VEGETATIVE MORPHOLOGY FOR SPECIES IDENTIFICATION OF TROPICAL TREES: FAMILY DISTRIBUTION

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ABSTRACT: Tree specimens from the ESAL herbarium of the Universidade Federal de Lavras, Minas Gerais, Brazil, were described by vegetative characteristics using CARipé, a Microsoft Access database application specially developed for this study. Only one specimen per species was usually described. Thus, 2 observers described 567 herbarium species as a base to test methods of identification as part of a larger study. The present work formed part of that study and provides information on the distribution of 22 vegetative characters among 16 families having 10 or more species described. The characters are discussed. The study found marked differences, even discontinuities, of distributions of characters between those families. Therefore it should be possible to incorporate phylogenetic relationships into the identification process.

Key words: Tree species identification, Brazilian Atlantic Forest, vegetative morphological characters, distribution by family.

MORFOLOGIA VEGETATIVA PARA IDENTIFICAÇÃO DE ÁRVORES TROPICAIS: DISTRIBUIÇÃO POR FAMÍLIAS

RESUMO: *Espécimes de árvores no Herbário ESAL da Universidade Federal de Lavras – Minas Gerais – foram descritos por caracteres vegetativos usando CARipé, um banco de dados de Microsoft Access especialmente desenvolvido para esse estudo. Normalmente, foi descrito só um espécime por espécie. Dessa maneira, em um estudo mais abrangente, 2 observadores descreveram 567 espécies como uma base para testar métodos de identificação. Com este artigo, apresenta-se uma discussão dos caracteres vegetativos, além de informações sobre distribuições de 22 deles entre 16 das famílias com 10 ou mais espécies descritas no banco de dados. O estudo encontrou diferenças notáveis, mesmo descontinuidades, de distribuições de caracteres entre essas famílias. Assim, deve ser possível incorporar informações filogenéticas no processo de identificação.*

Palavras-chave: Floresta Atlântica, morfologia vegetativa, filogenia, espécies de árvores.

1 INTRODUCTION

This study focuses on the southeast of Minas Gerais in the region of the Middle and Upper Rio Grande. Over the past fifteen years a team from the department of Forest Sciences and department of Biology of the Federal University of Lavras (UFLA) has conducted phytosociological research based on the hundreds of forest fragments still surviving (OLIVEIRA-FILHO et al., 1994). At present, 25 fragments have been studied and described in phytosociological surveys. However, many more are in need of survey before regional forest tree diversity can be fully evaluated.

Much of the success of forest surveys depends on the identification or determination of tree species. From an existing list it is known that the forests of the study region harbor 800 or more species of trees. However, until this study, a regional flora, including descriptions or keys for identification of forest trees, did not exist in any form. Existing tree identification guides such as published by Lorenzi (1992, 1998) do not cover half the trees of our list. Clearly much time is spent on species identification by new researchers.

Furthermore, very often the majority of identifications of some surveys must be based on sterile or vegetative material such as leaves, stems and bark and certain field characters. Some tree species remain several years without flowering. For this reason the use of vegetative characters to distinguish between tree families, genera or species is the norm. However, few comprehensive floras to this diverse tropical physiognomic group exist at the species level. Good treatments of the vegetative characters of tropical woody plants can be found in Gentry (1996) and Keller (1996) and an interesting, but difficult, treatment of tropical tree physiognomy or architecture is found in Hallé et al. (1978).

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Not only are vegetative features seen to be heritable but they also vary substantially between tree species. Also it is clear that the phenotype is fundamentally based on the genotype (HARTWELL et al., 2004; SINNOTT et al., 1958) and that previous studies indicate that most tropical trees are good biological species (BAWA, 1992). These considerations were the origin of the study's working hypothesis that vegetative features, in combination as a diagnostic character set, allow the confident determination of hundreds of tree species. Furthermore these characters are nearly always available and easy to observe with the aid only of a pocket lens of x10 magnification.

The objectives of the larger study (HARGREAVES, 2005) were the following:

(a)Produce a preliminary flora of the approximately 800 tree species recorded for the Middle and Upper Rio Grande in the state of Minas Gerais.

(b) Use vegetative morphological characters to describe the tree species.

(c) Develop a computer software system, CARipé, to describe the tree species rapidly and evaluate the system using different users.

(d) Digitize images of the botanical material and link them to the database of descriptions.

(e) To produce and evaluate an automated identification system, Empar, based on matching techniques that are tolerant to the natural variability of characters, differences of live material and herbarium material, different users, and human errors.

(f) Produce a DELTA interface to allow other taxonomists to access our data and also to give us access to other software systems that can use DELTA files for input.

(g) Produce a botanical key to all the species described in the study.

This paper came out of the highlighted areas (b) and (c).

Even though many vegetative characters are considered necessary for discriminating between species, few have been used for distinguishing between the higher taxonomic categories such as family. Therefore a study was made of the distribution of some of the characters among those plant families represented by 10 or more descriptions of herbarium specimens.

2 MATERIALS AND METHOD

2.1 Selection of characters

The vegetative features used in CARipé were those most commonly encountered in diagnostic descriptions encountered in floras in relation to trees. For identification purposes, one of the most important criteria for selection of characters is the ease of observation, which is a combination of conceptual simplicity and time taken to record the information without straying too far from the principles of plant morphology. The selection of characters for CARipé also had in view identification by matching as the principle method of identification and to a lesser degree the use of botanical keys.

There are many guides to botanical description and, though there is a good deal of synonymy of terms and different levels of treatment, on the whole they are consistent. This study generally uses the definitions of Ferri et al. (1981) and Lawrence (1951) and other sources are cited under the appropriate character group. The author has explicitly defined and illustrated many of the characters in the manual for the CARipé system and much of this has been incorporated in the online help.

Although the larger study used 57 non-numerical characters that were generally applicable to both simple and compound leaf types, only 22 characters were used for this analysis and these were true binary characters, for example, stipules present or absent. Binary characters were amenable to an easily presented common analysis in relation to the phylogenetic information at the family level available from the herbarium classification. This analysis was necessarily restricted to the 16 families that were represented by 10 or more herbarium specimens in the study's evaluation set which lacked some of the families generally possessing compound leaves: Rutaceae and most Fabaceae Mimosoideae, Meliaceae and Sapindaceae.

Lenticels, generally small and elliptic to linear in outline, are rough openings on the stem properly described as intercellular cavities, that allow the exchange of gases between the external environment and the stem tissues (RAVEN et al., 1996). According to Metcalfe & Chalk (1979) lenticels can be of considerable interest in the identification of woody plants. In CARipé lenticels are considered conspicuous when they contrast with the bark or attain lengths of at least 2 mm.

In CARipé lateral buds are considered conspicuous when they contrast with the leaf axils, attain lengths of at least 2 mm, or appear in a position above rather than in the leaf axils. Very often it was a presence of dense hairs or trichomes that produced the color or tonal contrast.

The morphological features giving rise to ringed nodes are varied but the concept as defined in CARipé was easily and successfully applied. The decision to use this character had been influenced by a key to neotropical tree families (LITTLE, 1968). A node completely encircled (or almost so) by a single organ or its scar, or a swelling of the stem, or a node with interpetiolar stipules or verticillate leaves, is considered a ringed node. As defined here it is based on the presence of a variety of morphological entities and thus is only useful for identification purposes.

Traditional treatment of the prophylls of dicotyledons have defined them as the first leaves to form on lateral buds. Some botanists simply consider them as the first leaves that may or may not have a particular size or structure to distinguish them from the leaves forming later and thus are not really a separate morphological entity. However, the fact is that they are often distinct enough to help define higher plant groups. In CARipé they were simply taken to be the first one or two leaves when these had less than half the size of later ones and, subsequently, were not used for leaf measurements.

The stipule is commonly defined as an appendage or pair of appendages at the base of the leaf (METCALFE & CHALK, 1979). During the study several types of stipule were encountered. They appear as lateral pairs (the ancestral form) in the Euphorbiaceae or single, as were the conical stipules covering the buds of the Moraceae, or, from their positions, appeared to be the union of two stipules: interpetiolar in the Rubiaceae and intrapetiolar in *Byrsonima*. They were large and foliaceous in the Cunoniaceae, appeared as sheaths or ocrea in *Hedyosmum* (Chloranthaceae) or reduced to mere lateral protuberances as in some *Ilex*. Stipules were often fragile and deciduous and thus often lost without trace during collection or herborization; this is especially common for lateral pairs. However, stipules when present could always be observed in the field on a fresh specimen and often only on the most recent growth. They have long been used as a diagnostic character in plant taxonomy.

Separate leaf laminas are generally taken to be the single lamina of simple leaves or the leaflets of compound leaves. In the larger study the standard characters of leaf form, leaf apex, leaf base and leaf margin were of course recorded but they did not enter this analysis. Rather, there was a limited set of infrequent characters associated with the leaf lamina. These are the seven characters that appear at the end of Table 1 and only two are discussed here. Recent experiments on tropical trees have demonstrated that leaf domatia can protect the trees from herbivory even though they provide shelter for herbivorous mites (ROMERO & BENSON, 2004). Rugose leaves are a more common feature of herbarium samples than observed in the field. When the leaves of herbarium specimens are checked as possessing rugose leaves in this study, it may reflect a true rugose condition that is not always maintained on herborization but more often it reflects a membranous leaf texture in nature that results in the veins shrinking and buckling during herborization. The two forms were not distinguished except by notes in an observations data field within CARipé.

The characters and character states used to describe leaf venation patterns in CARipé owe more to the inspiration of Hickey (1973) than to his actual classification that is far too detailed to be of use in floras generally. Characters to record whether a certain set of veins are prominent on a leaf surface do not appear in Hickey’s classification but have recently been used by Ribeiro et al. (1999) where the criterion of prominence is illustrated. For medium to large leaves the sensation from passing a finger-nail across the vein in question was sufficient to determine its prominence without damage to the leaves but for small leaves a purely visual inspection using a lens was made. As a presence-absence character it was important to check if the central vein was prominent anywhere along its length as some that are not prominent at the base are prominent towards the apex.

According to Theobald in Metcalfe & Chalk (1979) completely hairless or glabrous plant species represent a minority of the angiosperms.

2.2 CARipé

The CARipé system was constructed using the database management system of Microsoft Access but also includes stored image files which can be opened within Access by Windows mediated links to imaging software and individual image files. The whole system including compacted images uses less than 600 Mb of computer storage and thus fits easily on modern hard disks and needs only a single CD for transfer between computers.

2.3 The list of forest tree species

The study started with an Excel spreadsheet containing distribution and abundance data of 805 species of tree and shrub. Ary Teixeira de Oliveira Filho of the Department of Forest Sciences, UFLA, maintains this list of species. A list of the species and a list of the locations can be found in the doctoral thesis of Hargreaves (2005). The dataset of species was imported from Excel into the CARipé database to be stored as an Access table. The locations, species and associated abundance data are linked and accessible as a subsystem within CARipé. A printed version of the list was also used to extract a specimen, usually only one, of each of the species from the ESAL Herbarium of UFLA. Herbarium specimens of the listed species were selected and taken to the laboratory for description and scanning and then returned to the herbarium. Priority was given to material that was collected in the forests of the study area, that is, the Middle and Upper Rio Grande catchments and that had duplicate material to enable easier and more representative descriptions.

3 RESULTS AND DISCUSSION

The distribution of the characters among the plant families with 10 or more species described is presented in Table 1. It can be seen that conspicuous lenticels are well distributed among those plant families under consideration and are particularly frequent in the Salicaceae (Flacourtiaceae). There are also families where, at least in our species, they are notably absent: Fabaceae Caesalpinioideae, Melastomataceae, Myrtaceae and Vochysiaceae.

Tropical trees are not renowned for conspicuous lateral buds. However the study area has three characteristics that could modify this. Our region is located on the southern edge of the inter-tropical zone; it is a highland region and also a region that experiences a cold dry winter season of three to five months duration. Indeed, conspicuous lateral buds were frequent in most families with the notable exceptions of Asteraceae, Piperaceae, and Solanaceae.

Ringed nodes are well represented in the Melastomataceae, Moraceae, Piperaceae, Rubiaceae and Vochysiaceae whereas on the contrary they were completely absent in several other families. Prophylls are particularly distinguishable from the usual leaves in many Annonaceae but the study revealed them to be far from constant in this family and some were perhaps lost by herborization. They are also frequent in the Myrtaceae and Salicaceae (Flacourtiaceae), at least as prophylls defined in this study.

It is important to note that this study formed part of a practical evaluation of a system for characterizing tree species and this necessitated its use by at least two observers describing the tree specimens. More than 40,000 characters were attributed to specimens. The observers were careful but human error and observational constraints have to be taken into account in the discussion of results. Many plant families are known to possess stipules but Melastomataceae is not one usually associated with their presence (HEYWOOD, 1978; JOLY, 1993). However, it would appear from Table 1 that for our regional flora the probability of discovering stipules in a forest tree species of Melastomataceae is 0.075 when it should be zero. The stipule-like structures are now thought to be bracts at the base of inflorescences.

The prominence of the first two or three orders of venation on the superior or adaxial surface of the lamina seems to characterize certain families. Each of the vein orders is prominent in over 70% of Euphorbiaceae species (not necessarily the same species for each vein order). The Annonaceae show a particular pattern where the first order venation is usually not prominent while the second and third order venation is prominent in approximately 90% of species. Prominent veins on the superior surface of the leaf are almost absent in the Fabaceae (Faboideae and Caesalpinioideae), Melastomataceae and Myrtaceae.

Table 1 – Percentage occurrence of presence-absence characters among families with 10 or more species described from herbarium specimens.

***Tabela 1** – Porcentagem de ocorrências de caracteres de presença ou ausência entre famílias com 10 ou mais espécies descritas a partir dos espécimes do herbário.*

Family	Number of species	Lenticels	Lateral buds	Ringed nodes	Prophylls	Stipules	Stipules without use of lens	Stipules deciduous
Annonaceae	**16**	31.3	12.5	0.0	31.3	0.0	0.0	0.0
Asteraceae	**22**	4.6	4.6	13.6	9.1	4.6	4.6	0.0
Bignoniaceae	**10**	40.0	90.0	0.0	0.0	0.0	0.0	0.0
Euphorbiaceae	**24**	12.5	12.5	0.0	12.5	62.5	37.5	37.5
Fabaceae Caesalpinioideae	**18**	0.0	61.1	0.0	16.7	0.0	0.0	0.0
Fabaceae Faboideae	**30**	26.7	96.7	0.0	3.3	23.3	16.7	0.0
Lauraceae	**34**	5.9	29.4	0.0	11.8	0.0	0.0	0.0
Malvaceae	**12**	25.0	33.3	0.0	0.0	75.0	58.3	66.7
Melastomataceae	**40**	0.0	67.5	52.5	25.0	7.5	7.5	2.5
Moraceae	**18**	22.2	33.3	83.3	33.3	100.0	88.9	88.9
Myrtaceae	**75**	0.0	74.7	6.7	52.0	0.0	0.0	0.0
Piperaceae	**11**	36.4	0.0	100.0	9.1	100.0	100.0	100.0
Rubiaceae	**32**	6.3	34.4	68.8	18.8	78.1	75.0	3.1
Salicaceae (Flacourtiaceae)	**12**	58.3	25.0	0.0	41.7	41.7	33.3	41.7
Solanaceae	**18**	22.2	0.0	0.0	5.6	50.0	50.0	22.2
Vochysiaceae	**10**	0.0	30.0	50.0	30.0	90.0	50.0	10.0

Family	Number of species	Venation-1 prominent above	Venation-2 prominent above	Venation-3 prominent above	Venation-1 prominent below	Venation-2 prominent below	Venation-3 prominent below	Basal veins
Annonaceae	**16**	18.8	93.8	87.5	100.0	100.0	87.5	0.0
Asteraceae	**22**	36.4	31.8	22.7	100.0	95.5	81.8	13.6
Bignoniaceae	**10**	10.0	30.0	20.0	100.0	100.0	90.0	80.0
Euphorbiaceae	**24**	75.0	83.3	70.8	100.0	100.0	66.7	37.5
Fabaceae Caesalpinioideae	**18**	0.0	0.0	0.0	83.3	44.4	16.7	5.6
Fabaceae Faboideae	**30**	3.3	0.0	0.0	90.0	40.0	16.7	0.0
Lauraceae	**34**	58.8	55.9	58.8	100.0	100.0	88.2	2.9
Malvaceae	**12**	58.3	75.0	25.0	100.0	100.0	91.7	41.7
Melastomataceae	**40**	0.0	0.0	0.0	100.0	65.0	45.0	2.5
Moraceae	**18**	66.7	72.2	61.1	100.0	100.0	94.4	66.7
Myrtaceae	**75**	1.3	0.0	0.0	98.7	57.3	20.0	2.7
Piperaceae	**11**	36.4	36.4	36.4	100.0	100.0	90.9	72.7
Rubiaceae	**32**	25.0	12.5	3.1	100.0	93.8	18.8	3.1
Salicaceae (Flacourtiaceae)	**12**	58.3	66.7	75.0	100.0	100.0	91.7	16.7
Solanaceae	**18**	33.3	44.4	27.8	100.0	100.0	72.2	0.0
Vochysiaceae	**10**	20.0	30.0	10.0	100.0	100.0	80.0	10.0

To be continued ...
Continua ...

Table 1 – Continued...

Tabela 1 *– Continuação...*

Family	Number of species	Glabrous	Lamina folded	Glossy leaved	Thick leaved	Leaf domatia	Lamina rugose	Lamina bilaterally asymmetric	Lamina muricate
Annonaceae	**16**	0.0	0.0	0.0	12.5	6.3	12.5	0.0	0.0
Asteraceae	**22**	9.1	18.2	4.6	0.0	0.0	22.7	0.0	9.1
Bignoniaceae	**10**	0.0	0.0	0.0	0.0	50.0	10.0	20.0	10.0
Euphorbiaceae	**24**	20.8	0.0	16.7	0.0	8.3	25.0	0.0	0.0
Fabaceae Caesalpinioideae	**18**	27.8	nd	nd	nd	nd	nd	nd	nd
Fabaceae Faboideae	**30**	33.3	nd	nd	nd	nd	nd	nd	nd
Lauraceae	**34**	5.9	5.9	17.7	8.8	17.7	2.9	5.9	0.0
Malvaceae	**12**	8.3	0.0	0.0	0.0	8.3	50.0	0.0	0.0
Melastomataceae	**40**	20.0	5.0	0.0	0.0	10.0	2.5	2.5	5.0
Moraceae	**18**	27.8	5.6	5.6	0.0	0.0	38.9	0.0	16.7
Myrtaceae	**75**	58.7	1.3	16.0	1.3	2.7	13.3	0.0	0.0
Piperaceae	**11**	27.3	0.0	0.0	0.0	0.0	45.5	0.0	27.3
Rubiaceae	**32**	65.6	0.0	9.4	0.0	15.6	40.6	0.0	0.0
Salicaceae (Flacourtiaceae)	**12**	0.0	0.0	41.7	0.0	8.3	0.0	8.3	0.0
Solanaceae	**18**	16.7	11.1	5.6	0.0	5.6	22.2	0.0	5.6
Vochysiaceae	**10**	10.0	0.0	10.0	50.0	0.0	20.0	0.0	0.0

nd: no data

On the inferior or abaxial surface, for the same three families there is a gradual reduction in frequency of prominence from first to third order veins, whereas in the Rubiaceae this reduction is only seen in the third order veins. The venation on the inferior surface is generally more marked and a high frequency of prominence in all three orders of venation is general among the families. A prominent central vein on the lower surface is constant in nearly all species.

The complete lack of trichomes, that is, the glabrous condition ranged from absent in the Annonaceae, Bignoniaceae and Salicaceae (Flacourtiaceae) to moderate frequencies in the Myrtaceae and Rubiaceae.

Looking at those characters associated with the leaf lamina that are less common, it can been seen that though many trees have glossy leaves in nature they tend to lose this during herborization but it is frequently maintained in the Salicaceae (Flacourtiaceae). Thick leaves are most often found among the Vochysiaceae. Domatia are found more often in the Bignoniaceae, Lauraceae, Melastomataceae and Rubiaceae.

Thus it was found that there were marked differences and even discontinuities of distributions of these characters between those families with 10 or more species described. Therefore it may be possible to incorporate phylogenetic relationships into future tree identification systems employing vegetative characters.

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