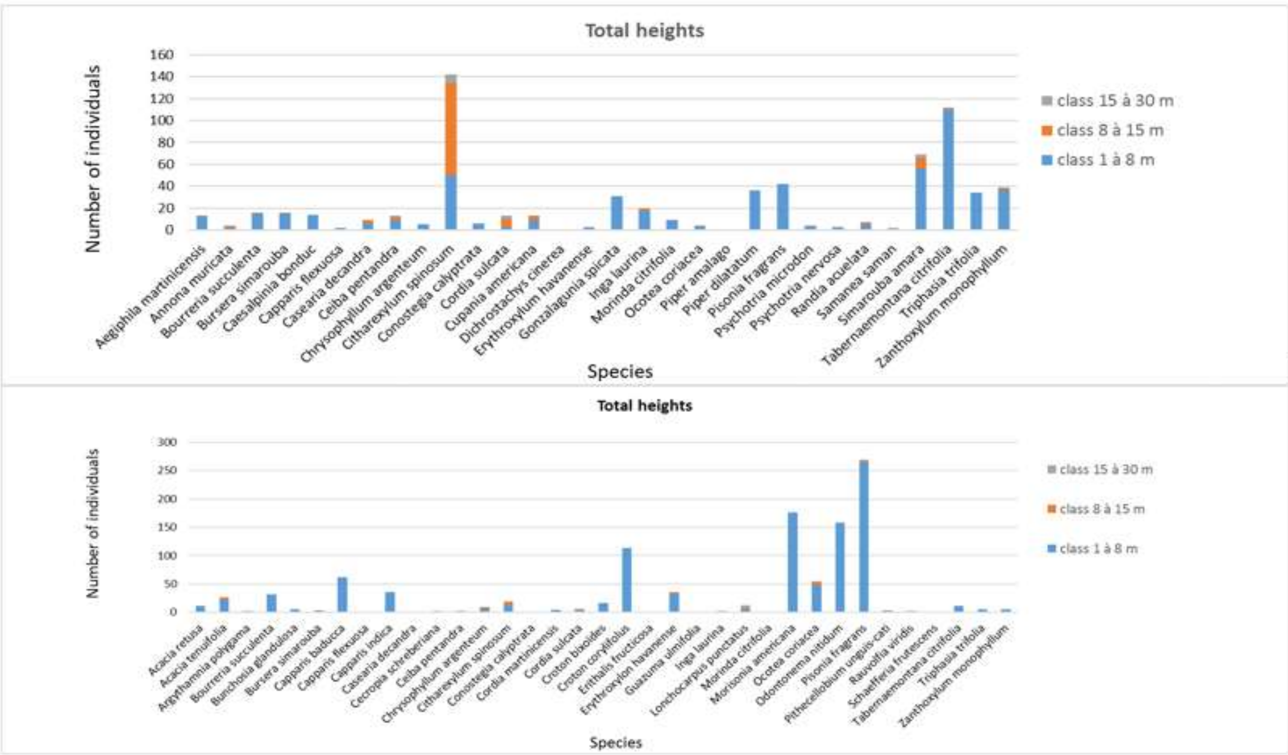


Figure 11: Distribution of height classes: station 1 (a), station 2 (b).

Table 8: Ranking of the top ten species per dominance indices for station 1 (a) and station 2 (b).

Family	Species	Absolute frequency	Relative frequency (%)	Number of individuals (without regeneration and dead trees)	Density (without regeneration and dead trees)	Distribution index	Land area per species (m²)	Dominance index
Verbenaceae	Citharexylum spinosum	9	100	121	0.134444444	0.13444444	1.33303667	0.179219374
Simaroubaceae	Simarouba amara	9	100	71	0.078888889	0.07888889	0.31023227	0.024473879
Apocynaceae	Tabernaemontana citrifolia	9	100	113	0.125555556	0.12555556	0.11339186	0.014236978
Sapindaceae	Cupania americana	9	100	82	0.091111111	0.09111111	0.03436117	0.003130684
Rutaceae	Triphasia trifolia	6	67	134	0.148888889	0.09925926	0.02797981	0.002777255
Boraginaceae	Cordia sulcata	6	67	13	0.014444444	0.00962963	0.27734373	0.002670717
Nyctaginaceae	Pisonia fragrans	9	100	40	0.044444444	0.04444444	0.0338703	0.001505346
Bombacaceae	Ceiba pentandra	5	56	12	0.013333333	0.00740741	0.09326603	0.000690859
Rutaceae	Zanthoxylum monophyllum	4	44	26	0.028888889	0.01283951	0.04810564	0.000617653
Piperaceae	Piper dilatatum	6	67	37	0.041111111	0.02740741	0.01767146	0.000484329
Rubiaceae	Gonzalagunia spicata	6	67	32	0.035555556	0.0237037	0.01521709	0.000360701
Rubiaceae	Morinda citrifolia	7	78	10	0.011111111	0.00864198	0.01767146	0.000152716
Rubiaceae	Randia acuelata	3	33	7	0.007777778	0.00259259	0.00343612	8.90845E-06
Rubiaceae	Psychotria nervosa	6	67	3	0.003333333	0.00222222	0.00147262	3.27249E-06
Rubiaceae	Psychotria microdon	1	11	3	0.003333333	0.00037037	0.00147262	5.4541 5E-07
Rubiaceae	Chiococca alba	2	22	0	0	0	0	0

Family	Species	Absolute frequency	Relative frequency (%)	Number of individuals (without regeneration and dead trees)	Density (without regeneration and dead trees)	Distribution index	Land area per species (m²)	Dominance index
Nyctaginaceae	Pisonia fragrans	10	100	270	0.27	0.27	0.43295074	0.116896699
Euphorbiaceae	Croton corylifoius	10	100	113	0.113	0.113	0.18996818	0.021466404
Capparaceae	Morisonia americana	9	90	176	0.176	0.1584	0.08393943	0.013296006
Acanthaceae	Odontonema nitidum	6	60	158	0.158	0.0948	0.07755807	0.007352505
Capparaceae	Ocotea coriacea	9	90	55	0.055	0.0495	0.11290099	0.005588599
Erythroxylaceae	Erythroxylon havanense	6	60	36	0.036	0.0216	0.11486448	0.002481073
Fabaceae	Lonchocarpus punctatus	7	70	12	0.012	0.0084	0.29059732	0.002441017
Flacourtiaceae	Capparis baducca	9	90	62	0.062	0.0558	0.0319068	0.001780399
Veibenaceae	Citharexylum spinosum	5	50	19	0.019	0.0095	0.13008157	0.001235775
Capparaceae	Capparis indica	8	80	36	0.036	0.0288	0.02503457	0.000720996
Rubiaceae	Morinda citrifolia	1	10	1	0.001	0.0001	0.0019635	1.9635E-07

The Rubiaceae species recorded in the stations fall outside the classification (very low index), but are placed at the bottom of the tables to allow comparisons.

b. Architecture and structure of the moderately wet bioclimate stations 3 and 4

Station 3 is in the young secondary forest stage: 60% of the trees have diameters of 5 cm, but 33% have larger diameters ranging from 10 to 25 cm and the majority of the trees have heights up to 15 meters (Figures 12 (a) and 13 (a)). Two species make up the dominant species population in terms of number of individuals and the occupied basal area: Myrcia Fallax (Myrtaceae) and Cassipourea guianensis (Rhizophoraceae) (Table 9 (a)).

Station 4 is also in the young secondary forest stage: 48% of the trees have small diameters of 2.5 to 5 cm, but 30% range between 10 and 30 cm in diameter. However, the majority of the trees have heights of no more than 8 meters (Figures 12 (b) and 13 (b)). The dominant species belong to the Myrtaceae family: Plinia Pinnata and Pimenta racemosa (Table 9 (b)).

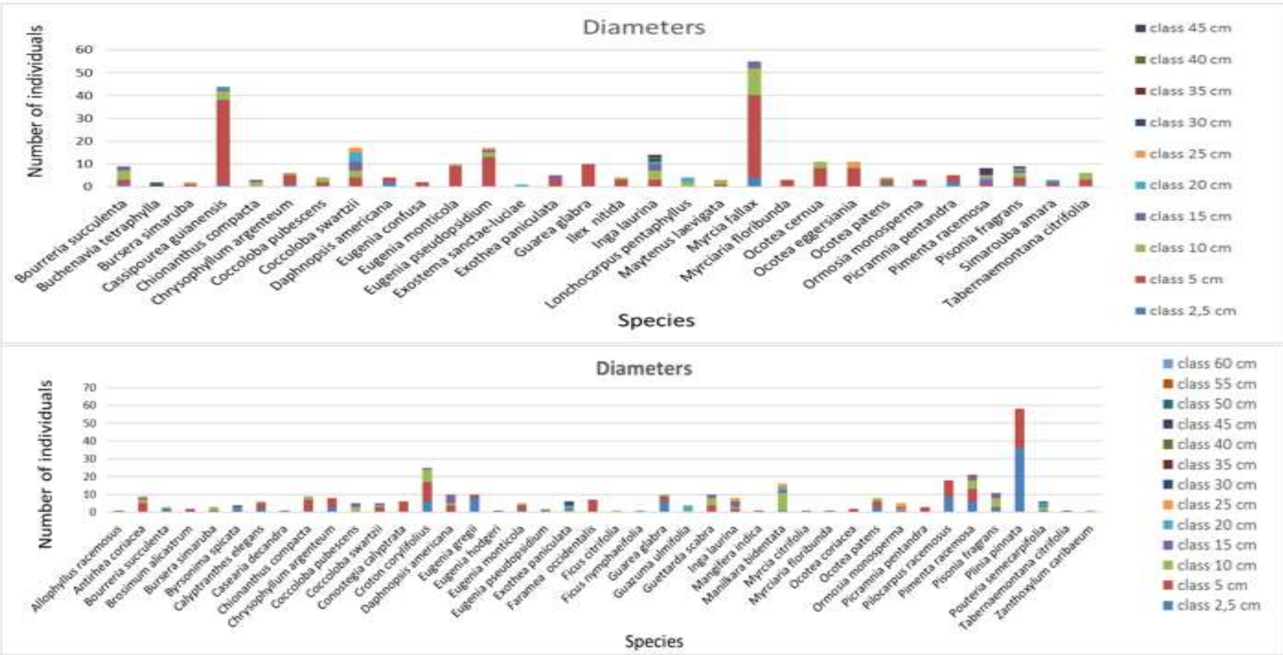


Figure 12: Distribution of live tree diameter classes: station 3 (a), station 4 (b).

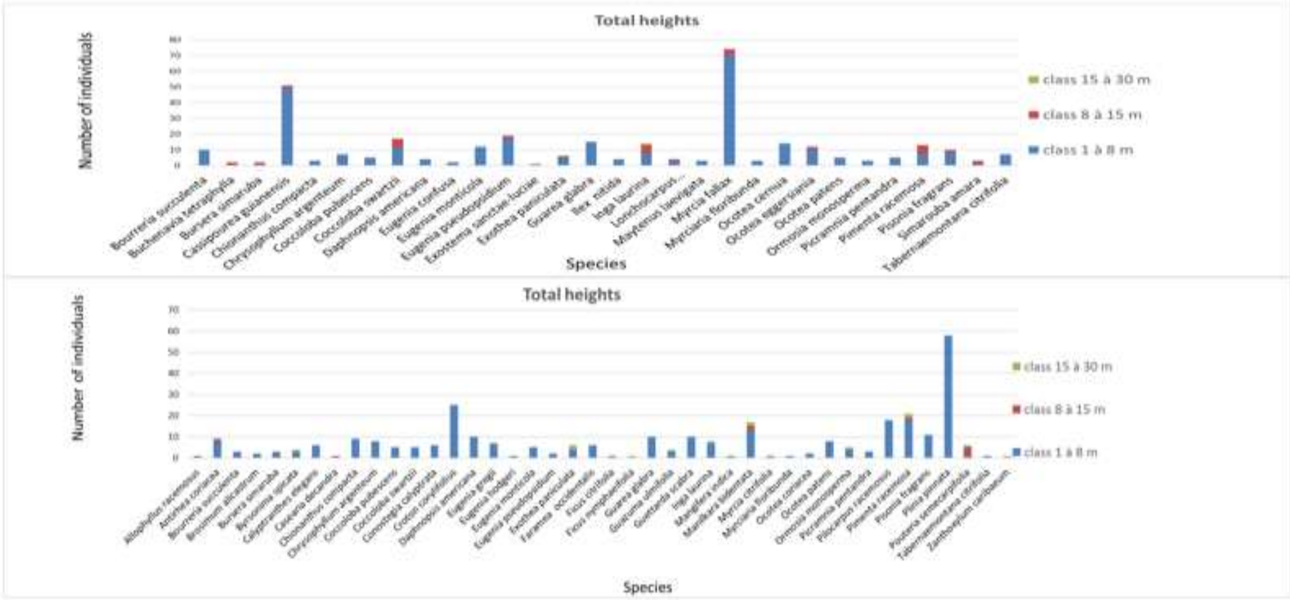


Figure 13: Distribution of height classes: station 3 (a), station 4 (b).

Table 9: Ranking of the top ten species per dominance indices for station 3 (a) and station 4 (b).

Family	Species	Absolute frequency	Relative frequency (%)	Number of individuals (without regeneration and dead trees)	Density (without regeneration and dead trees)	Distribution index	Land area per species (m²)	Dominance index
Myrtaceae	Myrcia falax	15	100	82	0.109333333	0.109333333	0.210231453	0.022985306
Rhizophoraceae	Cassipourea guanensis	15	100	58	0.077333333	0.077333333	0.151562211	0011720811
Mimosaceae	Inga laurina	10	67	14	0.018666667	0.012444444	0.477129384	0.00593761
Myrtaceae	Pimenta racemosa	9	60	14	0.018666667	0.0112	0.356668941	0 003994692
Polygonaceae	Coccoloba swartzii	6	40	17	0.022666667	0.009066667	0.325940238	0.002955191
Myrtaceae	Eugenia pseudopsidium	12	80	20	0.026666667	0.021333333	0.107678088	0 002297133
Nyctaginaceae	Pisonia fragrans	12	80	11	0.014666667	0 011733333	0.165188869	0.001938216
Lauraceae	Ocotea eggersiania	10	67	14	0.018666667	0.012444444	0.116396008	0.001448484
Lauraceae	Ocotea cernua	13	87	14	0.018666667	0 016177778	0.040074941	0.000648323
Boraginaceae	Bourreria succulenta	8	53	10	0.013333333	0.007111111	0.071490868	0.00050838
Rubiaceae	Palicourea crocea	6	40	3	0.004	0.0016	0.005890486	9.42478 E-06
Rubiaceae	Exostema sanctae-luciae	1	7	1	0.001333333	8.88889E-05	0.031415927	2.79253 E-06
Rubiaceae	Ixora ferrea	5	33	2	0.002666667	0.000888889	0.000490874	4.36332E-07
Rubiaceae	Chiococca alba	6	40	0	0	0	0	0
Rubiaceae	Geophila repens	1	7	0	0	0	0	0
Rubiaceae	Psychiotria microdon	1	7	0	0	0	0	0
Rubiaceae	Psychiotna nervosa	1	7	0	0	0	0	0

Family	Species	Absolute frequency	Relative frequency (%)	Number of individuals (without regeneration and dead trees)	Density (without regeneration and dead trees)	Distribution index	Land area per species (m²)	Dominance index
Myrtaceae	Plinia pinnata	10	100	132	0,264	0264	0,0787558	0.020 791531
Myrtaceae	Pimenta racemosa	8	80	26	0.052	0.0416	0.30605003	0.012731681
Sapotaceae	Manilkara bidentata	6	60	22	0,044	0.0264	0.23135866	0.006107869
Euphorbiaceae	Croton corylifolius	7	70	27	0,054	0,0378	0.08054258	0.00304451
Nyctaginaceae	Pisonia fragans	9	90	17	0,034	0,0306	0.08523534	0.002608201
Sapindaceae	Exothea paniculata	5	50	8	0,016	0,008	0.22676408	0.001814113
Mlmosaceae	Inga laurina	6	60	8	0,016	0.0096	0,14791011	0.001419937
Rutaceae	Pilocarpus racemosus	8	80	33	0,066	0.0528	0.02489712	0.001 314568
Sapotaceae	Pouteria semecarpifolia	4	40	6	0,012	0,0048	0,23650302	0,001 135215
Thymeleaceae	Daphnopsis americana	6	60	10	0,02	0,012	0.09171487	0.001 100578
Rubiaceae	Antirhea coriacea	4	40	14	0,028	0,01 12	0.08425359	0.00094364
Rubiaceae	Guettarda scabra	5	50	13	0,026	0,013	0.06719081	0.000873481
Rubiaceae	Faramea occidentalis	5	50	7	0,014	0,007	0.00636173	4.45321 E-05
Rubiaceae	Ixora ferrea	1	10	1	0,002	0 0002	0 00031416	6.2831 9E-08

The Rubiaceae species recorded in the stations fall outside the classification (very low index), but are placed at the bottom of the tables to allow comparisons.

c. Architecture and structure of the wet bioclimate stations 5 and 6

Station 5 is in the late secondary forest stage: 67% of the trees have large diameters ranging from 15 to 30 cm; 5% have diameters of 90 cm. The trees can reach 8 to 40 meters high (Figures 14 (a) and 15 (a)). Three species form the dominant species population: Dacryodes excelsa (Burseraceae), Pouteria multiflora (Sapotaceae), Chimarrhis cymosa (Rubiaceae) (Table 10 (a)).

Station 6 is also in the late secondary forest stage: circa 30% of the trees have diameters ranging from 10 to 40 cm, 3% have diameters greater than 60 cm. The majority of the trees range between 1 and 8 meters in height and 37% are well over 8 meters and can reach up to 40 meters (Figures 14 (b) and 15 (b)). Only one species is dominant for this station. It is Swietenia macrophylla (Meliaceae). Indeed we are located here in an old plantation of Swietenia macrophylla for the production of wood. Then, under this abandoned plantation of Swietenia, the other plant species, particularly native ones, developed and regenerated. Among these regenerations the dominant species are Pouteria multiflora (Sapotaceae) and Chimarrhis cymosa (Rubiaceae), (Table 10 (b)).

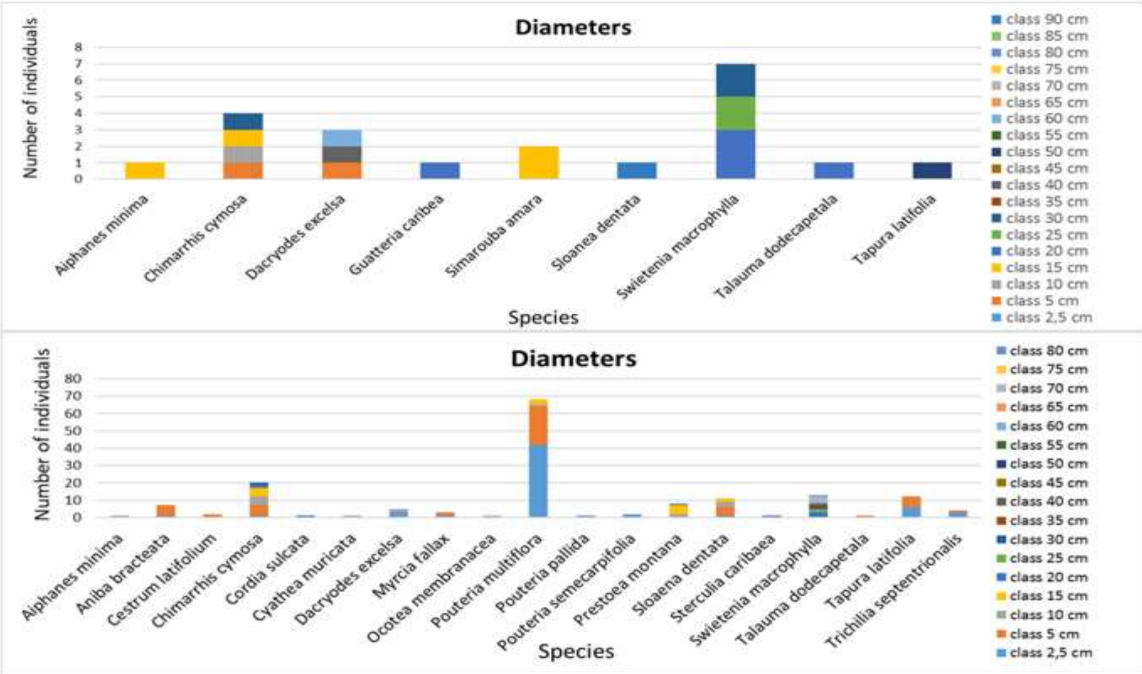


Figure 14: Distribution of live tree diameter classes: station 3 (a), station 4 (b).

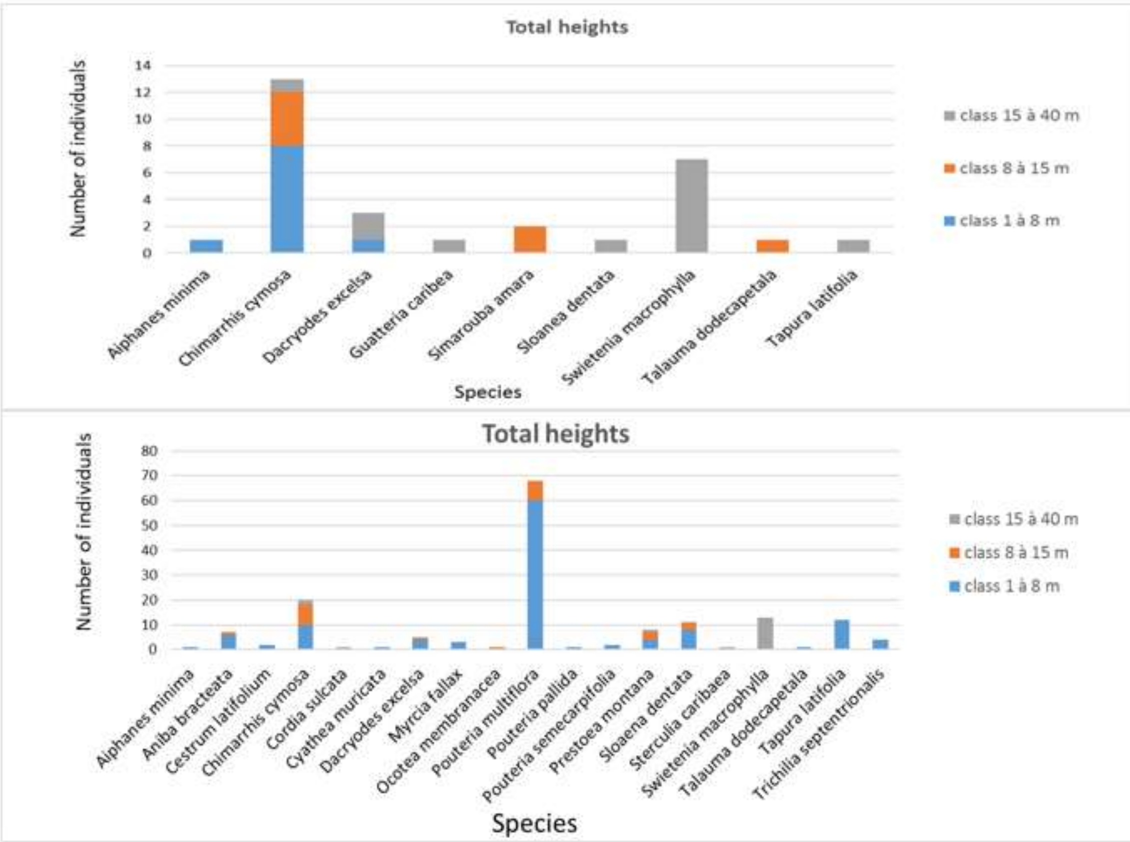


Figure 15: Distribution of height classes: station 3 (a), station 4 (b).

Table 10: The top ten ranking species per dominance indices for station 5 (a) and station 6 (b).

Family	Species	Absolute frequency	Relative frequency (%)	Number of individuals (without regeneration and dead trees)	Density (without regeneration and dead trees)	Distribution index	Land area per species (m^2)	Dominance index
Burseraceae	Dacryodes excelsa	4	80	3	0.006	0.0048	0.7866548	0.003775943
Meliaceae	Swietenia macrophylla	4	80	7	0.014	0.0112	0.3337942	0.003738495
Rubiaceae	Chimarrhis cymosa	4	80	13	0.026	0.0208	0.1335177	0.002777168
Elaocarpaceae	Sloanea dentata	3	60	1	0.002	0.0012	0.6361725	0.000763407
Dichapetalaceae	Tapura latifolia	3	60	1	0.002	0.0012	0.1963495	0.000235619
Simaroubaceae	Simarouba amara	1	20	2	0.004	0.0008	0.0353429	2.82743E-05
Annonaceae	Guatteria caribea	1	20	1	0.002	0.0004	0.0314159	1.25664E 05
Magnioliaceae	Talauma dodecapetala	1	20	1	0.002	0.0004	0.0314159	1.25664E-05
Arecaceae	Aiphanes minima	1	20	1	0.002	0.0004	0.0176715	7.06858E-06

Family	Species	Absolute frequency	Relative frequency (%)	Number of individuals (without regeneration and dead trees)	Density (without regeneration and dead trees)	Distribution index	Land area per species (m^2)	Dominance index
Meliaceae	Swietenia macrophylla	5	71	13	0.012380952	0.008843537	1.831941216	0.016200841
Sapotaceae	Pouteria multiflora	7	100	68	0.064761905	0.064761905	0.122227589	0.007915691
Rubiaceae	Chimarrhis cymosa	7	100	20	0.019047619	0.019047619	0.273416736	0.005207938
Arecaceae	Prestoea montana	5	71	8	0.007619048	0.005442177	0.135481183	0.000737313
Elaeocarpaceae	Sloaena dentata	6	86	11	0.01047619	0.008979592	0.069213213	0.000621506
Dichapetalaceae	Tapura latifolia	5	71	12	0.011428571	0.008163265	0.013744468	0.0001122
Lauraceceae	Aniba bracteata	5	71	7	0.006666667	0.004761905	0.012271846	5.84374E-05
Burseraceae	Dacryodes excelsa	4	57	5	0.004761905	0.002721088	0.017180585	4.67499E-05
Meliaceae	Trichilia septentrionalis	3	43	4	0.003809524	0.001632653	0.003436117	5.60999E-06
Boraginaceae	Cordia sulcata	1	14	1	0.000952381	0.000136054	0.031415927	4.27428E-06

DISCUSSION

According to the regional flora [60-61] in the Caribbean there are 129 species of Rubiaceae divided into 54 genera, and in Martinique there are 89 species of Rubiaceae divided into 41 genera (Table 5). All forms of life are represented, from trees to grasses, through arbusts, shrubs, lianas and epiphytes. In the West Indies, the predominant physiognomic type is the shrub (40%), followed by grasses (19%), trees (17%) and arbusts (15%). In Martinique the shrub type is also dominant (42%), but followed by trees (21%), grasses (15%) and arbusts (12%). The lianas and epiphytes are poorly represented or little known.

The genera of this family are almost quasi-composed of a single species. In fact, in the West Indies more than 60% of the family genera consist of a single species, less than 30% contain two to three species, and less than 6% contain more than ten species. The same applies to Martinique: 60% of the genera include a single species, less than 30% contain two to three species and less than 5% contain more than ten species. The diversity in terms of the number of species and physiognomic types within this family is undeniable. According to regional floras and field surveys, in Martinique the Rubiaceae occupy a wide range of habitats ranging from the dry to wet bioclimate. They are found in forest undergrowth, transition forests, damaged areas and in the climax of the meso-hygrophilous forest as well as in hygrophilous forests.

We can estimate the importance of the Rubiaceae within the island's natural vegetation due to the floristic surveys we carried out. First, in terms of the number of species, all the stations combined, the Rubiaceae are generally among the largest families (Table 6). Then, in terms of the number of individuals, this family is not the most important, but is nevertheless among the top ten (Table 7). It has a larger number of individuals in the wet environment stations despite a smaller number of species. Table 4 also indicates that the diversity in relation to the number of families, species, genera and individuals is greater in the southern stations located in the dry bioclimate.

These data indicate that the Rubiaceae are present: in bioclimates falling within the scope of the dry bioclimate and both in the young secondary forest stage and the shrub stage; in the bioclimates falling within the scope of the moderately wet bioclimate and in the young secondary forest stage, and in those of the wet bioclimate in the late secondary forest stage.

Then the architecture and the structure of the various surveyed biocenoses allow to place the Rubiaceae within the ecologically dominant species populations. In the dry bioclimate for station 1 (xerophytic biocenosis in the young secondary forest stage), there are six species of Rubiaceae (Table 8 (a)). None of them are part of the dominant species population because their distributions in terms of number of individuals and the basal area they occupy are negligible. For station 2 (xerophytic biocenosis in the shrub stage), only one species of Rubiaceae has been recorded: Morinda citrifolia, but its ecological importance is also negligible (Table 8 (b)). In the dry bioclimate plant formations with extra and intra-sylvatic successional cycles[7] [41], the Rubiaceae are well represented in relation to the number of species without being dominant.

[7] Stages of biocenoses evolution [41]

In the moderately wet bioclimate, station 3 (mesophilic biocenosis, young secondary forest stage) exhibits seven species of Rubiaceae (Table 9 (a)) but their ecological importance is also negligible. Station 4 (mesophilic biocenosis, young secondary forest stage) exhibits four species of Rubiaceae also with negligible ecological importance (Table 9 (b)).

The current vegetation in Martinique is a mosaic of various plant formations belonging to very different phases of evolution [41,51]. Facing a high degree of anthropization since the island was taken into possession in 1635 (even if the Amerindians were the first persons to occupy it from the 1st century), the biocenoses of the lower and middle floors (the dry and moderately wet bioclimate) have been severely damaged [41]. Therefore, our results match the descriptions in the global scientific literature that the Rubiaceae are very sensitive to environmental disturbances and are scarce in the tropics [4].

In the wet bioclimate, stations 5 and 6 (hygrophilous biocenosis in the late secondary forest stage) exhibit only one species of Rubiaceae: Chimarrhis cymosa. This Rubiaceae is part this time of the cortege of the dominant species among the regenerations pushing under the plantation of Swietenia (Table 10 (a and b)). Therefore it dominates in terms of the number of individuals and its total biomass, and is one of the species best suited to the environment (among regenerations). It is also part of the so-called climax species population, very specialized for the terminal stages of the hygrophilous forests in Martinique [55]. Our findings again coincide with the descriptions in the global scientific literature that the Rubiaceae are present in tropical wet forests with high tree abundance [4].

CONCLUSION

The Lesser Antilles have an important diversity of Rubiaceae. Martinique has 89 species divided into 41 genera. All forms of life are represented: trees and grasses, shrubs, arbusts, lianas and epiphytes. However, the lianas and epiphytes are poorly represented, or even little known. The Rubiaceae are present in Martinique in all bioclimates, in various plant formations and in various stages of evolution. The family seems well represented in relation to the recorded number of species and individuals. The Rubiaceae are part of the dominant species populations only in the wet tropical forests of the upper strata; the biocenoses of the island's lower and middle levels being more marked by anthropization characterised by a high degree of environment damage.

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