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Does the selection of medicinal plants by Brazilian local populations suffer taxonomic influence?

Patrícia Muniz de Medeiros [a,b,*], Ana Haydée Ladio [c], André Maurício Melo Santos [d], Ulysses Paulino de Albuquerque [a,**]

[a] Laboratório de Etnobotânica Aplicada, Departamento de Biologia, Universidade Federal Rural de Pernambuco, Rua Dom Manoel de Medeiros s/n, 52171-900 Dois Irmãos, Recife-PE, Brazil

[b] Instituto de Ciências Biológicas e Desenvolvimento Sustentável, Universidade Federal da Bahia, Estrada do Barrocão, s/n, 47800-000 Morada Nobre, Barreiras-BA, Brazil

[c] Laboratorio Ecotono, INIBIOMA (Instituto de Investigaciones en Biodiversidad y Medio Ambiente (CONICET-Universidad Nacional del Comahue), Centro Regional Universitario Bariloche, Quintral 1250, 8400 San Carlos de Bariloche, Río Negro, Argentina

[d] Centro Acadêmico de Vitória, Universidade Federal de Pernambuco, Rua Alto do Reservatório s/n, 50010-921 Vitória de Santo Antão-PE, Brazil

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ABSTRACT

Ethnopharmacological relevance: The analysis of the influence of taxonomic affiliation on the selection of medicinal plants by Brazilian local populations can help elucidate theoretical aspects of medicinal plant selection.

Materials and methods: Ethnobotanical medicinal plant studies were compiled and the resulting medicinal flora was compared to the total angiosperm flora with a Bayesian approach and the IDM model.

Results: A total of 35 families were considered to be overused and six were classified as underused for the Bayesian approach. On the other hand, the IDM model considered 13 families as overused and five as underused (all of them were also highlighted by the Bayesian approach). A high overuse level of Bixaceae, Amaranthaceae, Anacardiaceae and Smilacaceae was recorded for both Bayesian and IDM model, while Orchidaceae, Melastomataceae, Eriocaulaceae, Poaceae and Bromeliaceae were considered as underused for both analyses. The most dissimilar body system in terms of family composition was 'mental and behavioral disorders'. It was also found that the body systems are different from one another in the proportion of taxonomic groups, which could indicate chemical specificity in the treatment of diseases.

Conclusions: Results indicate that the chemical specificity of taxonomic groups directly influences medicinal plant selection. Moreover, when data presented here are compared to other studies, there is clearly an overuse pattern for families like Lamiaceae, Rosaceae and Euphorbiaceae and an underuse pattern for Poaceae and Orchidaceae.

1. Introduction

Ethnobotanical research associated with the study of chemical properties of plant species has become an important tool in bioprospecting. Many studies have associated information about the traditional use of medicinal plants with phytochemical and pharmacological studies for the development of new drugs, and other theoretical investigations have focused on identifying patterns and highlighting species with prospective potential (Heinrich, 2003).

Regarding the latter case, Moerman (1979) proposed and developed the total flora × medicinal flora approach to clarify overused and underused plant families for medicinal purposes in both local and regional contexts (see Moerman 1979, 1991). Moerman's approach is based on the idea that the disproportionately high or low number of medicinal species in certain botanical families constitutes evidence that the selection of species for therapeutic purposes is not performed randomly, but rather concentrated on specific taxa. Moerman and other researchers who used this approach (Amiguet et al., 2006; Bourbonnais-Spear et al., 2005; Leonti et al., 2003; Molares and Ladio, 2009a; Weckerle et al., 2011) discussed the therapeutic efficiency of overused families, strengthening the hypothesis that the selection of medicinal plants by local populations is primarily influenced by their effectiveness.

* Corresponding author at: Instituto de Ciências Biológicas e Desenvolvimento Sustentável, Universidade Federal da Bahia. Estrada do Barrocão, s/n, 47800-000, Morada Nobre, Barreiras-BA, Brazil
** Corresponding author.
E-mail addresses: patricia.muniz@gmail.com, patricia.muniz@ufba.br (P.M.d. Medeiros), upa@db.ufrpe.br (U.P.d. Albuquerque).

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From the perspective of ethnobotany, plausible explanations for this phenomenon are associated with the fact that different societies are able to chemo-taxonomically distinguish the differential properties of plants and culturally interpret these traits to treat important diseases (Leonti et al., 2003; Molander et al., 2012; Molares and Ladio, 2009b). Knowledge of the effectiveness of these plants in the treatment of diseases was culturally transmitted, resulting in the regular use of these species. Evidence of these regularities has become more pronounced, two extreme groups being observed: those of overused families and those of underused families.

From a methodological point of view, a pioneering study by Moerman (1979) has been questioned, since the author used the analysis of residues from a simple linear regression to show overused and underused families. Bennett and Husby (2008) call attention to the statistical inconsistency of this method, suggesting that: (1) it leads to a subjective analysis of what constitutes a residue of high or low value, not being a statistical inference tool, and (2) the analysis is not based on a comparison of the proportion of medicinal species in the family with the total proportion of medicinal species and (3) the independent variable (total number of species per family) contains the dependent variable (number of medicinal species per family). Thus, Bennett and Husby (2008) proposed contingency table analysis (using the chi-squared goodness of fit) to verify whether the distribution of medicinal species among families differs significantly from the expected distribution, plus a binomial analysis *a posteriori* to locate the overused and sub-used families. More recently, Weckerle et al. (2011) proposed the use of Bayesian statistics to identify overused and underused families. The authors state that although results for large datasets tend to be similar for both Bayesian and binomial approaches, the Bayesian approach is more suitable, especially for small samples, since it considers the uncertainty inherent in sampled information of medicinal flora.

An imprecise probability approach was also suggested by Weckerle et al. (2012), based on the IDM (Imprecise Dirichlet Model). According to the authors, this approach does not only consider uncertainty around the data of medicinal flora but also considers uncertainty around the total inventoried flora.

A significant number of studies concerning overused and underused families have been developed in America (Moerman, 1979, 1989, 1991, 1996, 2003; Moerman et al., 1999; Leonti et al., 2003; Bourbonnais-Spear et al., 2005; Hernández et al., 2005; Amiguet et al., 2006; Bennett and Husby, 2008; Thomas et al., 2009; Weckerle et al., 2012), but also in Africa (Douwes et al., 2008; Saslis-Lagoudakis et al., 2011), Asia (Kapur et al., 1992; Moerman et al., 1999; Saslis-Lagoudakis et al., 2011), Europe (Leonti et al., 2009; Weckerle et al., 2011) and Oceania (Saslis-Lagoudakis et al., 2011). The vast majority of these studies suggested the significant overuse of Asteraceae and the low vocation of Poaceae for medicinal purposes, among many other similarities that indicate a potential pattern.

However, there has been little effort made to determine whether these patterns change with different therapeutic indications. Hernández et al. (2005) focused solely on gastrointestinal disorders and observed patterns similar to other studies that have considered all indications, which included the overuse of Asteraceae and Lamiaceae, among others. However, Moerman (1991) conducted individual analyses using body systems and observed great differences between overused and underused families in each system. Weckerle et al. (2011) also observed that specific medicinal uses were associated with specific taxa, for example, monocotyledonous plants are specifically used for urological problems. Leonti et al. (2003) also observed the predominant use of monocots in the treatment of urological problems.

To further elucidate species patterns/differences and provide insight into the use of botanical families for each body system, this study analyzed Brazilian medicinal flora, considering the following questions:

(1) Are there botanical families overused and underused by Brazilian local populations for medicinal purposes? If so, which ones? Hypothesis: Some plant families will be overused and others will be underused for medicinal purposes.

(2) Which body systems are most similar in terms of the repertoire of families used to treat them?

(3) Are different body systems treated with families from distinct taxonomic groups? Hypothesis: Body systems will differ with respect to the proportion of families belonging to the higher taxonomic groups.

Brazil offers an interesting context for research, as the country contains great plant diversity, with an extensive number of species. In addition, a broad range of urban and rural communities lie within this country, leading to rich cultural diversity.

2. Methods

2.1. General characterization of the systematic review

This study was based on a systematic review (Cooper, 2009). We included ethnobotanical or ethnopharmacological works that addressed the use of medicinal plants by local communities. Brazilian ethnobotanical studies do not generally distinguish plants that are known for a particular purpose from those that are actually used (Ramos et al., 2008). Therefore, as there is no information available to interpret this distinction, we chose to treat these species as a single category, and so the search results refer to the knowledge and/or use of medicinal plants.

2.2. Criteria for study inclusion

Studies concerning only medicinal plants, as well as those that considered various categories of use were included in the review. In the latter case, the information for these studies was filtered so that only medical uses were considered. Review papers were excluded, but their references were used as a basis for the search for original articles. There were also studies that had used the same dataset or had been developed in the same community by authors from the same research group. In these cases, the studies with the most complete and detailed information were selected.

Studies with at least one botanical family were included in the review, although works with only one or a few species were disregarded. Studies focusing on one or a few indications were also included.

A methodological approach was used to determine the inclusion criteria so that only studies that had used systematic tools of data collection, such as structured or semi-structured interviews or free lists, were considered. Studies that did not mention the methodology of data collection were excluded. Moreover, studies that did not report the scientific names of species or did not show the therapeutic indications of each plant were also excluded.

2.3. Strategy of literature search

The major databases and publishers of scientific journals (Scopus, Scirus and Scielo) were consulted and, in some cases, periodicals containing a large body of information concerning ethnobotany (Economic Botany, Journal of Ethnobiology and Ethnomedicine, Ethnobotany Research and Applications, Journal of Ethnobiology, Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas, Acta Botanica Brasilica, Revista Brasileira de Plantas Medicinais e Revista Brasileira de Farmacognosia) were used.

2.4. Methods of study selection

Studies acquired from the literature search were screened, and those that were consistent with the initial criteria for inclusion were classified according to their risk of bias as 'Low-', 'Moderate-' and 'High-risk' in accordance with the following additional criteria:

A) Classification criteria for the three degrees of risk of bias

- Sample reliability—high risk of bias for low reliability; moderate risk of bias for intermediate reliability and low risk of bias for high reliability. Details of the criteria for this classification can be accessed in Medeiros (2012). The main reasons for considering studies as highly biased were the lack of information about the sample size or the universe in case of generalist surveys and the lack of information about the criteria for informant selection in case of intentional samples.
- Identification of botanical material—high risk of bias when less than 60% of taxa were identified at species level; moderate risk of bias when 60–80% of taxa were identified; and low risk of bias when more than 80% of taxa were identified.

B) Criteria applied only to turn a low risk of bias into a moderate risk of bias)

- No specification that the material was identified by herbarium exsiccates.
- Presentation of a partial list of the species used (e.g., only the 20 most commonly cited). Studies with complete lists or plants mentioned by at least 80% of respondents maintained a low risk of bias.
- Presence of excerpts concerning the habits, distribution, therapeutic indications or taxonomic groups, e.g., studies with only herbaceous, forest species or Cactaceae for the treatment of malaria.

Studies with low and moderate risks of bias were selected for analysis, while studies with a high risk of bias were not taken into account in this research.

2.5. Data treatment

Among the taxa recorded in each study, only the angiosperms identified at species level and listed as native on the Lista de Espécies da Flora do Brasil (Lista de Espécies da Flora do Brasil, 2012) were included in the database (Forzza et al., 2010). Thus, exotic species were not part of this research, as the objective was to evaluate native flora. Citations for cultural diseases, i.e., phenomena interpreted as diseases, but without a known cause for biomedicine, were also excluded (Pinto et al., 2006).

Despite having previously been classified in the APG III (The Angiosperm Phylogeny Group, 2009), the botanical families were classified according to the APG II system (The Angiosperm Phylogeny Group, 2003) for the database of the Flora of Brazil—2010 version. The World Health Organization classification (WHO, 2010) was used to group the therapeutic indications into body systems. These body systems are 'infectious and parasitic diseases'; 'disorders of the genitourinary system'; 'problems from external causes'; 'disorders of the respiratory system'; 'disorders of the circulatory system'; 'disorders of the musculoskeletal system'; 'disorders of the digestive system'; 'mental and behavioral disorders'; 'nutritional and metabolic disorders'; 'blood, hematopoietic and immune system disorders'; 'skin and subcutaneous tissue diseases'; 'pregnancy, childbirth and the puerperium'; 'factors influencing health status'; 'diseases of the eye and adnexa'; 'diseases of the ear and mastoid process'; 'conditions originating in the perinatal period'; 'neoplasms'; 'diseases of the nervous system', and 'symptoms and signs not elsewhere classified'.

2.6. Data analysis

To analyze whether botanical families depart from the expected proportion of medicinal species for the complete flora, we applied a Bayesian method based on Weckerle et al. (2011) and the IDM model based on Weckerle et al. (2012). We used the Excel function BETAINV (INV.BETA for Excel 21010) to calculate the interval of the most probable values of θ (proportion of medicinal species for the flora as a whole) and θj (proportion of medicinal species for a family j). We used an inferior and superior 95% probability credible interval. When the inferior limit of θj > superior limit of θ, a family is considered to be overused. On the other hand, when the superior limit of θj is < inferior limit of θ, a family can be considered as underused. Any other behavior (with a certain overlap between θj and θ limits) indicates that the family behaves according to the proportion of the complete flora. Bayesian and IDM models as calculated in Excel have different formulas, but are both calculated with the BETAINV function. More information about the theoretical aspects behind the application of these methods can be found in Weckerle et al. (2011, 2012).

To analyze whether body systems are different from one another in the proportion of taxonomic groups used to treat them, we performed a Chi-squared test on a contingency table. As many values in the contingency tables were lower than 5, we adjusted the p-value with Monte Carlo simulations (Bennett and Husby, 2008)

A similarity matrix was generated using the similarity index of Bray–Curtis, which is equivalent to the Sorensen similarity index for binary data, to determine the degree of similarity between body systems with regard to the presence and absence of the botanical families used to treat them. A cluster analysis was then performed with this similarity matrix (UPGMA mode). Another cluster analysis was performed, now considering a complete matrix with the number of species used for each family in each body system. These data generated a standardized similarity matrix (Bray–Curtis similarity) which were used for the cluster analysis (UPGMA mode). Cluster analysis was performed in the Software Primer 5 (Primer-E Ltd.), while the chi-square was developed in the R software version 2.13.2 (the R Foundation for Statistical Computing).

3. Results

3.1. Medicinal flora × total flora

A total of 126 articles met the criteria for study inclusion. Among them, however, 92 were deemed to have a high risk of bias, while 28 had a moderate risk of bias, and six had a low risk of bias. Specific information concerning the reasons for this elevated number of high-risk ethnobotanical studies developed in Brazil can be found in Medeiros (2012). The 34 articles that were part of this analysis were Brandão et al. (1992, 2006), Begossi et al. (1993), Hanazaki et al. (2006), Rizzo et al. (1999), Dorgioni et al. (2001), Garlet and Irgang (2001), Albuquerque and Andrade (2002), Ritter et al. (2002), Vila Verde et al. (2003), Andrade et al. (2006), Franco and Barros (2006), Freitas and Fernandes (2006), Maciel and Guarim-Neto (2006), Pilla et al. (2006), Vendruscolo and Mentz (2006), Lima et al. (2007), Macedo et al. (2007), Negrelle Fornazzari (2007), Oliveira et al. (2007), Souza (2007), Almeida et al. (2009), Baldauf et al. (2009), Cruz-Silva et al. (2009), Lima et al. (2009), Moreira and Guarim-Neto (2009), Pereira et al. (2009), Ustulin et al. (2009), Albertasse et al. (2010), Cartaxo et al. (2010), Merétika et al. (2010), Oliveira et al. (2010), Roque et al. (2010) and Silva et al. (2011). Together, these articles address the main Brazilian ecosystems (Amazon, Atlantic forest, Cerrado, Caatinga, Pampas and Mata dos cocais), with the exception of the Pantanal (wetlands).

The overused and underused higher taxonomic groups are listed in Table 1. The clades 'Core Eudicots', 'Eurosids I' and 'Eurosids II' were considered to be overused, while 'Commelinids' and 'Monocots' were the underused groups. The Bayesian and the IDM model indicated exactly the same clades as overused and underused.

The overused and underused medicinal plant families are shown in Table 2. For the Bayesian approach a total of 35 families were considered overused, while six families were classified as underused. The overused families with a higher difference (margin) between the interval of θ (0.0145, 0.0173) and the inferior interval of θj were Bixaceae, Adoxaceae, Plumbaginaceae, Anacardiaceae and Smilacaceae. The underused families with a higher margin between the interval of θ and the superior interval of θj were Orchidaceae, Melastomataceae, Eriocaulaceae, Poaceae and Bromeliaceae (Table 2).

The IDM model was more conservative, as it indicated a total of 13 families as overused and five as underused. The overused families with a higher difference (margin) between the interval of θ (0.0144, 0.0174) and the inferior interval of θj were Anacardiaceae, Smilacaceae, Simaroubaceae, Amaranthaceae and Bixaceae. The ranking of underused families for the IDM model according to the margin between the interval of θ and the superior interval of θj highlights the family Orchidaceae, followed by Melastomataceae, Poaceae, Eriocaulaceae and Bromeliaceae (Table 2).

All the overused families for the IDM model were also overused for the Bayesian approach and the same happened to the underused families. The more conservative nature of the IDM model led to a lower number of overused families. Nevertheless, the only difference in underuse between the two approaches was the inclusion of the family Acanthaceae in the Bayesian approach.

3.2. Medicinal flora by body system: cluster analysis

The body systems that relied on more than 15 families were: 'infectious and parasitic diseases'; 'disorders of the genitourinary system'; 'problems from external causes'; 'disorders of the respiratory system'; 'disorders of the circulatory system'; 'disorders of the musculoskeletal system'; 'disorders of the digestive system'; 'mental and behavioral disorders'; 'nutritional and metabolic disorders'; 'blood, hematopoietic and immune system disorders' and 'skin and subcutaneous tissue diseases'.

For the binary matrix, similarity between body systems varied from 42.1% ('mental and behavioral disorders' and 'disorders of the musculoskeletal system') to 76.1% ('disorders of the circulatory system' and 'disorders of the genitourinary system'). The body system most dissimilar to the others was 'mental and behavioral disorders' (Fig. 1), which had a lower total number of medicinal families and showed strong differences in the repertoire of families when compared to the other body systems (e.g., the use of the family Siparunaceae and non-use of the family Anacardiaceae). When the complete matrix with the number of species per family is considered, similarity varies from 38.2% ('mental and behavioral disorders' and 'skin and subcutaneous diseases') to 71.3% ('disorders of the respiratory system' and 'infectious and parasitic diseases').

3.3. Medicinal flora by body system: comparisons of the proportion of higher groups

The chi-squared test showed a significant difference between body systems in the proportion of taxonomic groups used to treat them (chi-square=133.99; $p < 0.05$). It indicates that body systems are somehow different from one another regarding elements used for their treatment.

4. Discussion

4.1. Medicinal flora × total flora

The result found in our study is consistent with the hypothesis that species are not evenly chosen as medicinal and that several families are favored by carrying a proportionally higher number of applicable medicinal species, whereas other families contain fewer members of these species. Thus, we can infer that people select species with greater medical effectiveness, and that this differential selection influences the medicinal importance of botany families.

There is evidence in other parts of the world that the use of medicinal plants by local populations is not random. Studies conducted in Ecuador (Bennett and Husby, 2008), Bolivia (Thomas et al., 2009) and Italy (Leonti et al., 2009) also showed

Table 1
Over- and underused higher taxonomic groups (APGII classification) for the Brazilian flora. n_j, number of species for the group J; x_j, number of medicinal species for group J; inf(B), inferior limit for the Bayesian approach; sup(B), superior limit for the Bayesian approach; status(B), status for the Bayesian approach; inf(I), inferior limit for the IDM model; sup(I), superior limit for the IDM model; status(I), status for the IDM model; under, underused family; over, overused family.

Family (J)	n_j	x_j	inf(B)	sup(B)	status(B)	inf(I)	sup(I)	status(I)
Asterids	766	6	0.0037	0.0169	Ns	0.0029	0.0221	Ns
Commelinids	4545	33	0.0052	0.0102	Under	0.0050	0.0109	Under
Core Eudicots	918	34	0.0267	0.0513	Over	0.0257	0.0550	Over
Euasterids I	5317	92	0.0141	0.0212	Ns	0.0140	0.0218	Ns
Euasterids II	2242	45	0.0151	0.0268	Ns	0.0147	0.0282	Ns
Eudicots	168	6	0.0168	0.0757	Ns	0.0130	0.0976	Ns
Eurosids I	6921	146	0.018	0.0248	Over	0.0178	0.0252	Over
Eurosids II	1689	50	0.0225	0.0388	Over	0.0220	0.0408	Over
Magnoliids	1483	25	0.0115	0.0248	Ns	0.0109	0.0271	Ns
Monocots	3731	15	0.0025	0.0066	Under	0.0023	0.0076	Under
Rosids	2812	32	0.0081	0.016	Ns	0.0078	0.0172	Ns
Unplaced	46	0	0.0005	0.0755	Ns	0.0000	0.1687	Ns
Total/common	***n***	***x***	**inf(*B*)**	**sup(*B*)**		**inf(*I*)**	**sup(*I*)**	
	30,638	484	0.0145	0.0173		0.0144	0.0174	

Table 2
Over- and underused families of the Brazilian flora. n_j, number of species for a family J; x_j, number of medicinal species for family J; inf(B), inferior limit for the Bayesian approach; sup(B), superior limit for the Bayesian approach; status(B), status for the Bayesian approach; inf(I), inferior limit for the IDM model; sup(I), superior limit for the IDM model; status(I), status for the IDM model; under: underused family; over: overused family.

Family (J)	n_j	x_j	inf(B)	sup(B)	status(B)	inf(I)	sup(I)	status(I)
Acanthaceae	428	1	0.0006	0.0129	Under	0.0001	0.0236	Ns
Achariaceae	17	0	0.0014	0.1853	Ns	0.0000	0.3789	Ns
Achatocarpaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Adoxaceae	2	1	0.0943	0.9057	Over	0.0051	0.9949	Ns
Agavaceae	13	1	0.0178	0.3387	Over	0.0016	0.5238	Ns
Aizoaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Alismataceae	30	2	0.0204	0.2142	Over	0.0074	0.3190	Ns
Alliaceae	29	0	0.0008	0.1157	Ns	0.0000	0.2502	Ns
Alstroemeriaceae	44	0	0.0006	0.0787	Ns	0.0000	0.1754	Ns
Amaranthaceae	132	9	0.0366	0.1246	Over	0.0309	0.1501	Over
Amaryllidaceae	103	0	0.0002	0.0348	Ns	0.0000	0.0805	Ns
Anacardiaceae	55	9	0.0891	0.2833	Over	0.0735	0.3335	Over
Anisophylleaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Annonaceae	385	8	0.0107	0.0404	Ns	0.0089	0.0502	Ns
Apiaceae	68	2	0.0091	0.1008	Ns	0.0034	0.1567	Ns
Apocynaceae	753	11	0.0082	0.026	Ns	0.0073	0.0309	Ns
Apodanthaceae	9	0	0.0025	0.3085	Ns	0.0000	0.5719	Ns
Aquifoliaceae	63	0	0.0004	0.056	Ns	0.0000	0.1271	Ns
Araceae	457	3	0.0024	0.019	Ns	0.0013	0.0282	Ns
Araliaceae	89	0	0.0003	0.0402	Ns	0.0000	0.0924	Ns
Arecaceae	264	7	0.0131	0.0537	Ns	0.0106	0.0678	Ns
Aristolochiaceae	89	4	0.0183	0.1099	Over	0.0120	0.1505	Ns
Asteraceae	1925	42	0.0162	0.0294	Ns	0.0157	0.0311	Ns
Balanophoraceae	11	0	0.0021	0.2646	Ns	0.0000	0.5080	Ns
Basellaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Bataceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Begoniaceae	208	2	0.003	0.0341	Ns	0.0011	0.0544	Ns
Berberidaceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Bignoniaceae	390	14	0.0216	0.0593	Over	0.0196	0.0684	Over
Bixaceae	6	2	0.099	0.7096	Over	0.0281	0.8630	Over
Bonnetiaceae	8	0	0.0028	0.3363	Ns	0.0000	0.6097	Ns
Boraginaceae	121	7	0.0287	0.1146	Over	0.0230	0.1433	Over
Brassicaceae	3	1	0.0676	0.8059	Over	0.0042	0.9567	Ns
Bromeliaceae	1205	6	0.0023	0.0108	Under	0.0018	0.0141	Under
Brunelliaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Burmanniaceae	26	0	0.0009	0.1277	Ns	0.0000	0.2735	Ns
Burseraceae	100	3	0.0109	0.0844	Ns	0.0060	0.1225	Ns
Cabombaceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Cactaceae	221	7	0.0157	0.0639	Ns	0.0127	0.0806	Ns
Calceolariaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Calyceraceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Campanulaceae	55	0	0.0005	0.0638	Ns	0.0000	0.1438	Ns
Canellaceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Cannabaceae	7	0	0.0032	0.3694	Ns	0.0000	0.6525	Ns
Cannaceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Capparaceae	55	3	0.0198	0.1487	Over	0.0108	0.2117	Ns
Cardiopteridaceae	8	0	0.0028	0.3363	Ns	0.0000	0.6097	Ns
Caricaceae	8	0	0.0028	0.3363	Ns	0.0000	0.6097	Ns
Caryocaraceae	16	2	0.038	0.3644	Over	0.0130	0.5120	Ns
Caryophyllaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Celastraceae	134	3	0.0081	0.0636	Ns	0.0045	0.0929	Ns
Ceratophyllaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Chloranthaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Chrysobalanaceae	278	2	0.0022	0.0257	Ns	0.0009	0.0410	Ns
Cistaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Clethraceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Clusiaceae	203	2	0.003	0.035	Ns	0.0012	0.0557	Ns
Combretaceae	78	2	0.0079	0.0885	Ns	0.0030	0.1382	Ns
Commelinaceae	73	4	0.0223	0.1327	Over	0.0145	0.1806	Ns
Connaraceae	69	0	0.0004	0.0513	Ns	0.0000	0.1170	Ns
Convolvulaceae	322	5	0.0068	0.0358	Ns	0.0050	0.0479	Ns
Costaceae	23	2	0.0266	0.27	Over	0.0095	0.3935	Ns
Crassulaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Cucurbitaceae	145	7	0.024	0.0963	Over	0.0192	0.1207	Over
Cunoniaceae	10	0	0.0023	0.2849	Ns	0.0000	0.5381	Ns
Cyclanthaceae	28	0	0.0009	0.1194	Ns	0.0000	0.2575	Ns
Cymodoceaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Cyperaceae	590	7	0.0059	0.0243	Ns	0.0048	0.0308	Ns
Cyrillaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Dichapetalaceae	24	0	0.001	0.1372	Ns	0.0000	0.2916	Ns
Dilleniaceae	82	3	0.0133	0.102	Ns	0.0073	0.1473	Ns
Dioscoreaceae	127	1	0.0019	0.0428	Ns	0.0002	0.0769	Ns
Droseraceae	14	0	0.0017	0.218	Ns	0.0000	0.4343	Ns

Table 2 (*continued*)

Family (*J*)	n_j	x_j	inf(*B*)	sup(*B*)	status(*B*)	inf(*I*)	sup(*I*)	status(*I*)
Ebenaceae	58	0	0.0004	0.0606	Ns	0.0000	0.1371	Ns
Elaeocarpaceae	41	0	0.0006	0.0841	Ns	0.0000	0.1866	Ns
Elatinacae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Ericaceae	95	0	0.0003	0.0377	Ns	0.0000	0.0869	Ns
Eriocaulaceae	629	0	0	0.0058	Under	0.0000	0.0138	Under
Erythroxylaceae	114	0	0.0002	0.0316	Ns	0.0000	0.0731	Ns
Escalloniaceae	9	0	0.0025	0.3085	Ns	0.0000	0.5719	Ns
Euphorbiaceae	765	27	0.0244	0.0509	Over	0.0233	0.0553	Over
Euphroniaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Fabaceae	2653	63	0.0186	0.0303	Over	0.0183	0.0315	Over
Gelsemiaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Gentianaceae	114	0	0.0002	0.0316	Ns	0.0000	0.0731	Ns
Geraniaceae	8	0	0.0028	0.3363	Ns	0.0000	0.6097	Ns
Gesneriaceae	207	0	0.0001	0.0176	Ns	0.0000	0.0412	Ns
Goodeniaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Goupiaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Griseliniaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Gunneraceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Haemodoraceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Haloragaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Heliconiaceae	29	0	0.0008	0.1157	Ns	0.0000	0.2502	Ns
Hernandiaceae	12	0	0.0019	0.2471	Ns	0.0000	0.4809	Ns
Humiriaceae	35	0	0.0007	0.0974	Ns	0.0000	0.2138	Ns
Hydnoraceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Hydrocharitaceae	14	0	0.0017	0.218	Ns	0.0000	0.4343	Ns
Hydroleaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Hypericaceae	50	1	0.0048	0.1045	Ns	0.0005	0.1821	Ns
Hypoxidaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Icacinaceae	20	0	0.0012	0.1611	Ns	0.0000	0.3359	Ns
Iridaceae	158	2	0.0039	0.0447	Ns	0.0015	0.0710	Ns
Ixonanthaceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Juncaceae	23	0	0.0011	0.1425	Ns	0.0000	0.3015	Ns
Juncaginaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Krameriaceae	5	0	0.0042	0.4593	Ns	0.0000	0.7551	Ns
Lacistemataceae	11	0	0.0021	0.2646	Ns	0.0000	0.5080	Ns
Lamiaceae	482	14	0.0175	0.0482	Over	0.0159	0.0555	Ns
Lauraceae	417	2	0.0015	0.0172	Ns	0.0006	0.0276	Ns
Laxmanniaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Lecythidaceae	118	3	0.0092	0.0719	Ns	0.0051	0.1048	Ns
Lentibulariaceae	76	0	0.0003	0.0468	Ns	0.0000	0.1070	Ns
Limnocharitaceae	5	0	0.0042	0.4593	Ns	0.0000	0.7551	Ns
Linaceae	12	0	0.0019	0.2471	Ns	0.0000	0.4809	Ns
Linderniaceae	8	0	0.0028	0.3363	Ns	0.0000	0.6097	Ns
Loasaceae	14	0	0.0017	0.218	Ns	0.0000	0.4343	Ns
Loganiaceae	115	1	0.0021	0.0471	Ns	0.0002	0.0845	Ns
Loranthaceae	144	2	0.0043	0.0489	Ns	0.0017	0.0776	Ns
Lythraceae	201	6	0.014	0.0635	Ns	0.0109	0.0821	Ns
Magnoliaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Malpighiaceae	528	6	0.0053	0.0245	Ns	0.0042	0.0319	Ns
Malvaceae	724	15	0.0127	0.0339	Ns	0.0116	0.0388	Ns
Marantaceae	198	0	0.0001	0.0184	Ns	0.0000	0.0430	Ns
Marcgraviaceae	38	0	0.0006	0.0903	Ns	0.0000	0.1992	Ns
Martyniaceae	3	1	0.0676	0.8059	Over	0.0042	0.9567	Ns
Mayacaceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Melastomataceae	1312	0	0	0.0028	Under	0.0000	0.0067	Under
Meliaceae	79	3	0.0138	0.1057	Ns	0.0076	0.1525	Ns
Menispermaceae	110	6	0.0257	0.1139	Over	0.0197	0.1458	Over
Menyanthaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Molluginaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Monimiaceae	43	0	0.0006	0.0804	Ns	0.0000	0.1790	Ns
Moraceae	196	4	0.0083	0.0512	Ns	0.0055	0.0711	Ns
Muntingiaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Myoporaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Myristicaceae	63	0	0.0004	0.056	Ns	0.0000	0.1271	Ns
Myrsinaceae	120	0	0.0002	0.03	Ns	0.0000	0.0696	Ns
Myrtaceae	921	15	0.01	0.0267	Ns	0.0091	0.0306	Ns
Nyctaginaceae	44	1	0.0054	0.1177	Ns	0.0005	0.2038	Ns
Nymphaeaceae	16	0	0.0015	0.1951	Ns	0.0000	0.3958	Ns
Ochnaceae	197	0	0.0001	0.0185	Ns	0.0000	0.0432	Ns
Olacaceae	53	1	0.0045	0.0989	Ns	0.0005	0.1729	Ns
Oleaceae	11	0	0.0021	0.2646	Ns	0.0000	0.5080	Ns
Onagraceae	61	0	0.0004	0.0578	Ns	0.0000	0.1309	Ns
Opiliaceae	5	0	0.0042	0.4593	Ns	0.0000	0.7551	Ns
Orchidaceae	2414	1	0.0001	0.0023	Under	0.0000	0.0042	Under
Orobanchaceae	39	0	0.0006	0.0881	Ns	0.0000	0.1948	Ns
Oxalidaceae	95	1	0.0025	0.0567	Ns	0.0003	0.1012	Ns

Table 2 (*continued*)

Family (*J*)	n_j	x_j	inf(*B*)	sup(*B*)	status(*B*)	inf(*I*)	sup(*I*)	status(*I*)
Passifloraceae	133	4	0.0122	0.0747	Ns	0.0081	0.1032	Ns
Pentaphylacaceae	19	0	0.0013	0.1684	Ns	0.0000	0.3491	Ns
Peraceae	17	0	0.0014	0.1853	Ns	0.0000	0.3789	Ns
Peridiscaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Phyllanthaceae	117	4	0.0139	0.0845	Ns	0.0092	0.1165	Ns
Phytolaccaceae	20	1	0.0117	0.2382	Ns	0.0011	0.3878	Ns
Picramniaceae	21	0	0.0012	0.1544	Ns	0.0000	0.3236	Ns
Picrodendraceae	4	0	0.0051	0.5218	Ns	0.0000	0.8159	Ns
Piperaceae	444	8	0.0093	0.0351	Ns	0.0078	0.0436	Ns
Plantaginaceae	101	4	0.0161	0.0974	Ns	0.0106	0.1338	Ns
Plumbaginaceae	2	1	0.0943	0.9057	Over	0.0051	0.9949	Ns
Poaceae	1227	5	0.0018	0.0095	Under	0.0013	0.0128	Under
Podostemaceae	86	0	0.0003	0.0415	Ns	0.0000	0.0954	Ns
Polygalaceae	185	3	0.0059	0.0464	Ns	0.0033	0.0682	Ns
Polygonaceae	86	4	0.0189	0.1136	Over	0.0124	0.1554	Ns
Pontederiaceae	19	0	0.0013	0.1684	Ns	0.0000	0.3491	Ns
Portulacaceae	15	2	0.0405	0.3835	Over	0.0138	0.5348	Ns
Potamogetonaceae	10	0	0.0023	0.2849	Ns	0.0000	0.5381	Ns
Proteaceae	33	0	0.0007	0.1028	Ns	0.0000	0.2247	Ns
Putranjivaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Quiinaceae	39	0	0.0006	0.0881	Ns	0.0000	0.1948	Ns
Quillajaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Ranunculaceae	11	0	0.0021	0.2646	Ns	0.0000	0.5080	Ns
Rapateaceae	35	0	0.0007	0.0974	Ns	0.0000	0.2138	Ns
Rhabdodendraceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Rhamnaceae	45	3	0.0242	0.179	Over	0.0131	0.2525	Ns
Rhizophoraceae	10	0	0.0023	0.2849	Ns	0.0000	0.5381	Ns
Rosaceae	21	2	0.0291	0.2916	Over	0.0103	0.4215	Ns
Rubiaceae	1344	16	0.0074	0.0192	Ns	0.0068	0.0219	Ns
Ruppiaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Rutaceae	189	3	0.0058	0.0454	Ns	0.0032	0.0668	Ns
Sabiaceae	10	0	0.0023	0.2849	Ns	0.0000	0.5381	Ns
Salicaceae	96	3	0.0113	0.0877	Ns	0.0063	0.1273	Ns
Santalaceae	78	3	0.014	0.107	Ns	0.0077	0.1543	Ns
Sapindaceae	408	5	0.0054	0.0283	Ns	0.0040	0.0380	Ns
Sapotaceae	220	1	0.0011	0.025	Ns	0.0001	0.0453	Ns
Sarraceniaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Schlegeliaceae	7	0	0.0032	0.3694	Ns	0.0000	0.6525	Ns
Schoepfiaceae	3	0	0.0063	0.6024	Ns	0.0000	0.8819	Ns
Scrophulariaceae	16	0	0.0015	0.1951	Ns	0.0000	0.3958	Ns
Simaroubaceae	28	4	0.0585	0.3166	Over	0.0363	0.4110	Over
Siparunaceae	20	2	0.0305	0.3038	Over	0.0107	0.4370	Ns
Smilacaceae	32	5	0.0698	0.319	Over	0.0481	0.4014	Over
Solanaceae	452	7	0.0077	0.0316	Ns	0.0062	0.0400	Ns
Staphyleaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Stemonuraceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Strelitziaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Styracaceae	23	0	0.0011	0.1425	Ns	0.0000	0.3015	Ns
Surianaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Symplocaceae	40	1	0.006	0.1286	Ns	0.0006	0.2214	Ns
Taccaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Tetrameristaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Theaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Theophrastaceae	14	1	0.0166	0.3195	Ns	0.0015	0.4990	Ns
Thismiaceae	8	0	0.0028	0.3363	Ns	0.0000	0.6097	Ns
Thurniaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Thymelaeaceae	26	1	0.0091	0.1897	Ns	0.0009	0.3166	Ns
Trigoniaceae	20	0	0.0012	0.1611	Ns	0.0000	0.3359	Ns
Triuridaceae	11	0	0.0021	0.2646	Ns	0.0000	0.5080	Ns
Tropaeolaceae	5	1	0.0433	0.6412	Over	0.0032	0.8430	Ns
Turneraceae	155	1	0.0016	0.0352	Ns	0.0002	0.0635	Ns
Typhaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Ulmaceae	6	0	0.0036	0.4096	Ns	0.0000	0.7007	Ns
Urticaceae	89	5	0.0249	0.1249	Over	0.0179	0.1642	Over
Valerianaceae	15	0	0.0016	0.2059	Ns	0.0000	0.4142	Ns
Velloziaceae	211	0	0.0001	0.0172	Ns	0.0000	0.0404	Ns
Verbenaceae	302	11	0.0206	0.064	Over	0.0181	0.0758	Over
Violaceae	72	1	0.0033	0.074	Ns	0.0003	0.1310	Ns
Vitaceae	48	3	0.0227	0.1687	Over	0.0123	0.2387	Ns
Vivianiaceae	1	0	0.0126	0.8419	Ns	0.0000	0.9937	Ns
Vochysiaceae	160	6	0.0177	0.0793	Over	0.0136	0.1022	Ns
Winteraceae	3	1	0.0676	0.8059	Over	0.0042	0.9567	Ns
Xyridaceae	179	0	0.0001	0.0203	Ns	0.0000	0.0474	Ns
Zingiberaceae	23	2	0.0266	0.27	Over	0.0095	0.3935	Ns
Zygophyllaceae	2	0	0.0084	0.7076	Ns	0.0000	0.9473	Ns
Total			0.0145	0.0173		0.0144	0.0174	

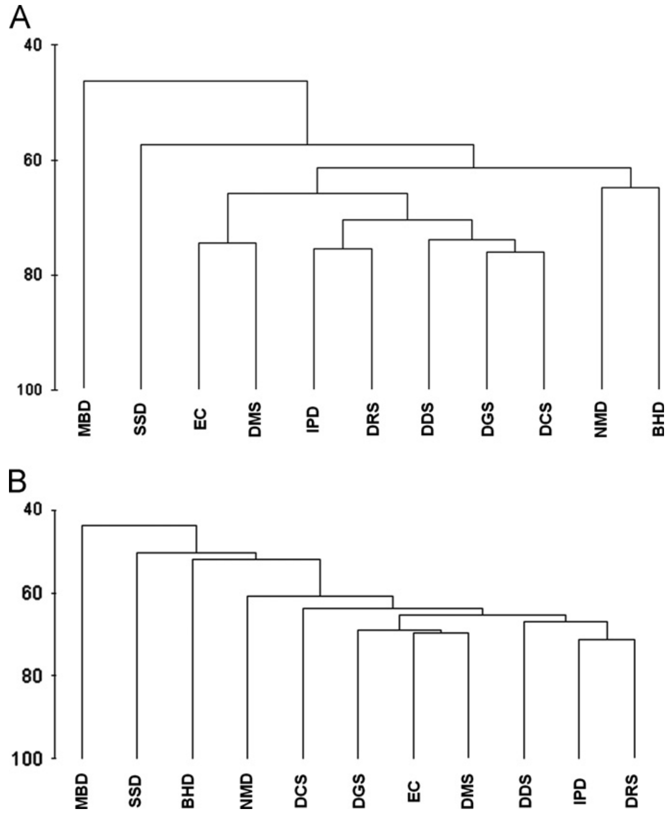

Fig. 1. Cluster analysis (Sorensen, UPGMA) among body systems treated by species from the Brazilian flora. The cluster analysis was based on similarity matrices with the body systems as objects and botanical families used to treat them as descriptors. A, binary matrix (presence/absence of families to treat the body systems); B, complete matrix (number of species in each family to treat each body system); MBD, mental and behavioral disorders; MND, nutritional and metabolic disorders; SSD, skin and subcutaneous tissue diseases; DCS, disorders of the circulatory system; DDS, disorders of the digestive system; DGS, disorders of the genitourinary system; BHD, blood, hematopoietic and immune system disorders; DMS, disorders of the musculoskeletal system; DRS, disorders of the respiratory system; EC, external causes; IPD, infectious and parasitic diseases.

that the distribution of medicinal species in families is significantly distant from the null hypothesis (with distribution proportional to the size of families). Although investigations using residual analysis cannot properly make statistical inferences about the degree of discrepancy in the distribution of medicinal plants in relation to the null hypothesis, the presence of underused and overused families is also an indication of non-randomness in the medical use of plants. This result can be observed in virtually all studies that address this issue (Moerman, 1979, 1989, 1991, 1996, 2003; Kapur et al., 1992; Moerman et al., 1999; Leonti et al., 2003; Bourbonnais-Spear et al., 2005; Hernández et al., 2005; Amiguet et al., 2006; Douwes et al., 2008; Saslis-Lagoudakis et al., 2011). With regard to underused and overused families, the results of our study were consistent with those observed in the literature. Almost all previous studies showed that at least one of the prominent families identified in our study was overused (Moerman, 1979, 1989, 1991, 1996, 2003; Kapur et al., 1992; Moerman et al., 1999; Leonti et al., 2003; Bourbonnais-Spear et al., 2005; Hernández et al., 2005; Bennett and Husby, 2008; Douwes et al., 2008; Leonti et al., 2009; Saslis-Lagoudakis et al., 2011; Weckerle et al., 2011, 2012). Regarding underuse, the vast majority of previous studies considered here had at least one underused family which was also so defined in our study.

The family Bixaceae, whose expected proportions of medicinal species departed most from the margin of θ (Bayesian approach), has few species in the Brazilian medicinal flora. Some Bixaceae species, such as *Bixa orellana* L. are known for their antimicrobial activity (Irobi et al., 1996; Fleischer et al., 2003), which justifies their use for respiratory diseases by local Brazilian populations. An antimicrobial effect was also found in *Cochlospermum regium* (Mart. ex Schrank) Pilg. (Solon, 2009), another member of the Bixaceae family used for infections and other purposes.

Euphorbiaceae and Lamiaceae were also overused in several studies (at least one of them in Amiguet et al., 2006; Bennett and Husby, 2008; Douwes et al., 2008; Hernández et al., 2005; Kapur et al., 1992; Leonti et al., 2003; Moerman, 1979, 1989, 1991, 1996; Moerman et al., 1999; Molares and Ladio, 2009a; Saslis-Lagoudakis et al., 2011; Weckerle et al., 2011) and are known to have a vast repertoire of secondary compounds (Moerman, 1991; Tanvir et al., 1994; Heinrich et al., 1998; Wink, 2003). Despite these patterns, some discrepancies can be observed in the literature. The family Anacardiaceae, which was highlighted (overuse) in this study (for both models), has not been well described in literature and in some cases (Moerman et al., 1999; Kapur et al., 1992) has also appeared among underused families. Fabaceae, which was an overused family in our study and several others (Moerman et al., 1999; Leonti et al., 2003; Douwes et al., 2008; Saslis-Lagoudakis et al., 2011), has also been reported in the literature as underused (Moerman, 1991; Moerman et al., 1999; Leonti et al., 2009; Weckerle et al., 2011).

Among the leading underused families, Poaceae and Orchidaceae presented similar behavior in many other regions of the world (Moerman, 1979; Kapur et al., 1992; Moerman et al., 1999; Leonti et al., 2003, 2009; Bourbonnais-Spear et al., 2005; Amiguet et al., 2006; Thomas et al., 2009; Saslis-Lagoudakis et al., 2011). Bromeliaceae and Melastomataceae have also been classified as underused (Bennett and Husby, 2008), but not with the same frequency as Poaceae and Orchidaceae. There have been a number of studies addressing the Poaceae vocation for medicinal purposes because this family has few medical attributes from a chemical point of view (Moerman, 1991). Orchidaceae, however, has known medicinal properties (Gutiérrez, 2010). One explanation for its limited medical use is the difficulty of collection and contact with these species, resulting from their epiphytic habit (Amiguet et al., 2006) and low abundance. However, this low-use family needs to be further investigated to elucidate the reasons for these patterns. Interestingly, the family Cyperaceae, which has been classified as underused in many studies (Moerman 1989; Moerman et al., 1999; Leonti et al., 2003; Bourbonnais-Spear et al., 2005; Amiguet et al., 2006; Weckerle et al., 2011), was not observed in the present study.

4.2. An examination of body systems

The dissimilarity between body systems regarding the families used to treat them is a strong indication that people have well-established criteria for the selection of medicinal plants, and such criteria are graded according to the treatment differences required for each body system. In fact, the most similar body systems, considering the complete matrix ('disorders of the respiratory system' and 'infectious and parasitic diseases'), have similar requirements related to the antimicrobial activity of the species because, in both cases, there is a relationship between microbial diseases and contamination. The body systems 'external causes' and 'disorders of the musculoskeletal system' were also very similar in both binary and complete matrices and this similarity can be attributed to the fact that much damage caused by external factors gives rise to problems in the musculoskeletal system (such as injuries). As such, treatment in some cases is based on the same principles.

Mental and behavioral disorders, in turn, have different treatment requirements associated with the nervous system, and therefore, this was the most dissimilar system when compared with the others.

Moerman (1991) also observed dissimilarity between body systems. From these findings, we infer that the systems are often treated with different compounds, which are found in different botanical families. In fact, certain compounds appeared during the evolution of plant species which occur only in certain groups of plants (Gottlieb et al., 1995, 2002), and different compounds are often used in the treatment of particular diseases (Coe and Anderson, 1996).

Many of the discrepancies between body systems can be explained via the families employed in each case. Families for 'mental and behavioral disorders' vary widely with respect to other systems because treatment involving the nervous system requires a variety of specific bioactive compounds. The family Passifloraceae, for example, had a higher number of species being used for this purpose than for any other body system. The importance of Passifloraceae for mental and behavioral disorders can be demonstrated by its proven anxiolytic effectiveness (Dhawan et al., 2001; Santos et al., 2006; Castro et al., 2007), probably due to the presence of certain flavonoids (Santos et al., 2006), especially in the genus *Passiflora*.

Among the families used for 'skin and subcutaneous tissue diseases', certain species of Anacardiaceae contain anacardic acid, which is lethal against gram-positive bacteria that cause acne (Himejima and Kubo, 1991; Correia et al., 2006). The Plumbaginaceae is another important family for 'skin and subcutaneous tissue diseases', and also contains species suitable for the treatment of skin problems, such as *Plumbago zeylanica* L., with proven activity that explains its popular use against skin diseases of viral origin (Gebre-Mariam et al., 2006).

4.3. Taxonomy and use of botanical families

Our study showed differences in the proportion of taxonomic groups for different body systems. Thus, we can infer that people recognize the therapeutic characteristics of species in such a way as to employ them for specific use in the most appropriate body system. As species with closer taxonomic relationships tend to share certain attributes, the selection pattern of medicinal plants might lead to differences between the body systems and the clades of families used to treat them. From a chemical point of view, this finding might be explained by the increased similarity of secondary compounds among the closest taxa, which are the current subject of chemosystematic studies (Reynolds, 2007).

5. Limitations and challenges

The main limitation of this study is related to the restricted number of articles considered for the analysis, since we used rigorous inclusion criteria. Since Brazil has one of the most diverse floras in the world and covers an extremely large area, several studies would be necessary to characterize medicinal plant use more thoroughly. We are aware that the proportion of medicinal species found here far from represents the total number of plants used for this purpose by Brazilian communities. On the other hand, biased studies could constitute a source of error by not adequately representing the used species.

Although the most important Brazilian ecosystems were represented (except for the *pantanal*), we believe that this approach shall be repeated in the future, when more quality literature on Brazilian ethnobotany has been generated. Nevertheless, we also believe that this first approach is an important step towards characterizing medicinal plant use by Brazilian local populations.

6. Conclusion

The characterization of the underuse and overuse of medicinal botanical families for medicinal purposes by local Brazilian populations provided additional evidence that there may be certain universal patterns of species selection. Moreover, the differential and non-proportional use of certain families, combined with the differences in taxonomic groups that treat the body systems, suggests that the traditional use of medicinal plant resources is not performed at random and is strongly influenced by the chemical framework of the species. However, in spite of our beliefs in a somewhat standardized behavior regarding plant use, we also acknowledge that cultural specificity plays an important role in shaping medicinal plant use among different human groups. This becomes clear when we find, among a series of similar behaviors, some that are exactly the opposite (e.g.) the overuse of Fabaceae in some areas and its underuse in others.

Although the theoretical assumption of this study was that the chemical characteristics of the species influence the selection of medicinal plants, we believe that other biological and cultural factors also compound this multivarietal phenomenon. In Brazil, medicinal plant use is embedded in bio-cultural systems and is shaped by other non-random factors, including disease prevalence, plant abundance, socio-economical dimensions and singular local explanatory models for disease, among others. These factors modulate selection by local people. Thus, the elucidation of these factors in a more holistic way could enhance ethnopharmacological research.

Since ancestral times, different Brazilian societies have explored plants intensively, selecting or rejecting native resources, and developing a system of knowledge which, in spite of its rationality, has suffered a process of marginalization by modern bioscience. Thus, this work shows that the scientific community should acknowledge and value this contribution, and establish a real dialog that could be useful for the revitalization of this traditional knowledge and for the advance of modern pharmacology.

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