MALPIGHIACEAE: CORRELATIONS BETWEEN HABIT, FRUIT TYPE AND BASIC CHROMOSOME NUMBER

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Recebido em 21/05/2002. Aceito em 10/06/2002

ABSTRACT – (Malpighiaceae: correlations between habit, fruit type and basic chromosome number). The family Malpighiaceae presents species with different habits, fruit types and cytological characters. Climbers are considered the most derived habit, followed, respectively, by the shrubby and arboreal ones. The present study examines the relationship between basic chromosome numbers and the derivation of climbing habit and fruit types in Malpighiaceae. A comparison of all the chromosome number reports for Malpighiaceae showed a predominance of chromosome numbers based on x=5 or 10 in the genera of sub-family Malpighioideae, mainly represented by climbers with winged fruits, whereas non-climbing species with non-winged fruits, which predominate in sub-family Byrsonimoideae, had counts based on x=6, which is considered the less derived basic number for the family. Based on such data, confirmed by statistic assays, and on the monophyletic origin of this family, we admit the hypothesis that morphological derivation of habit and fruit is correlated with chromosome basic number variation in the family Malpighiaceae.

Key words – Malpighiaceae, Malpighioideae, Byrsonimoideae, chromosome number, habit, fruit types

RESUMO – (Malpighiaceae: correlações entre hábito, tipo de fruto e número cromossômico básico). A família Malpighiaceae apresenta diferentes tipos de hábito, frutos e caracteres citogenéticos. Em geral, espécies lianas são consideradas as mais derivadas, seguidas, respectivamente, pelas arbustivas e arbóreas. O presente estudo propõe para Malpighiaceae uma relação entre a variação do número cromossômico básico e a derivação do hábito trepador e da morfologia dos frutos. Para estabelecer esta relação analisamos todas as contagens de cromossomos já relatadas para a família Malpighiaceae, sendo que a freqüência relativa destas contagens foi calculada para todos os gêneros estudados. Esta comparação mostrou a predominância de números cromossômicos baseados em x=5 ou 10 na sub-família Malpighioideae, predominantemente composta por lianas com frutos alados, enquanto que espécies de outros hábitos, com frutos não alados, apresentaram contagens baseadas em x=6, considerado o número básico menos derivado para a família, predominante na sub-família Byrsonimoideae. Baseados em consistentes dados estatísticos, e também na origem monofilética da família, admitimos a hipótese de que as derivações do hábito e dos tipos de fruto estão diretamente relacionadas com a variação do número cromossômico na família Malpighiaceae.

Palavras-chave – Malpighiaceae, número cromossômico, número básico, hábito, tipos de fruto

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Introduction

The family Malpighiaceae comprises about 71 genera and 1250 species. These species are mostly climbers, although trees and shrubs are also present (Robertson 1972; Judd *et al.* 1999). Some Malpighiaceae species are of economic interest, e.g. Barbados cherry (*Malpighia emarginata*), a rich source of vitamin C (Mezquita & Vigoa 2000). The genera *Banisteriopsis* and *Diplopterys* include some species with hallucinogenic compounds (Desmarchelier *et al.* 1996), the most famous of which is *Banisteriopsis caapi*, found in North of South America (Gates 1982). Species of the genera *Banisteriopsis*, *Galphimia*, *Malpighia*, *Peixotoa* and *Stigmaphyllon* are cultivated as ornamental plants (Lorenzi & Souza 1999).

Based on morphological characters and palynological data, Vogel (1990) characterized this family as a natural monophyletic group. It is taxonomically organized in two sub-families: Malpighioideae, with samaroid winged fruits that are wind dispersed, and Byrsonimoideae with schizocarpic, drupaceous fruits, which are dispersed by the water or animals (Anderson 1977; 1993). Based partly on the anemocoric dispersion of their fruits and the climbing habit of its species, Anderson (1983) considered Malpighioideae the most derived sub-family. Although several habits are found in both sub-families, lianas clearly predominate in Malpighioideae, and trees and shrubs in Byrsonimoideae (Anderson 1977). Climbers are plants that organize their growth strategy upon whatever rigid support, even themselves. The literature proposes two different terms to identify climbers: vines for herbaceous climbers, and lianas for woody climbers. Evolutionary studies usually consider climbers as the most derived species (Radford *et al.* 1974), with shrubby species as intermediate and trees as the least derived taxa (Carlquist 1991).

Few studies have attempted to compare the adaptive features in plant structure with variation in chromosome structure. Lombello & Forni-Martins (1998a) observed a relationship between the climbing habit and some trends in chromosome morphology in Sapindaceae. This pattern of karyotype derivation consisted of a decrease in chromosome number and an increase in chromosome size.

Chromosome number reports exist for about 10% of Malpighiaceae species, presenting basically the haploid chromosome number (Bawa 1973; Anderson 1983; 1990; 1993; Forni-Martins *et al*. 1992; 1995; Lombello & Forni-Martins 1998b). The sub-family Malpighioideae presents the basic number x=10 for most of its species, although some genera, such as *Peixotoa* with chromosome number n=15 (Anderson 1993; Forni-Martins *et al*. 1995) and *Heteropterys* with counts 2n=30 (Lombello & Forni-Martins 2001), show a possible basic number x=5. Other exceptions are the chromosome numbers reported (n=9) for the genus *Acridocarpus*, which belongs to tribe Banisterieae, sub-tribe Sphedamnocarpinae (Anderson 1993). Sub-family Byrsonimoideae presents chromosome numbers based on x=6, with two exceptions: *Macvaughia bahiana*, with n=10 (Anderson 1993) and *Byrsonima crassifolia*, with 2n=20 (Nanda 1962).

Based on chromosome numbers reported for Malpighiaceae species, this paper aims to investigate the existence of a relationship between the climbing habit derivation, as well as the fruit type derivation and the inter-specific and inter-generic basic chromosome number variation in the family.

Material and methods

Chromosome numbers of Malpighiaceae species are listed in Bolkhovskikh *et al.* (1969), Moore (1973; 1974; 1977), Goldblatt (1981; 1984; 1985; 1988), Goldblatt & Johnson (1990; 1991; 1994; 1997) and Lombello (2000) (Tab. 1). Out of the 128 species with chromosome number report, 69 species (54%)

Table 1. Sub-families, tribes and genera of Malpighiaceae with chromosome counts. Systematic based on Niedenzu (1928), nomenclature on Morton (1968) and Anderson (1977, 1993), with studied species habits (C-climbers, N-non-climbers), fruit types (W-winged, N-non-winged), percentage of studied species in the genera (Sp%) and chromosome number (2n) as well as its frequency in each genera ($F_{i,g}$).

Sub-family Tribe	Genus	Habit	Fruit	Sp%	2n ($F_{i,g}$)
Malpighioideae					
Hiptageae	*Aspidopterys*	C	W	6,2	20(100%)
	Callaeum	C	W	20,0	20(100%)
	Hiptage	C	W	3,8	42(16,6%), 56(49,9%), 58(16,6%), 60(16,6%)
	Mascagnia	C	W	8,7	20(50%), 40(25%), 60(25%)
	Malpighia	N	N	5,5	20(66,6%), 40(33,3%)
	Tetrapterys	C	W	2,3	20(50%), 50(50%)
	Triapsis	C	W	11,7	20(100%)
	Tristellateia	C	W	5,8	18(100%)
Banisterieae	*Acridocarpus*	N	W	3,8	18(100%)
		C	W	7,6	18(100%)
	Banisteriopsis	N	W	7,6	20(85,7%), 40(14,3%)
		C	W	10,8	20(80%), 40(10%), 80(10%)
	Cordobia	C	W	50,0	18(100%)
	Heteropterys	N	W	16,0	20(49,9%), 30(21,4), 34(7,1%), 42(7,1%), 56(7,1%), 58(7,1%)
	Jubelina	C	W	-	20(100%)
	Peixotoa	N	W	25,0	20(60%), 30(40%)
		C	W	8,3	20(100%)
	Sphedamnocarpus	C	W	12,5	20(100%)
	Stigmaphyllon	C	W	14,0	18(10%), 20(60%), 22(10%), 24(10%), 40(10%)
Gaudichaudieae	*Aspicarpa*	N	N	50	40(16,6%), 80(83,3%)
	Camarea	N	N	50	34(100%)
	Gaudichaudia	N	W	100	80(100%)
		C	W	52,0	80(61,5%), 160(30,7%), 240(7,7%)
	Janusia	C	W	61,1	20(15,3%), 38(7,6%), 40(69,2%), 80(7,6%)
	Peregrina	C	W	100	38(100%)
Tricomarieae	*Echinopterys*	C	W	50,0	20(50%), 40(50%)
Indeterminate	*Bunchosia*	N	N	2,0	60(100%)
	Dicella	C	N	20,0	20(100%)
	Ectopopterys	C	W	100	16(100%)
	Thryallis	N	N	33,3	60(100%)
Byrsonimoideae					
Galphimieae	*Blepharandra*	N	N	100	24(100%)
	Galphimia	N	N	60,0	12(25%), 20(12,5%), 24(62,5%)
	Lophanthera	N	N	66,6	12(100%)
	Verrucularia	N	N	100	12(100%)
Byrsoniminae	*Byrsonima*	N	N	8,1	20(10%), 24(90%)
	Diacidia	N	N	50,0	48(100%)
	Macvaughia	C	N	100	20(100%)
Acmanthereae	*Pterandra*	N	N	50,0	24(100%)
Indeterminate	*Barnebya*	C	W	100	60(100%)

are climbing. With respect to fruit morphology, 88 species (68,7%) have winged-fruits.

These chromosome data allowed us to calculate the relative frequency (***F***$_{i,g}$) of a given chromosome number ***i*** in a genus ***g*** with ***T*** studied species, through the following formula:

$F_{ig} = 100S_i / T g$

Where ***S***$_i$ = number of species with a same habit with ***i*** chromosomes in a genus ***g***.

The ***F***$_{i,g}$ value were used to calculate the weighted relative frequency (***Rf***$_i$) of each chromosome number in the two sub-families of Malpighiaceae, as well as for climbers or non-climbers species, according to the following formula:

$$RFi = 100(/\sum_{j=1}^{G} F_{i,j}) / \sum_{k=1}^{L} F_k$$

Where G= number of calculated frequency for a given chromosome number i, and

L= total frequency data for all species with the same habit.

These formulas were used for the first time in relative chromosome number frequency determination by Lombello & Forni-Martins (1998a) in their study on Sapindaceae.

Taxonomic and morphological literature (Niedenzu 1928; Anderson 1977; 1979; 1983; 1985; 1993; Gates 1982; Mamede 1990; Vogel 1990) were used to characterize the habit and fruit types of the Malpighiaceae genera studied. Some of them, e.g. *Banisteriopsis*, *Gaudichaudia* and *Peixotoa*, present more than one habit. For these genera, the relative chromosome number frequency was calculated for each habit separately. For genera such as *Camarea*, that present varied habits, the chromosome counts considered in Tab. 1 were those available, even when they only accounted for species with the same habit.

In order to analyze the relationship between the fruit type derivation and chromosome number variation we distinguished between winged and non-winged fruits. The methodology used for the relative chromosome number frequency distribution was the same as that used in habit derivation analysis.

Results and discussion

Fig. 1 shows the distribution of the weighted relative frequency of each chromosome number

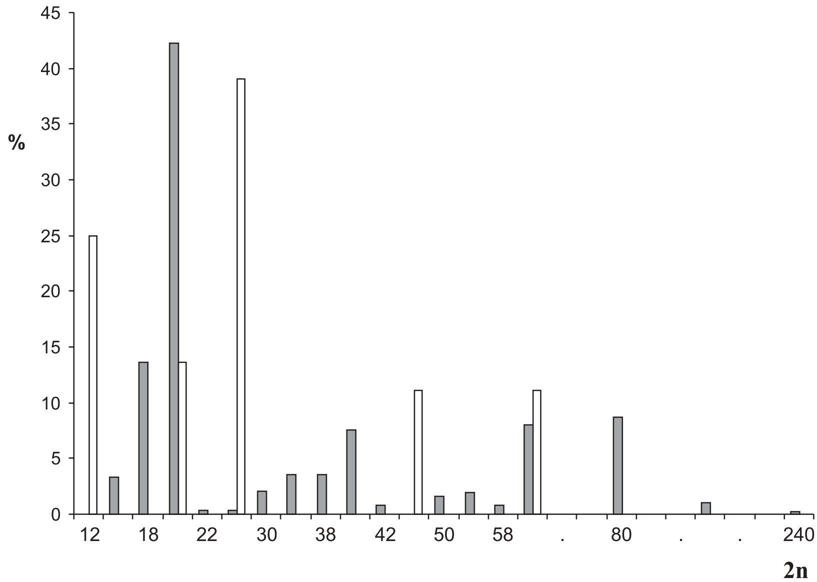

Figure 1. Distribution of weighted relative frequency ($Rf_{i,g}$) of each chromosome number for the two sub-families of Malpighiaceae. ■ Malpighioideae; □ Byrsonimoideae.

for the two sub-families of Malpighiaceae. This figure shows a distribution strongly based on x=5 and x=10 for Malpighioideae species, and on x=6 for Byrsonimoideae. The diploid number 2n=20 represents 42,2% of the chromosome counts of Malpighioideae. For Byrsonimoideae the most significant diploid number is 2n=24 with 39,1% of the counts. Fig. 2 shows the distribution of chromosome numbers versus climbing habit for the two subfamilies. Again the diploid number 2n=20 is by far the most important for this habit, with 50,25% of the counts. The non-climber species also presented a peak for 2n=20, with 16,75% of their counts. These species presented peaks in 2n=12 and 2n=24, the latter representing the most important diploid number of the group, with 20,74% of the counts.

Adding the frequency of numbers based on x=6, and comparing the result with the total amount of numbers based on x=5 and 10, showed that x=6 derived numbers account for 62,82% of all non-climbers counts. The diploid number 2n=18 reported for *Acridocarpus* by Mangenot & Mangenot (1962) and Can & McPherson (1986), which could be considered as a triploid based on x=6, is here understood as an aneuploid derivation of 2n=20, based on its winged fruits, which Anderson (1993) considers derived from *Mascagnia*.

The results observed by Lombello & Forni-Martins (1998a) for Sapindaceae showed lower chromosome numbers in more derived species, i.e., those with climbing habits. The present paper reveals peaks of chromosome numbers in both habit types (Fig. 2). The relationship between the habit derivation and the basic number variation is evident, although non-climber species also have a significant peak at 2n=20. This requires further studies and considerations. Climbers only presented one reported chromosome number based on x=6, considering that 2n=42, observed for *Hiptage benghalensis* (Roy & Mishra 1962), is probably a derivation of a tetraploid 2n=4x=40. This only cited climber species belongs to the genus *Stigmaphyllon*, in which only 10% of the chromosome number reports are 2n=24 (Tab. 1).

We also observed that the genera *Banisteriopsis* and *Peixotoa* present climbers and non-climbers species, all based on x=5 and 10. Some shrubby or arboreal species of these genera contributed to the 2n=20 peak (Fig. 2).

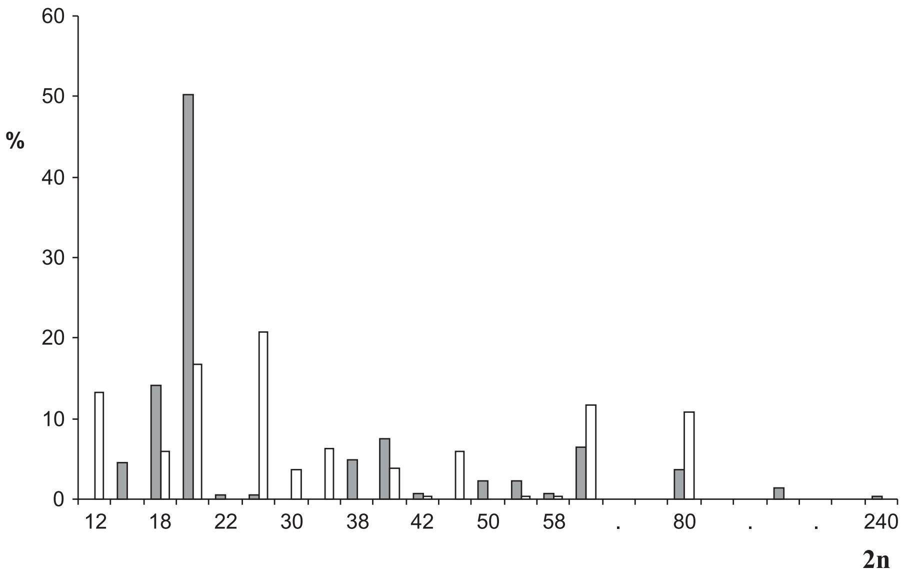

Figure 2. Distribution of weighted relative frequency ($Rf_{i,g}$) of each chromosome number for climber and non-climber genera of Malpighiaceae. ■ Climbers; □ Non-climbers.

Since some genera present habit diversity, we must consider the possibility that habit diversity occurs in some genera here classified as non-climbing, like *Heteropterys*. This occurrence would certainly reduce the significance of the 2n=20 peak in the non-climbers curve.

The distribution of chromosome number frequency related to fruit type variation is similar to that observed above (Fig. 3). However, the winged fruit character is not necessarily linked to climbing habit, as seen for *Dicella* (Tab. 1). Whilst, in genera with non-winged fruits, we almost always observe species based on x=6. Exceptions are *Macvaughia* and *Barnebya*, that show climbers based on x=10.

Given the strong relationship between basic chromosome numbers x=5 and 10 and winged fruits, and between x=6 with non-winged fruits (Fig. 2), we can interpret that the presence of winged fruits as a derived character in Malpighiaceae is a general trend. Since Malpighiaceae is a monophyletic group (Vogel 1990; Judd *et al.* 1999), we can hypothesize that the derivation of basic chromosome numbers x=5 and x=10 is closely related to the evolution of climbing habit and winged fruits.

Even with few chromosome data for the family (no more than 10% of the species have chromosome number reports), the importance of polyploidy is quite clear for Malpighiaceae, since about 75% of the chromosome number reports are polyploid (Tab. 1).

Although Tab. 1 presents some exceptions, the similar chromosome number distribution observed for the two morphological characters analyzed (Figs. 2 and 3) reveals that Malpighiaceae is a model of relationship between evolution of morphological features and chromosome number variation. The sub-family Malpighioideae is characterized by species with climbing habit, winged fruits and basic chromosome numbers based on x=5 and 10. Byrsonimoideae shows predominance of species with arboreal or shrubby habits, non-winged fruit and basic chromosome number x=6. These latter morphological features are related to the least derived basic number in the family.

Acknowledgments

The authors would like to thank Dr. Maria Cândida Mamede, of Instituto de Botânica de São Paulo, for corrections in systematics of Malpighiaceae, and CAPES, for financial support.

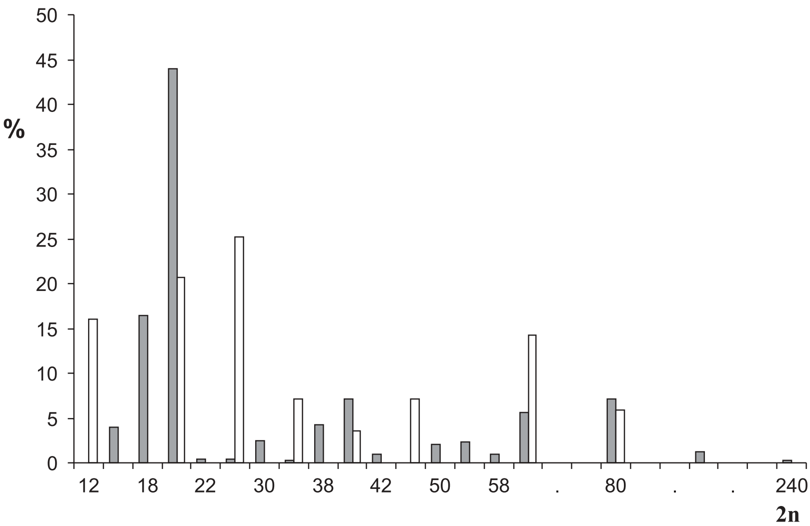

Figure 3. Distribution of weighted relative frequency ($Rf_{i,g}$) of each chromosome number for winged and non-winged fruit genera of Malpighiaceae. ■ Winged; □ Non-Winged.

References

Anderson, W. R. 1977. Byrsonimoideae, a new subfamily of Malpighiaceae. **Biotropica 7**: 5-18.

Anderson, W. R. 1979. *Macvaughia*, a genus new of Malpighiaceae from Brazil. **Taxon 28**(1,2/3): 157-161.

Anderson, W. R. 1983. *Lophanthera*, a genus of Malpighiaceae new to Central America. **Brittonia 35**(1): 37-41.

Anderson, W. R. 1985. *Peregrina*, a genus new of Malpighiaceae from Brazil and Paraguay. **Systematic Botany 10**: 303-307.

Anderson, W. R. 1990. The taxonomy of *Jubelina* (Malpighiaceae). **Contributions to the University of Michigan Herbarium 19**: 341-354.

Anderson, W. R. 1993. Chromosome numbers of neotropical Malpighiaceae. **Contributions to the University of Michigan Herbarium 17**: 21-37.

Bawa, K. S. 1973. Chromosome number of tree species of lowland tropical community. **Journal of the Arnold Arboretum 54**: 422-434.

Bolkhovskikh, Z.; Grif, V.; Matvejeva, T. & Zacharyeva, O. 1969. Chromosome numbers of flowering plants. Pp. 925. In: V. L. Komarov (Ed.). Botanical Inst., Academy of Sciences of the URSS.

Can, G. D. & McPherson, G. 1986. Chromosome numbers of New Caledonian plants. **Annals of the Missouri Botanical Garden 73**: 486-489.

Carlquist, S. 1991. Anatomy of vine and liana stems: a review and synthesis Capt. 2: 53-72. In: F. E. Putz, & H. A. Monney (Eds.). **The biology of vines**. Univ. Cambridge Press, New York.

Desmarchelier, C.; Gurni, A.; Ciccia, G. & Giulietti A.M. 1996. Ritual and medicinal plants of the Ese´ejas of the Amazonian rainforest (Madre de Dios, Peru). **Journal of Ethnopharmacology 52**: 45-51.

Forni-Martins, E. R.; Pinto-Maglio, C. A. & Da Cruz, N. D. 1992. Biologia da reprodução em plantas de cerrado: microsporogênese. **Anais do 8º Congresso da Sociedade Botânica de São Paulo**: 77-82.

Forni-Martins, E. R.; Pinto-Maglio, C. A. & Da Cruz, N. D. 1995. Chromosome numbers in Brazilian cerrado plants. **Revista Brasileira de Genética 18**(2): 281-288.

Gates, B. 1982. *Banisteriopsis*, *Diplopterys* (Malpighiaceae). **Flora Neotropica Monographs 30**: 1-236.

Goldblatt, P. 1981. Index to plant chromosome numbers, 1975-1978. **Monographs on Systematic of the Missouri Botanical Garden** 4.

Goldblatt, P. 1984. Index to plant chromosome numbers, 1979-1981. **Monographs on Systematic of the Missouri Botanical Garden** 8.

Goldblatt, P. 1985. Index to plant chromosome numbers, 1982-1983. **Monographs on Systematic of the Missouri Botanical Garden** 13.

Goldblatt, P. 1988. Index to plant chromosome numbers, 1984-1985. **Monographs on Systematic of the Missouri Botanical Garden** 23.

Goldblatt, P. & Johnson, D.E. 1990. Index to plant chromosome numbers, 1984-1985. **Monographs on Systematic of the Missouri Botanical Garden** 30.

Goldblatt, P. & Johnson, D.E. 1991. Index to plant chromosome numbers, 1988-1989. **Monographs on Systematic of the Missouri Botanical Garden** 40.

Goldblatt, P. & Johnson, D. E. 1994. Index to plant chromosome numbers, 1990-1991. **Monographs on Systematic of the Missouri Botanical Garden** 51.

Goldblatt, P. & Johnson, D. E. 1997. Index to plant chromosome numbers, 1992-1994. **Monographs on Systematic of the Missouri Botanical Garden** 61.

Judd, W. S.; Campbell, C. S.; Kellogg, E. A. & Stevens, P. F. 1999. **Plant systematics, a phylogenetic approach**. Sinauer Assoc., Inc. Publishers, Suderland, Massachusetts, USA.

Lombello, R. A. 2000. **Estudos cromossômicos em Malpighiaceae A. Jussieu**. PhD thesis, Universidade Estadual de Campinas, Campinas.

Lombello, R. A. & Forni-Martins E. R. 1998a. Chromosomal studies and evolution in Sapindaceae. **Caryologia 51** (1): 81-93.

Lombello, R. A. & Forni-Martins E. R. 1998b. Cytological studies in climbers of a Brazilian Forest Reserve. **Cytologia 63**: 415-420.

Lombello, R. A. & Forni-Martins E. R. 2001. Cytological studies on *Banisteriopsis* C.B. Robinson *ex* Small and *Heteropterys* Kunth (Malpighiaceae). **Cytologia 66**: 253-259.

Lorenzi, H. & Souza, H. M. 1999. **Plantas ornamentais do Brasil: arbustivas, herbáceas e trepadeiras** 2ª ed. Instituto Plantarum ed., Nova Odessa.

Mamede, M.C.H. 1990. Revisão do gênero *Camarea* St.-Hilaire (Malpighiaceae). **Hoehnea 17**: 1-34.

Mangenot, S. & Mangenot, G. 1962. Enquête sur les nombres chromosomiques dans une collection d'espèces tropicales. **Reviste du Cytologie et Biologie Végetal 25**(3-4): 411-447.

Mezquita, P. C. & Vigoa, Y. G. 2000. The acerola: marginal fruit from America with a high level of ascorbic acid. **Alimentaria 37**: 113-125.

Moore, R. V. 1973. Index to plant chromosome numbers, 1967-1971. **Regnum Vegetabile 90**: 1-539.

Moore, R. V. 1974. Index to plant chromosome numbers, 1972. **Regnum Vegetabile 91**: 1-108.

Moore, R. V. 1977. Index to plant chromosome numbers, 1973-1974. **Regnum Vegetabile** 96: 1-257.

Morton, C. V. 1968. A typification of some sub-family, sectional and subsectional names in the family Malpighiaceae. **Taxon 17**: 314-324.

Nanda, P.C. 1962. Chromosome number of trees and shrubs. **Jounal of Indian Botanical Society 1**(2): 271-277.

Niedenzu, F. 1928. Malpighiaceae. In: Engler, A. (ed.). **Das Pflanzenreich**. Im Auftrage der Preuss, Akademie der Wissenchaften.

Radford, A. E.; Dickson, W. C.; Massey, J. R. & Bell, C. R. 1974. **Vascular plant systematics**. Harper & Row, New York.

Robertson, K. R. 1972. The Malpighiaceae in the southeastern United States. **Jounal of the Arnold Arboretum 53**(1): 101-112.

Roy, R. P. & Mishra, N. C. 1962. Cytological studies in Malpighiaceae. **Proceedings of the 49th Indian Science Congress 3**: 335.

Vogel, S. 1990. History of the Malpighiaceae in the light of pollination ecology. **Memoirs of the New York Botanical Garden 55**: 130-142.