Journal of Ethnopharmacology 249 (2020) 112351

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jethpharm

A family-level floristic inventory and analysis of medicinal plants used in Traditional African Medicine

B.-E. Van Wyk

Department of Botany and Plant Biotechnology, University of Johannesburg, P.O. Box 524, Auckland Park, 2006, Johannesburg, South Africa

ARTICLE INFO

Keywords:
African medicinal flora
Bayesian analysis
Commercialised medicinal plants
IDM analysis
Linear regression analysis
Sub-saharan Africa

ABSTRACT

Ethnopharmacological relevance: Floristic diversity patterns of medicinal plants in sub-Saharan Africa are compared to global patterns to gain insights into the selection of plants used in Traditional African Medicine.

Aims of the study: To answer two questions: Firstly, is the selection of medicinal plants used in Traditional African Medicine in sub-Saharan Africa based on availability or is it biased towards certain plant families? Secondly, does the floristic composition of African medicinal plants differ from the global pattern and from other healing systems of the world?

Materials and methods: Data edited and summarized from recent reviews and on-line databases were compiled into an inventory of all vascular plant families of the world, showing the global numbers of species per family, the numbers of African taxa per family, the numbers of African medicinal plant species per family and the numbers of commonly traded African medicinal plants. These data were subjected to linear regression analyses, as well as Bayesian analysis and Imprecise Probability calculation (using the Imprecise Dirichlet model).

Results: At least 4576 vascular plant species from 1518 genera are used in Traditional African Medicine in sub-Saharan Africa, representing 192 families (out of 254 African families). Traditional African Medicine is dominated by Fabaceae (567 spp., 156 genera), Rubiaceae (318 spp., 99 genera), Asteraceae (314 spp., 112 genera), Malvaceae (202 spp., 46 genera), Euphorbiaceae (197 spp., 47 genera), Apocynaceae (167 spp., 68 genera), Lamiaceae (142 spp., 37 genera), Acanthaceae (106 spp., 40 genera), Asparagaceae (90 spp., 18 genera) and Poaceae (85 species, 47 genera). Regression analysis of the African medicinal flora shows that the Fabaceae (576 medicinal species/residual +136), Malvaceae (202/+105), Rubiaceae (318/+85), Lamiaceae (142/+55), Euphorbiaceae (197/+54) and Combretaceae (72/+49) are overused, while Aizoaceae (10/−136), Orchidaceae (34/−127), Iridaceae (16/−101) and Poaceae (85/−87) are underused. Bayesian and IDM analysis showed that a large number of smaller families are also overused and underused. Commonly traded African medicinal plants species are mostly from Fabaceae (27 species), Apocynaceae (16), Burseraceae (12) and Rubiaceae (9).

Conclusion: The selection of African medicinal plants appears to be based on availability (for some families) and apparently cultural and other criteria, such as the presence of alkaloids, terpenoids and volatile compounds for others (e.g., Fabaceae, Apocynaceae and Burseraceae). In terms of commercialised species in international trade, Traditional African Medicine differs from the global pattern (and other healing systems) in the dominance of Fabaceae and Apocynaceae and the relatively low numbers of Asteraceae, Lamiaceae, Apiaceae and Rosaceae.

1. Introduction

Several publications and databases have become available in recent years in which species lists are provided for both the global flora (e.g., The Plant List, 2013; World Flora online, 2019) and the African flora (e.g., African Plant Database). There are also reviews and inventories of the African medicinal flora, giving insights into the most popular and commercially important species (e.g., Neuwinger, 2000; Arnold et al., 2002; Schmelzer and Gurib-Fakim, 2008; Gurib-Fakim and Schmelzer, 2013; Brendler et al., 2010; Van Wyk, 2015, 2017; Van Wyk and Wink, 2015). However, the overall patterns of diversity of the African flora and the African medicinal flora have apparently never been compared to the global pattern. Are some families over-represented and under-represented in the African *materia medica* simply because they are also over- and under-represented in the African flora? Do the most overused African medicinal plant families also have larger numbers of commercialised medicinal products of African origin? How do commercial species of African origin (often iconic plants with long histories of use)

E-mail address: bevanwyk@uj.ac.za.

https://doi.org/10.1016/j.jep.2019.112351
Received 31 May 2019; Received in revised form 23 October 2019; Accepted 23 October 2019
Available online 30 October 2019
0378-8741/

compare to those of other continents and healing systems? Such comparisons and analyses may lead to a better understanding of the selection of species that are used in Traditional African Medicine and hence also potential similarities and differences between continental medicinal floras and between other great healing systems of the world, such as Traditional European Medicine, Ayurvedic Medicine and Traditional Chinese Medicine. Traditional African Medicine has not yet been systematically recorded and no detailed synthesis is available, so that comparisons between these systems, especially in terms of commercialised species, may provide important new perspectives.

I hypothesized that the selection of medicinal plant species used in Traditional African Medicine in sub-Saharan Africa is not only based on availability but that it is biased towards certain plant families. I also hypothesized that the composition of the African medicinal flora (both the traditional *materia medica* and commercialised species) differs from the global pattern and from other healing systems of the world.

2. Materials and methods

2.1. Data used

Data for the global floristic composition of vascular plants were taken from The Plant List (2013) (www.theplantlist.org), which represents a global working checklist of all vascular plants and bryophytes. It includes 350 699 accepted species in 17 020 genera and 642 families. Despite being static since 2013, it remains the most complete and useful source of information on the world flora. The Plant List is currently used as the taxonomic backbone for the *World Flora Online* project (www.worldfloraonline.org) that is being developed by a group of taxonomic experts from all parts of the world.

Data for the floristic composition of the flora of sub-Saharan Africa (excluding Madagascar) were taken from *The* African Plant Database (version 3.4.0) (www.ville-ge.ch/musinfo/bd/cjb/africa), which currently includes 203 013 names of species and infraspecific taxa. The data in this list reflect the four main regions of Africa, namely tropical Africa [with data from Lebrun and Stork (1991–2015), southern Africa [with data from Germishuizen and Meyer (2003)], North Africa (with data from Dobignard and Chatelain (2010–2013) and Madagascar [with data from the Catalogue of the Vascular Plants of Madagascar (2019) (www.tropicos.org/Project/Madagascar)]. In this study, the focus is on tropical Africa and southern Africa. North Africa and Madagascar were excluded because they are floristically very different from the rest of the continental. The North African flora more closely resemble that of Mediterranean Europe and the Arabian Peninsula, while the flora of Madagascar has no less than 83% of the ca. 12 000 species endemic to the island. According to *The* African Plant Database (version 3.4.0), the total flora of tropical and southern Africa comprises 254 families and ca. 50 281 taxa (excluding synonyms).

Several sources of information are available on the most popular and most widely used African medicinal plants. In his comprehensive review, Neuwinger (2000) included more than 5400 species. For the purposes of this paper, the data were summarized and edited, resulting in a list of 192 families, 1518 genera and 4576 species. The lower number of species resulted from the exclusion of all Malagasy species, all infraspecific taxa (they were reduced to species level) and all multiple entries (where the same species were listed under two or more synonyms, or duplications resulting from different spellings). The edited data are presented as an Excell spreadsheet (Electronic Supplement).

Two main sources of information were used for compiling lists of commercially relevant African medicinal plant species. Those that are actively traded, at least on the continent itself, came from the recent review of Van Wyk (2017). This list was based on a careful consideration of global reviews and pharmacopoeias. Once again, the North African and Malagasy species were excluded, for reasons stated above. The reduced list comprised 179 species of medicinal plants of sub-Saharan Africa. For global comparisons of medicinal plants in international trade, data were taken from the revised edition of *Medicinal Plants of the World* by Van Wyk and Wink (2017), resulting in 801 species. The data were collated in Excel and are provided as the second part of the Electronic Supplement, to allow future authors access to the dataset.

Although none of the sources of data can be considered complete and up-to-date, they are sufficiently accurate to serve as a proxy for comparative analyses, in order to obtain a first bird's eye view of the floristic composition of Traditional African Medicine and how it compares to the rest of the world.

2.2. Analyses

Simple linear regression was performed on the data sets highlighted above, using Excel and following the approach of Moerman (1979, 1991, 1996), which he applied to North American medicinal plants. The purpose of the first analysis (Analysis 1) was to see if the composition of species-rich families of the African flora differs from the rest of the world, using the global numbers of species in all vascular plant families as independent variable and the numbers of African taxa in all vascular plant families as dependent variable. Three more regression analyses were done to see if the selection of species of large (species-rich) families is biased towards certain families (and how this compares to other parts of the world). Analysis 2 – the number of African taxa in all vascular plant families as independent variable and the number of African medicinal species per family as dependent variable; Analysis 3 – the global number of species as independent variable and the global number of commercialised medicinal plant species in international trade as dependent variable; Analysis 4 – the global number of species as independent variable and the number of commonly traded African medicinal plant species as dependent variable. Analysis 2 allows for a direct comparison of the African medicinal flora with five other medicinal floras where the same approach was used (Moerman et al., 1999). Analyses 3 and 4 allow for a direct comparison between the global and African selection of commercialised medicinal plant species.

Although widely used, regression analysis is sometimes considered an outdated method for analyzing over- and under-representation of specific taxa in a medicinal flora (Weckerle et al., 2011). The main problem is that the regression residuals of small families are unlikely to exceed the standard error, resulting in a bias towards large plant families. Furthermore, there is no *a priori* reason to expect that the relation between the number of used species and the total number of species per family is linear. Bayesian analysis (Weckerle et al., 2011) and especially the IDM model (Weckerle et al., 2012) are considered to be more appropriate, especially when the number of used taxa and the total numbers of taxa in a flora are imprecise and subject to change. For these reasons, the data used in Analysis 2 were re-analysed using the Bayesian approach (Weckerle et al., 2011) and the more conservative Imprecise Probability approach (Weckerle et al., 2012). The last-mentioned method was also used to re-analyse the data of Analysis 1, i.e., with the global numbers of species as independent variable and the numbers of African taxa as dependent variable.

3. Results

3.1. Inventory

At least 4576 vascular plant species from 1518 genera are used in Traditional African Medicine in sub-Saharan Africa, representing 192 families out of the 254 families of vascular plants present in sub-Saharan Africa (Electronic Supplement). As shown in Fig. 1, the African medicinal flora is dominated by the Fabaceae (576 species from 156 genera), with nearly double the number of species of the second and third most diverse families, the Rubiaceae (318 species from 99 genera) and Asteraceae (314 species from 112 genera). Other prominent

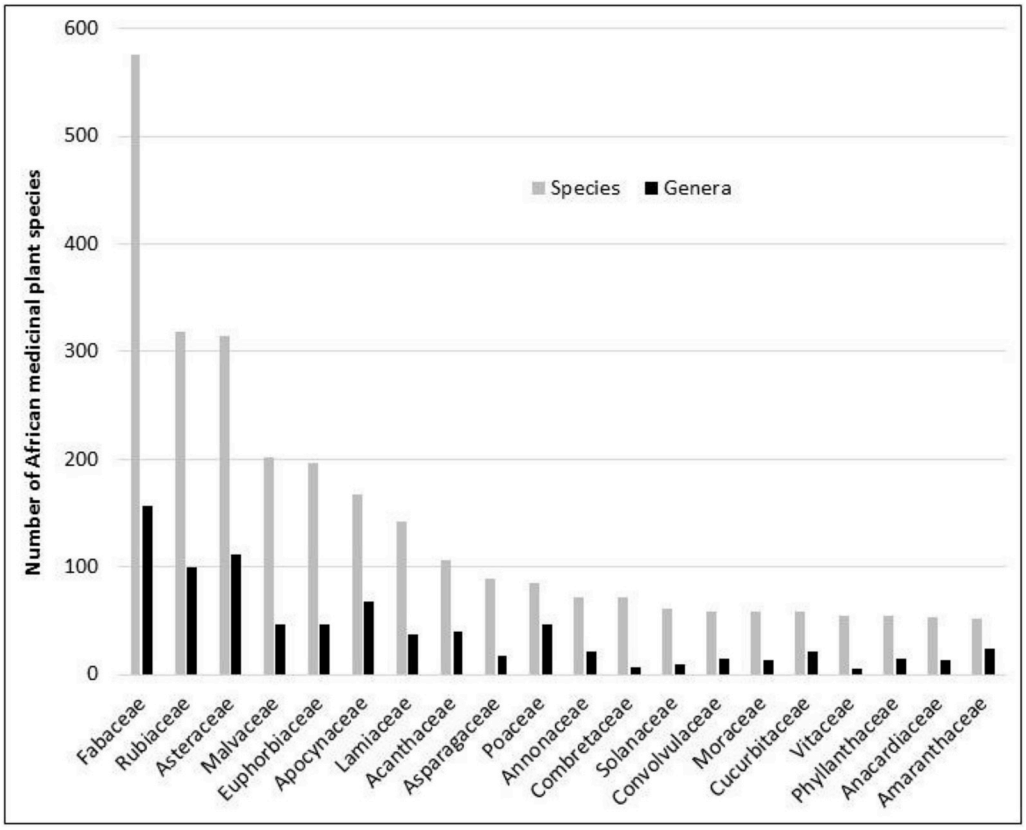

Fig. 1. The most species-rich medicinal plant families of sub-Saharan Africa, showing the numbers of species and genera. The complete data set is provided in Appendix 1.

families are the Malvaceae (202 species from 46 genera), Euphorbiaceae (197 species from 47 genera), Apocynaceae (167 species from 68 genera), Lamiaceae (142 species from 37 genera), Acanthaceae (106 species from 40 genera), Asparagaceae (90 species from 18 genera) and Poaceae (85 species from 47 genera). Families with 50–75 species are the Annonaceae (72 species from 22 genera), Solanaceae (61 species from seven genera), Convolvulaceae (59 species from 15 genera), Cucurbitaceae (58 species from 22 genera), Vitaceae (56 species from five genera), Phyllanthaceae (54 species from 15 genera), Anacardiaceae (53 species from 14 genera) and Amaranthaceae (52 species from 24 genera). The relatively low numbers of African medicinal species from internationally well-known medicinal plant families such as Rutaceae (43 species), Apiaceae (34 species) and Rosaceae (13 species) are noteworthy.

3.2. African flora versus the global flora

As can be expected, there is a strong correlation between the numbers of African species per family and the global numbers of species per family, as shown in Fig. 2. More than 75% of the variance can be explained by the data (p-value < 0.001). The analysis showed that the African flora differs from the rest of the world in the prominence of Fabaceae (actual taxa 5220, predicted 3455, residual +1765), Aizoaceae (1717/347/+1370), Iridaceae (1381/353/+1028), Acanthaceae (1593/581/+1012), Apocynaceae (1741/806/+935) and Rubiaceae (2754/1941/+813) – see Appendix 2. Other families for which the residual values exceed the standard error of 174 taxa are the Scrophulariaceae, Euphorbiaceae, Asparagaceae, Cyperaceae, Ericaceae, Malvaceae, Poaceae, Crassulaceae, Restionaceae, Campanulaceae, Proteaceae, Geraniaceae, Xanthorrhoeaceae, Convolvulaceae, Vitaceae, Verbenaceae and Commelinaceae. Families with species numbers significantly below the global pattern are Orchidaceae, Myrtaceae, Bromeliaceae, Rosaceae, Asteraceae, Piperaceae, Brassicaceae, Primulaceae, Lauraceae, Araceae, Cactaceae, Gesneriaceae, Arecaceae, Ranunculaceae, Melastomataceae, Polypodiaceae, Dryopteridaceae, Plantaginaceae, Caryophyllaceae, Araliaceae, Solanaceae and Fagaceae (Appendix 2). It is not surprising to find that plant family diversity is not evenly spread across the world but it is interesting to see which families are over-represented in the African flora and which ones are under-represented, and to have a quantitative measure of the degree of departure from the global pattern.

3.3. African medicinal flora versus the African flora

3.3.1. Regression analysis

Regression analysis of African medicinal species versus all African taxa (Fig. 3) revealed a pattern very similar to the one shown in Fig. 2, except that several previously over-represented families are now under-represented, while several “new” families are now over-represented (see residual values listed in Appendix 2). The Fabaceae, Malvaceae, Rubiaceae and Euphorbiaceae maintained their prominent positions, indicating that plants of these families are overused not only because of their high representation in the African flora. Other families that are apparently also overused (with residual values exceeding the standard error of 24 taxa) are the Lamiaceae, Combretaceae, Solanaceae, Annonaceae, Cucurbitaceae, Moraceae, Meliaceae, Anacardiaceae, Menispermaceae and Phyllanthaceae. The Orchidaceae and Asteraceae are the only families that are under-represented in both the African flora and the African medicinal flora (residual values respectively −127 and −45). Families that are over-represented according to the first analysis (Fig. 1) yet apparently less suitable for medicinal use in Africa (with residual values significantly below the standard error of 24 taxa) are the

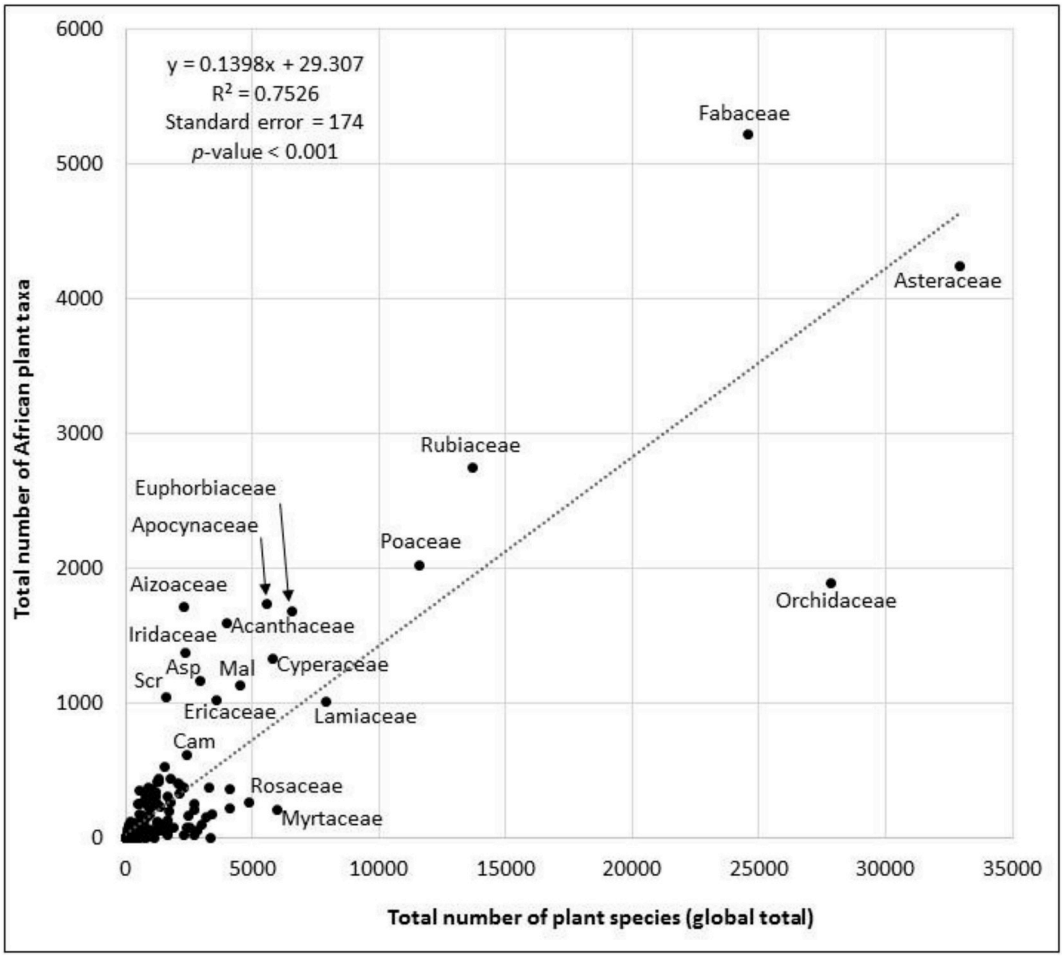

Fig. 2. Regression analysis of the total (global) number of plant species per family and the total number of African plant taxa (including infraspecific taxa) of sub-Saharan Africa. The results are summarized in Appendix 2.

Aizoaceae, Iridaceae, Poaceae, Ericaceae, Cyperaceae, Scrophulariaceae, Campanulaceae, Proteaceae, Restionaceae, Acanthaceae and Crassulaceae.

3.3.2. Bayesian and IDM analyses

As expected, the Bayesian and IDM analyses indicated several smaller families as over- and underutilized (Appendices 3 and 4). In total, 61 families were shown to be overused in the Bayesian analysis and 51 in the IDM analysis (Appendix 3). Underused families totaled 25 in the Bayesian analysis and 18 in the IDM analysis. All 14 families indicated as overused and all 13 indicated as underused by the regression analysis are present in Appendices 3 and 4, respectively (they are shown in bold type). It is noteworthy that the sequence has changed, with the top three families of the regression analysis (Fabaceae, Malvaceae and Rubiaceae) now ranked much lower. Regression analysis resulted in the lowest ranks for Aizoaceae, Orchidaceae and Iridaceae, while Bayesian analysis had Ericaceae, Aizoaceae and Iridaceae as the most underused families.

An IDM analysis was also performed on the data used in Analysis 1 (global flora versus the African flora) to see if there is a direct relationship between overused and over-represented, and also between underused and under-represented African families. A total of 88 families were shown to be over-represented and 86 under-represented in the African flora. The results for the relevant families are shown in the last column of Appendices 3 and 4. The IDM analysis demonstrated the importance of also considering smaller families – the Molluginaceae, Bruniaceae, Hypoxidaceae, Aizoaceae, Pedaliaceae, Restionaceae, Hydrostachyaceae, Scrophulariaceae, Penaeaceae, Iridicaceae, Anacampserotaceae, Capparaceae, Marsileaceae, Irvingiaceae, Combretaceae, Dichapetalaceae, Melianthaceae, Zygophyllaceae, Stilbaceae, Oxalidaceae, Anisophylleaceae, Geraniaceae, Commelinaceae, Acanthaceae and Asparagaceae were the top 25 over-represented families in the African flora. The 25 most under-represented families were the Bromeliaceae, Fagaceae, Liliaceae, Piperaceae, Cactaceae, Berberidaceae, Pandanaceae, Papaveraceae, Aquifoliaceae, Primulaceae, Theaceae, Polypodiaceae, Goodeniaceae, Loasaceae, Arecaceae, Myrtaceae, Ranunculaceae, Smilacaceae, Plantaginaceae, Araliaceae, Lauraceae, Cunoniaceae, Tectariaceae, Dryopteridaceae and Pinaceae.

3.4. African medicinal flora versus five other medicinal floras

Moerman et al. (1999) used linear regression to compare the North American medicinal flora with four other regions for which data were available (Ecuador, Kashmir, Chiapas Highlands and Korea). A close similarity was found between the four northern hemisphere regions (North America, Kashmir, Chiapas and Korea) when compared to Ecuador (the only southern hemisphere region available for comparison). Their data were used for a comparison with the corresponding ranks of African medicinal plant families (Table 1). Conspicuous differences are apparent, especially in the much lower ranks for the top African families Fabaceae, Malvaceae, Rubiaceae, Annonaceae and Cucurbitaceae, as well as some of the lowest ranking African families (Ericaceae and Asteraceae). There are some similarities with Ecuador, as seen in the high ranks for Fabaceae (2), Malvaceae (5) and the low rank for Asteraceae (47). On the other hand, there are also conspicuous similarities, such as the high rank for Lamiaceae (all except Ecuador)

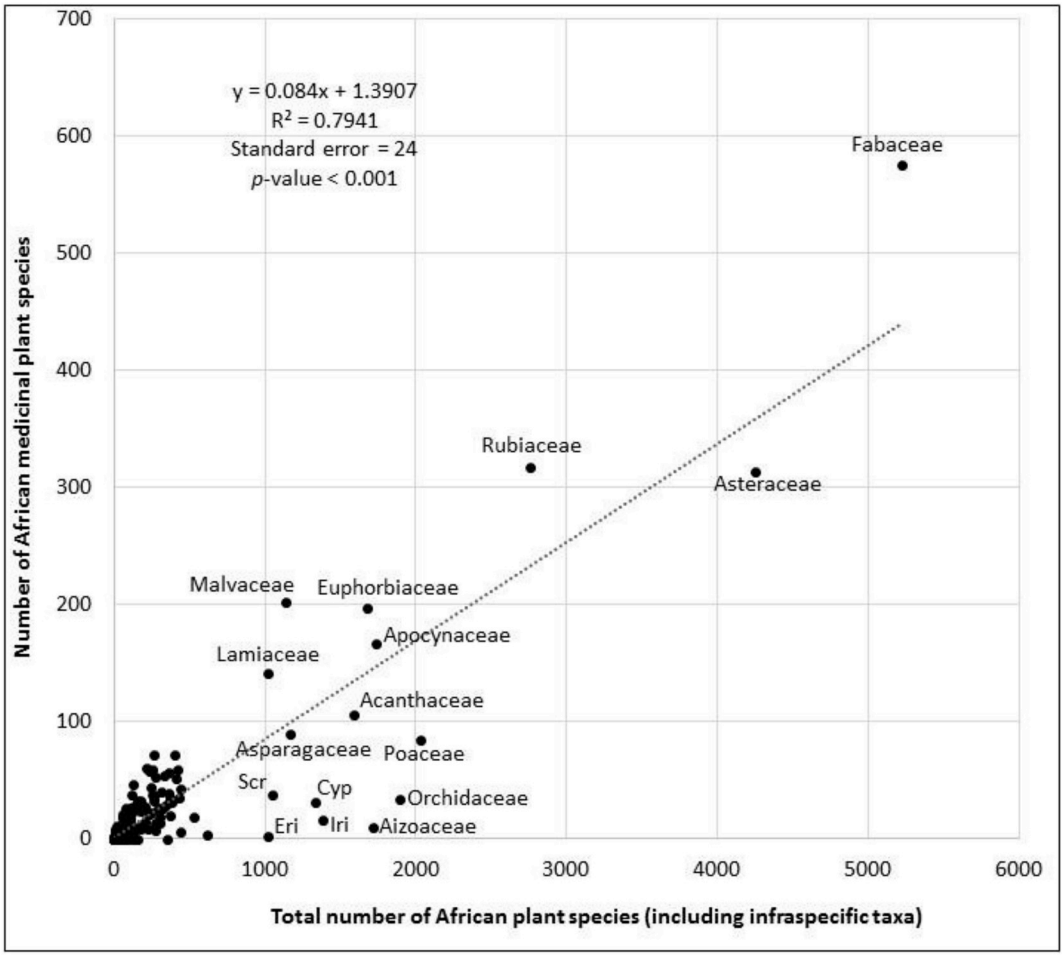

Fig. 3. Regression analysis of the total number of African plant taxa per family (including infraspecific taxa) of sub-Saharan Africa and the total number of medicinal plant species per family in sub-Saharan Africa. The results are summarized in Appendix 2.

and the low ranks for Orchidaceae, Poaceae, Cyperaceae and Scrophulariaceae.

3.5. Commercialised medicinal species versus the global flora

This regression analysis was an attempt to see if the global choice of plant species that have been commercialised (Van Wyk and Wink, 2017) is directly related to the species diversity of their respective families. The results (Fig. 4) reveal that less than 50% of the variation in the data can be explained by species numbers (indicating strong, non-random selection) and that a total of 11 species-rich families have residuals exceeding the standard error of 6.4 (see data in Appendix 5). These are the Apiaceae, Lamiaceae, Rosaceae, Fabaceae, Asteraceae, Amaranthaceae, Apocynaceae, Ranunculaceae, Rutaceae, Solanaceae and Scrophulariaceae. In this analysis, only five families had residual values of less than 6.4, namely the Orchidaceae (−40), Rubiaceae (−11), Poaceae (−10), Cyperaceae (−8) and Bromeliaceae (−7).

3.6. Commonly traded African medicinal species versus the global flora

In this analysis, the model (Fig. 5) can explain only a third of the variance. The result differs considerably from the global pattern of commercialised medicinal plants. Only four of the large families share statistically significant over-representation in both analyses (see data in Appendix 3), namely the Fabaceae, Apocynaceae, Rutaceae and Apiaceae. Seemingly unique to commonly traded African species are the prominence of Burseraceae, Commelinaceae, Xanthorrhoeaceae, Rubiaceae, Euphorbiaceae, Malvaceae, Moringaceae, Meliaceae, Cucurbitaceae, Clusiaceae and Sapotaceae, and the relative paucity of Poaceae, Asteraceae and Melastomataceae. The switched positions of the Asteraceae and Rubiaceae are particularly striking.

3.7. Comparison of continents and traditional medicine systems

A visual summary of the data in Appendix 3 is presented in Fig. 6, showing the most species-rich families of commercialised medicinal plants (the “top 12” medicinal plant families of the world): Asteraceae (63 species), Fabaceae (59), Lamiaceae (43), Apiaceae (37), Rosaceae (28), Apocynaceae (24), Ranunculaceae (19), Rutaceae (15), Solanaceae (15), Amaranthaceae (14), Euphorbiaceae (14) and Rubiaceae (13). The corresponding numbers of species are also shown at continental level, corresponding to, or representing Traditional African Medicine, Traditional European Medicine, Traditional Asian Medicine (mostly Ayurveda), Traditional East Asian Medicine (mostly Traditional Chinese Medicine), Traditional North American Medicine, Traditional South American Medicine, Traditional Central American Medicine and Traditional Australian Medicine. The large numbers of commercialised plants of European and Asian origin are conspicuous, showing that the global statistics are skewed in favour of these two prominent regions of origin. Given the high levels of species diversity in other continents, especially in the southern hemisphere, it can be expected that the imbalance will gradually become less conspicuous as more and more medicinal plants from these continents become commercialised for international markets. Ongoing efforts to document traditional knowledge (Van Wyk and Moteetee, 2019) and to subject medicinal plants to scientific research (Van Wyk, 2015) will contribute to this process.

Table 1
Ranking of the 15 most used and 13 least used species-rich plant families in Africa (all families with the residuals exceeding the standard error of 24) as compared to the rankings obtained in a study of five medicinal floras by Moerman et al. (1999). Families with conspicuously different rankings in Africa compared to the five other regions are shown in bold.

Family	Africa	Ecuador	Kashmir	Chiapas Highlands	Korea	North America
Fabaceae	**1**	**2**	**85**	**131**	**7**	**253**
Malvaceae	**2**	**5**	**13**	**19**	**118**	**238**
Rubiaceae	**3**	**110**	**10**	**83**	**66**	**251**
Lamiaceae	4	95	4	2	3	8
Euphorbiaceae	5	85	2	21	12	234
Combretaceae	6	–	–	–	–	–
Solanaceae	7	16	6	3	24	14
Annonaceae	**8**	**114**	**-**	**101**	**-**	**212**
Cucurbitaceae	**9**	**53**	**96**	**43**	**81**	**28**
Moraceae	10	117	9	115	21	34
Meliaceae	**11**	–	–	–	–	–
Anacardiaceae	12	86	98	29	22	19
Menispermaceae	13	–	–	–	–	–
Phyllanthaceae*	14	–	–	–	–	–
Vitaceae	15	–	–	–	–	–
Aizoaceae	254	–	–	–	–	–
Orchidaceae	253	118	16	143	134	246
Iridaceae	252	–	–	–	–	–
Poaceae	251	52	100	144	135	255
Ericaceae	**250**	**79**	**60**	**13**	**17**	**3**
Cyperaceae	249	103	95	142	136	254
Scrophulariaceae	248	78	15	7	123	252
Campanulaceae	247	–	–	–	–	–
Asteraceae	**246**	**47**	**1**	**1**	**2**	**1**
Proteaceae	245	–	–	–	–	–
Restionaceae	244	–	–	–	–	–
Acanthaceae	243	–	–	–	–	–
Crassulaceae	242	–	–	–	–	–
Total families	254	118	100	144	136	255

The uneven distribution of medicinal plant species numbers for the top medicinal plant families across the globe is also visible in Fig. 6. The Asteraceae are dominant in the north temperate regions of the world (Europe, Asia and North America), while the Fabaceae are conspicuous in the more tropical regions (Africa, East Asia, South America and Central America). Africa is the only continent in which a relatively large number of Apocynaceae has been commercialised. It is noteworthy that the Apocynaceae and Fabaceae are also the most species-rich families of food plants in southern Africa, with respectively 137 and 135 species of edible plants (Welcome and Van Wyk, 2019).

4. Discussion

The oral-traditional knowledge systems of sub-Saharan Africa remain incompletely documented despite numerous publications and a rapid increase in the number of research publications in recent years (Van Wyk, 2015). The data presented here, incomplete as it may be, were sufficiently detailed for comparative purposes and the analyses showed that there are conspicuous differences between the African medicinal flora and other medicinal floras. The same is true for commercialised medicinal plants.

It was not the aim of this paper to provide full details of all African medicinal plants and their uses. Such information can be found in recent reviews (e.g., Van Wyk, 2008, 2015, 2017) and major historical contributions, such as Watt and Breyer-Brandwijk (1962), Burkill (1985–2004), Oliver-Bever (1986), Iwu (1993), Kokwaro (1993) and especially Neuwinger (2000). A database for the southern Africa region was published by Arnold et al. (2002). The first African pharmacopoeia (African Pharmacopoeia, 1981, 1986) was followed by a more recent one (Brendler et al., 2010), in which monographs were provided for 51 important African plants. A database of African medicinal plants (detailing their chemistry and biological activity) was produced by Prof Dagne of Ethiopia (Natural Database for Africa, 2011). Accurate and detailed information on African medicinal plants can also be found in the PROTA series (Schmelzer and Gurib-Fakim, 2008; Gurib-Fakim and Schmelzer, 2013; see also PROTA (2010), for a list of 3644 important medicinal plants of tropical Africa and Madagascar. For more details of regional publications and market surveys, see Van Wyk (2008, 2015, 2017) and references cited therein, as well as 40 papers in a Special Edition of the South African Journal of Botany dedicated to the ethnobotany of sub-Saharan Africa (Van Wyk and Moteetee, 2019). Recent surveys of the supposedly well-studied Venda and Zulu cultural groups in South Africa (Magwede et al., 2019; Mhlongo and Van Wyk, 2019) revealed large numbers of useful plants and medicinal use-records that have hitherto remained undocumented in both the scientific and grey literature. It may be useful to incorporate all these data in future studies and to refine the analyses presented here. However, it is unlikely that the main patterns emerging from this broad preliminary analysis will change much with the addition of more data.

The available data show that the majority of medicinal plant species used in Traditional African Medicine belong the Fabaceae (576 species, 156 genera), Rubiaceae (318 species, 99 genera) and Asteraceae (314 species, 112 genera), followed by Malvaceae, Euphorbiaceae, Apocynaceae, Lamiaceae, Acanthaceae, Asparagaceae, Poaceae, Annonaceae, Solanaceae, Convolvulaceae, Cucurbitaceae, Vitaceae, Phyllanthaceae, Anacardiaceae and Amaranthaceae (Fig. 1). The African flora differs from the rest of the world in the diversity of Fabaceae, Aizoaceae, Iridaceae, Acanthaceae, Apocynaceae, Rubiaceae, Scrophulariaceae, Euphorbiaceae, Asparagaceae, Cyperaceae, Ericaceae, Malvaceae, Poaceae, Crassulaceae, Restionaceae, Campanulaceae, Proteaceae, Geraniaceae, Xanthorrhoeaceae, Convolvulaceae, Vitaceae, Verbenaceae and Commelinaceae (Appendix 2). Families with diversity below the global pattern are the Orchidaceae, Myrtaceae, Bromeliaceae, Rosaceae, Asteraceae, Piperaceae, Brassicaceae, Primulaceae, Lauraceae, Araceae, Cactaceae, Gesneriaceae, Arecaceae, Ranunculaceae, Melastomataceae, Polypodiaceae, Dryopteridaceae, Plantaginaceae, Caryophyllaceae, Araliaceae, Solanaceae and Fagaceae (Appendix 2). Several smaller families were identified by IDM analysis as over-represented or under-represented, as listed above. Much of this variation seem to be due to geographical distribution patterns, with several typical north temperate families (such as Rosaceae and Ranunculaceae) among the under-represented group and several African-endemic or near endemic families (such as Aizoaceae and Bruniaceae) among the over-represented group.

Large families that are statistically shown to be overused in Traditional African Medicine are the Fabaceae, Malvaceae, Rubiaceae, Euphorbiaceae, Lamiaceae, Combretaceae, Solanaceae, Annonaceae, Cucurbitaceae, Moraceae, Meliaceae, Anacardiaceae, Menispermaceae and Phyllanthaceae, while the Orchidaceae and Asteraceae are the only families that are both under-used and under-represented in the African flora and the African medicinal flora. Families that are also statistically underused in Traditional African Medicine are the Aizoaceae, Iridaceae, Poaceae, Ericaceae, Cyperaceae, Scrophulariaceae, Campanulaceae, Proteaceae, Restionaceae, Acanthaceae and Crassulaceae. Several smaller families were added by the Bayesian and IDM analyses, resulted in respectively 61 and 51 families shown to be overused (including the 14 species-rich families singled out by regression analysis). The 25 and 18 underused families identified by Bayesian and IDM analyses respectively, also closely agree with the results of the regression analysis. The result of IDM analysis demonstrated the importance of considering the smaller families (Appendices 3 and 4). If species were selected according to their representation in the Flora, then one would expect the overused families to be over-represented, and the underused families to be under-represented. This is clearly not the case – 26 of the overused

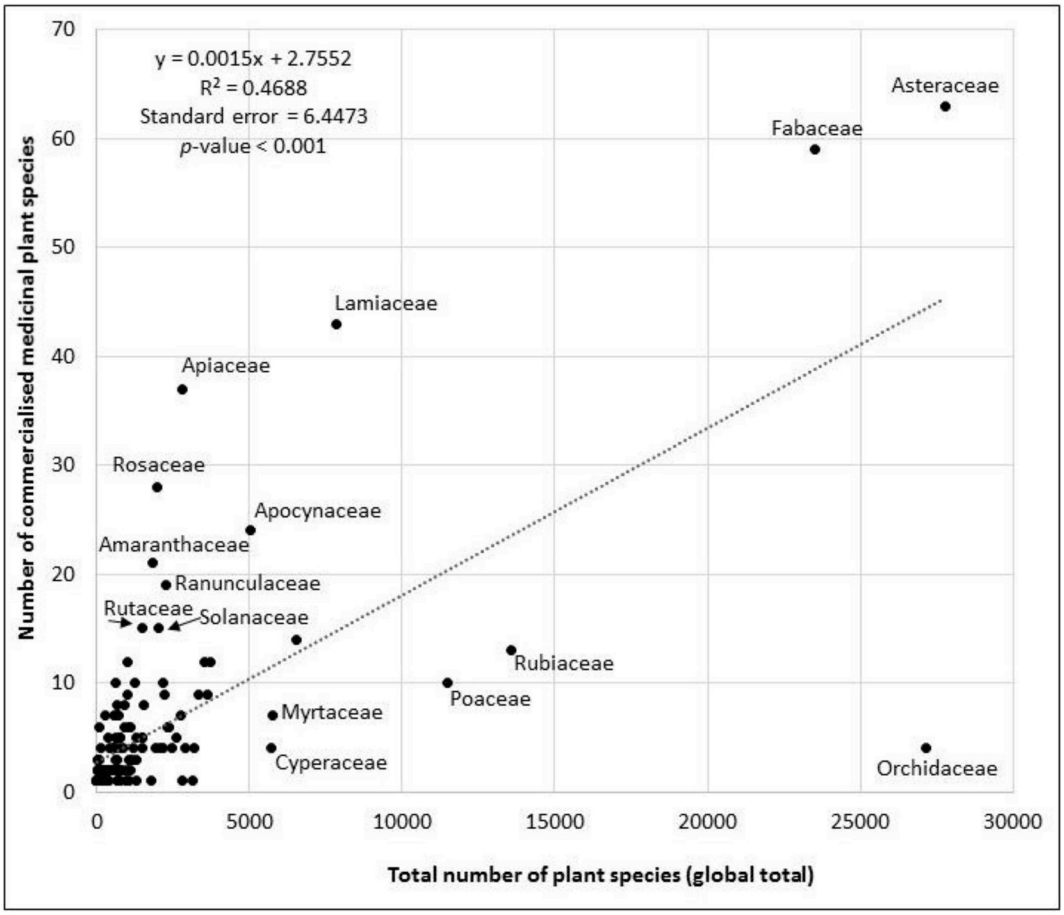

Fig. 4. Regression analysis of the total (global) number of plant species per family and the total number of commercialised medicinal plant species per family (Data from The Plant List, 2013 and Van Wyk and Wink, 2017). The results are summarized in Appendix 3.

families are over-represented but a similar number (22) are under-represented (Appendix 3). Of the 25 underused families (Appendix 4), only six are under-represented and 18 are over-represented. The logical conclusion is that there is no general or predictable taxonomic pattern for the selection of species but that some large families are prominent mainly because of their larger numbers of utilized species, while other large families are apparently not really suitable for medicinal use, neither in Africa nor elsewhere in the world. The choice of smaller families seem to be partly related to their continental geographical distribution patterns and endemism.

The comparison with the North American medicinal flora and four other regions supports the idea that Traditional African Medicine is different from other medicinal floras. Important (overused) African families such as the Fabaceae, Malvaceae, Rubiaceae, Annonaceae and Cucurbitaceae are much less prominent in other medicinal floras, while there is considerable agreement with underused African families such Orchidaceae, Poaceae, Cyperaceae and Scrophulariaceae (but not Ericaceae and Asteraceae).

Commercialised African medicinal species share with the global pattern an apparent overuse of Fabaceae, Apocynaceae, Rutaceae and Apiaceae. The overuse of Burseraceae, Commelinaceae, Xanthorrhoeaceae, Rubiaceae, Euphorbiaceae, Malvaceae, Moringaceae, Meliaceae, Cucurbitaceae, Clusiaceae and Sapotaceae, and the underuse of Asteraceae appear to be uniquely African. By using the global flora as independent variable in both analyses (i.e., for the global medicinal flora – Fig. 4, and the commercialised African species – Fig. 5), these results can be directly compared. It is interesting to see how some families maintain their positions along the regression line while others swop from overused to underused (e.g., the Asteraceae) and *vice versa* (e.g., the Rubiaceae). There is a close similarity between Fig. 3 (with the African flora along the x-axis) and Fig. 5 (with the global flora along the x-axis) but the commercial importance of the Apocynaceae, Burseraceae, and other overused African families are emphasised. When comparing continents (Fig. 6), some striking differences in commercialised medicinal plants emerged. Fabaceae and Apocynaceae seem to dominate in Africa, Asteraceae, Lamiaceae and Apiaceae in Europe, Asteraceae, Fabaceae and Apiaceae in Asia, Fabaceae and Rutaceae in East Asia, Asteraceae in North America and Fabaceae and Asteraceae in Central and South America.

5. Conclusions

The analyses showed a random pattern for some families and a non-random pattern for others (apparently partly based on availability but also on other criteria, perhaps historical and cultural preferences, or the presence of biologically active alkaloids, terpenoids and volatile compounds, e.g., Fabaceae, Apocynaceae and Burseraceae). The comparison with the North American medicinal flora and four other regions showed that in Africa, the Fabaceae, Malvaceae, Rubiaceae, Annonaceae and Cucurbitaceae are much more and the Asteraceae and Ericaceae much less prominent than in other medicinal floras. Commercialised African species in international trade differ from the global patterns in the dominance of Fabaceae and Apocynaceae and the relatively low numbers of Asteraceae, Lamiaceae, Apiaceae and

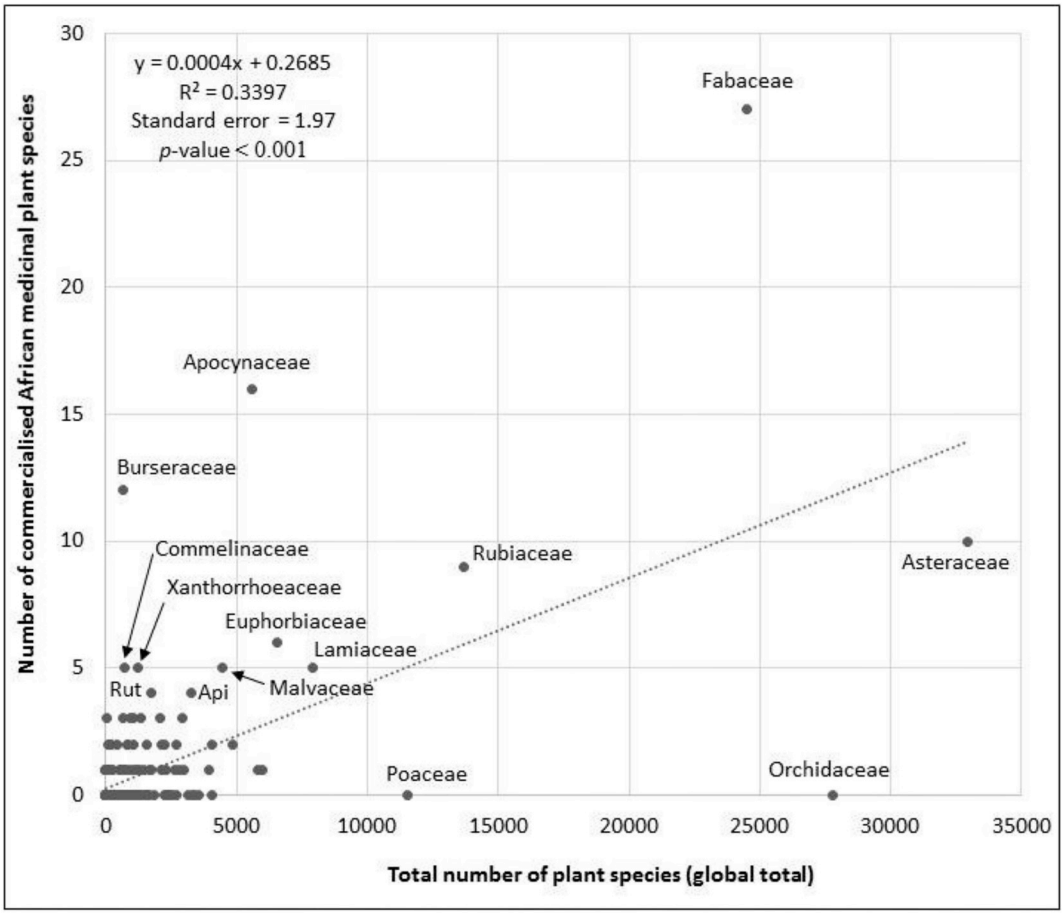

Fig. 5. Regression analysis of the total (global) number of plant species per family and the total number of commercialised medicinal plant species per family in sub-Saharan Africa (Data from The Plant List, 2013 and Van Wyk and Wink, 2017). The results are summarized in Appendix 3. The species numbers of the global flora were again used as independent variable (and not the African flora) to allow for direct comparisons with the results in Fig. 4.

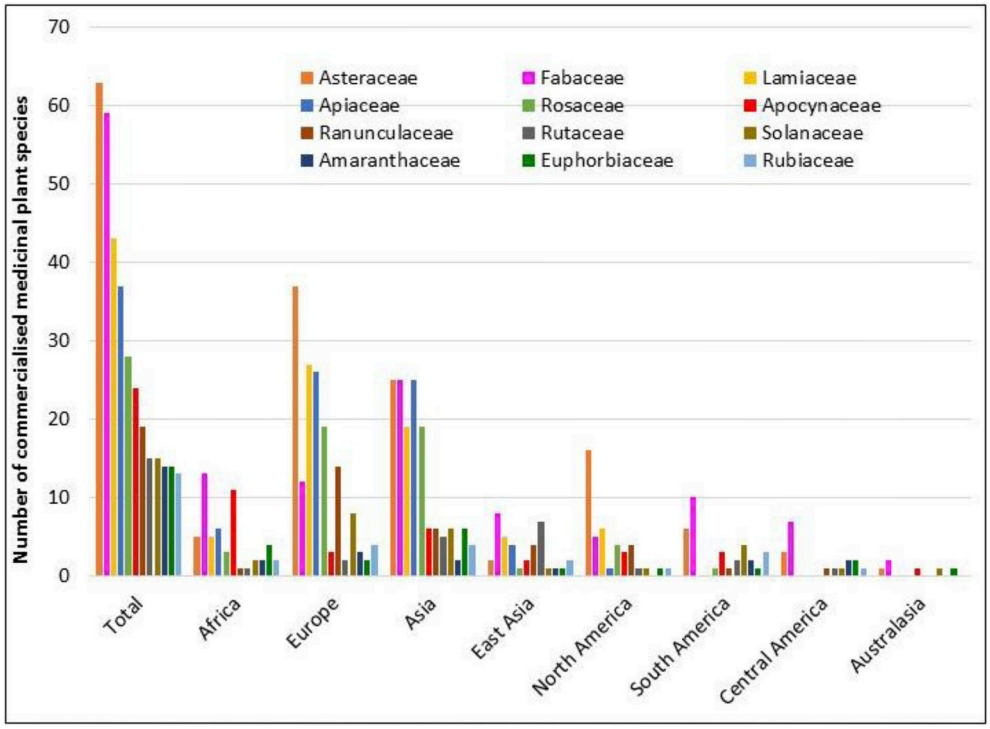

Fig. 6. Summary of the most species-rich medicinal plant families of the world, showing the total numbers of commercialised medicinal plant species, as well as the relative importance of the families, as reflected in the numbers of commercialised species, for the entire world (far left), Africa and seven other continents or regions. (Data summarized from Van Wyk and Wink, 2017 – see Appendix 5).

Rosaceae. Further comparative studies between the floristically uniform western and eastern parts of tropical Africa, and between temperate areas with high endemism (such as Madagascar and the Cape Floristic Region) would be of special interest to identify and characterise geographically distinct traditional medicine systems within the continent, and to compare them with other healing systems of the world.

Acknowledgements

I gratefully acknowledge funding from the University of Johannesburg and the National Research Foundation of South Africa (to the National Research Chair in Indigenous Plant Use, NRF Grant Number 8442).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jep.2019.112351.

Appendix 1. List of vascular plant families, showing the global number of species per family [data summarized from The Plant List (2013)] and African taxa per family [data summarized from the African Plant Database], as well as the number of African medicinal plants per family [data (summarized and edited) from Neuwinger (2000)]. The families are listed alphabetically on the left and according to the number of African medicinal species on the right

Families (alphabetical) *non-indigenous	Global species	Africa taxa	Medicinal species	Families (by number of African medical species)	Global species	Africa taxa	Medicinal species
Acanthaceae	3947	1593	106	Fabaceae	24505	5220	576
Achariaceae	101	28	3	Rubiaceae	13 673	2754	318
Acoraceae*	2	1	1	Asteraceae	32 913	4250	314
Aizoaceae	2271	1717	10	Malvaceae	4465	1141	202
Alismataceae	120	12	3	Euphorbiaceae	6547	1681	197
Amaranthaceae	2052	412	52	Apocynaceae	5556	1741	167
Amaryllidaceae	2258	382	31	Lamiaceae	7886	1015	142
Anacampserotaceae	58	42	1	Acanthaceae	3947	1593	106
Anacardiaceae	701	270	53	Asparagaceae	2929	1169	90
Ancistrocladaceae	21	13	0	Poaceae	11 554	2031	85
Anemiaceae	102	10	1	Annonaceae	2106	399	72
Anisophylleaceae	39	24	5	Combretaceae	480	259	72
Annonaceae	2106	399	72	Solanaceae	2678	211	61
Aphloiaceae	2	2	1	Convolvulaceae	1296	425	59
Apiaceae	3257	375	34	Moraceae	1217	253	59
Apocynaceae	5556	1741	167	Cucurbitaceae	965	238	58
Aponogetonaceae	58	22	0	Vitaceae	985	364	56
Aquifoliaceae	480	3	1	Phyllanthaceae	2099	332	54
Araceae	3368	177	24	Anacardiaceae	701	270	53
Araliaceae	1533	49	7	Amaranthaceae	2052	412	52
Araucariaceae*	39	1	0	Meliaceae	669	130	47
Arecaceae	2522	79	15	Sapotaceae	1343	239	44
Aristolochiaceae	624	23	5	Rutaceae	1730	439	43
Asparagaceae	2929	1169	90	Celastraceae	1168	316	40
Aspleniaceae	515	93	4	Verbenaceae	1035	361	39
Asteraceae	32 913	4250	314	Capparaceae	449	253	38
Balanophoraceae	45	5	2	Scrophulariaceae	1576	1045	38
Balsaminaceae	488	176	9	Menispermaceae	448	117	37
Basellaceae	19	3	1	Sapindaceae	1751	263	36
Begoniaceae	1601	134	9	Melastomataceae	4079	369	35
Berberidaceae	755	4	1	Xanthorrhoeaceae	1236	426	35
Bignoniaceae	852	67	16	Apiaceae	3257	375	34
Bixaceae	23	9	2	Orchidaceae	27 801	1897	34
Blechnaceae	219	9	0	Boraginaceae	2686	261	33
Boraginaceae	2686	261	33	Ebenaceae	751	157	33
Brassicaceae	4060	223	8	Burseraceae	649	172	32
Bromeliaceae	3320	4	0	Amaryllidaceae	2258	382	31
Bruniaceae	92	84	0	Cyperaceae	5784	1335	31
Burmanniaceae	163	25	0	Polygalaceae	1163	344	29
Burseraceae	649	172	32	Myrtaceae	5970	209	27
Buxaceae	122	10	0	Ochnaceae	560	129	27
Cabombaceae	6	1	0	Commelinaceae	728	318	26
Cactaceae	2233	23	3	Loganiaceae	351	75	26
Campanulaceae	2385	617	4	Polygonaceae	1384	105	26
Canellaceae	21	5	2	Thymelaeaceae	938	294	26
Cannabaceae	102	11	8	Passifloraceae	932	185	25
Cannaceae*	12	1	1	Araceae	3368	177	24
Capparaceae	449	253	38	Urticaceae	1465	87	24
Caprifoliaceae	857	38	4	Loranthaceae	886	243	23
Caricaceae	47	5	2	Salicaceae	1269	119	23
Caryophyllaceae	2456	172	10	Olacaceae	149	56	21
Casuarinaceae*	91	7	0	Rhamnaceae	839	233	21
Celastraceae	1168	316	40	Clusiaceae	1047	63	20
Ceratophyllaceae	4	2	0	Geraniaceae	841	374	20
Chrysobalanceae	535	78	13	Pedaliaceae	67	58	20
Cistaceae	201	7	0	Crassulaceae	1482	531	19
Cleomaceae	257	62	8	Hypericaceae	584	56	18

Clusiaceae	1047	63	20
Colchicaceae	284	113	5
Combretaceae	480	259	72
Commelinaceae	728	318	26
Connaraceae	267	18	9
Convolvulaceae	1296	425	59
Cornaceae	124	8	2
Costaceae	139	31	7
Crassulaceae	1482	531	19
Ctenolophonaceae	2	1	0
Cucurbitaceae	965	238	58
Cunoniaceae	245	2	0
Cupressaceae	166	10	0
Cyatheaceae	514	19	2
Cymodoceaceae	16	5	0
Cyperaceae	5784	1335	31
Davalliaceae	60	1	0
Dennstaedtiaceae	220	20	1
Dichapetalaceae	196	110	12
Dilleniaceae	219	15	5
Dioncophyllaceae	3	3	1
Dioscoreaceae	653	58	17
Dipterocarpaceae	147	40	3
Dirachmaceae	2	1	0
Droseraceae	189	35	1
Dryopteridaceae	1871	78	5
Ebenaceae	751	157	33
Elatinaceae	57	14	1
Ephedraceae	70	1	0
Equisetaceae	27	1	1
Ericaceae	3554	1021	2
Eriocaulaceae	1206	130	0
Erythroxylaceae	267	20	3
Escalloniaceae	55	2	0
Euphorbiaceae	6547	1681	197
Fabaceae	24 505	5220	576
Fagaceae*	1101	1	0
Flaggelariaceae	4	1	1
Geissolomataceae	1	1	0
Gentianaceae	1682	203	15
Geraniaceae	841	374	20
Gerrardinaceae	2	2	1
Gesneriaceae	3122	155	0
Gleicheniaceae	136	5	0
Gnetaceae	41	4	2
Goodeniaceae	329	1	1
Grossulariaceae	195	3	0
Grubbiaceae	3	3	0
Gunneraceae	69	1	1
Haemodoraceae	101	9	0
Haloragaceae	92	3	1
Hamamelidaceae	99	5	1
Heliconiaceae	204	8	0
Hernandiaceae	51	9	4
Huaceae	4	3	1
Humiriaceae	63	1	1
Hydnoraceae	10	7	3
Hydrocharitaceae	133	34	2
Hydrostachyaceae	19	19	0
Hymenophyllaceae	431	27	0
Hypericaceae	584	56	18
Hypoxidaceae	154	128	4
Icacinaceae	212	92	15
Iridicaceae	2315	1381	16
Irvingiaceae	11	11	7
Isoëtaceae	93	24	0
Ixonanthaceae	20	7	1
Juncaceae	506	30	3
Juncaginaceae	35	1	0
Lamiaceae	7886	1015	142
Lanariaceae	1	1	0
Lauraceae	2978	108	13
Lecythidaceae	341	48	7
Lentibulariaceae	312	43	1
Lepidobotryaceae	2	1	1
Liliaceae	746	1	0
Linaceae	213	48	5
Linderniaceae	164	29	3
Loasaceae	314	2	0
Loganiaceae	351	75	26
Oleaceae	688	81	18
Orobanchaceae	1613	307	18
Dioscoreaceae	653	58	17
Zingiberaceae	1587	108	17
Bignoniaceae	852	67	16
Iridicaceae	2315	1381	16
Arecaceae	2522	79	15
Gentianaceae	1682	203	15
Icacinaceae	212	92	15
Ranunculaceae	2377	78	14
Chrysobalanceae	535	78	13
Lauraceae	2978	108	13
Marantaceae	569	63	13
Rosaceae	4828	270	13
Santalaceae	992	307	13
Dichapetalaceae	196	110	12
Malpighiaceae	1301	64	12
Primulaceae	2788	56	12
Myristicaceae	170	14	11
Aizoaceae	2271	1717	10
Caryophyllaceae	2456	172	10
Violaceae	806	155	10
Balsaminaceae	488	176	9
Begoniaceae	1601	134	9
Connaraceae	267	18	9
Pteridaceae	1226	118	9
Simaroubaceae	121	28	9
Brassicaceae	4060	223	8
Cannabaceae	102	11	8
Cleomaceae	257	62	8
Lythraceae	604	132	8
Nyctaginaceae	450	46	8
Onagraceae	832	31	8
Araliaceae	1533	49	7
Costaceae	139	31	7
Irvingiaceae	11	11	7
Lecythidaceae	341	48	7
Molluginaceae	103	102	7
Oxalidaceae	601	273	7
Rhizophoraceae	142	52	7
Zygophyllaceae	211	112	7
Melianthaceae	20	16	6
Phytolaccaceae	62	11	6
Plantaginaceae	1614	52	6
Portulacaceae	258	55	6
Proteaceae	1252	443	6
Anisophylleaceae	39	24	5
Aristolochiaceae	624	23	5
Colchicaceae	284	113	5
Dilleniaceae	219	15	5
Dryopteridaceae	1871	78	5
Linaceae	213	48	5
Musaceae	78	6	5
Pandaceae	17	11	5
Selaginellaceae	404	49	5
Velloziaceae	278	44	5
Aspleniaceae	515	93	4
Campanulaceae	2385	617	4
Caprifoliaceae	857	38	4
Hernandiaceae	51	9	4
Hypoxidaceae	154	128	4
Nymphaeaceae	70	14	4
Opiliaceae	33	13	4
Plumbaginaceae	635	50	4
Polypodiaceae	1601	30	4
Stilbaceae	38	24	4
Thelypteridaceae	951	42	4
Achariaceae	101	28	3
Alismataceae	120	12	3
Cactaceae	2233	23	3
Dipterocarpaceae	147	40	3
Erythroxylaceae	267	20	3
Hydnoraceae	10	7	3
Juncaceae	506	30	3
Linderniaceae	164	29	3
Nephrolepidaceae	22	5	3
Piperaceae	2658	22	3
Salvadoraceae	8	6	3
Balanophoraceae	45	5	2
Bixaceae	23	9	2

Lomariopsidaceae	39	14	1	Canellaceae	21	5	2
Loranthaceae	886	243	23	Caricaceae	47	5	2
Lycopodiaceae	475	17	2	Cornaceae	124	8	2
Lygodiaceae	20	3	1	Cyatheaceae	514	19	2
Lythraceae	604	132	8	Ericaceae	3554	1021	2
Malpighiaceae	1301	64	12	Gnetaceae	41	4	2
Malvaceae	4465	1141	202	Hydrocharitaceae	133	34	2
Marantaceae	569	63	13	Lycopodiaceae	475	17	2
Marsileaceae	32	24	0	Moringaceae	13	10	2
Mayacaceae	6	1	0	Pittosporaceae	170	6	2
Melastomataceae	4079	369	35	Podocarpaceae	191	11	2
Meliaceae	669	130	47	Potamogetonaceae	186	7	2
Melianthaceae	20	16	6	Ulmaceae	64	4	2
Menispermaceae	448	117	37	Acoraceae*	2	1	1
Menyanthaceae	55	14	0	Anacampserotaceae	58	42	1
Molluginaceae	103	102	7	Anemiaceae	102	10	1
Monimiaceae	134	6	1	Aphloiaceae	2	2	1
Montiniaceae	4	1	1	Aquifoliaceae	480	3	1
Moraceae	1217	253	59	Basellaceae	19	3	1
Moringaceae	13	10	2	Berberidaceae	755	4	1
Musaceae	78	6	5	Cannaceae*	12	1	1
Myricaceae	53	19	0	Dennstaedtiaceae	220	20	1
Myristicaceae	170	14	11	Dioncophyllaceae	3	3	1
Myrothamnaceae	2	1	1	Droseraceae	189	35	1
Myrtaceae	5970	209	27	Elatinaceae	57	14	1
Nephrolepidaceae	22	5	3	Equisetaceae	27	1	1
Neuradaceae	7	7	0	Flaggelariaceae	4	1	1
Nyctaginaceae	450	46	8	Gerrardinaceae	2	2	1
Nymphaeaceae	70	14	4	Goodeniaceae	329	1	1
Ochnaceae	560	129	27	Gunneraceae	69	1	1
Olacaceae	149	56	21	Haloragaceae	92	3	1
Oleaceae	688	81	18	Hamamelidaceae	99	5	1
Oleandraceae	19	5	0	Huaceae	4	3	1
Onagraceae	832	31	8	Humiriaceae	63	1	1
Opiliaceae	33	13	4	Ixonanthaceae	20	7	1
Orchidaceae	27 801	1897	34	Lentibulariaceae	312	43	1
Orobanchaceae	1613	307	18	Lepidobotryaceae	2	1	1
Osmundaceae	16	2	0	Lomariopsidaceae	39	14	1
Oxalidaceae	601	273	7	Lygodiaceae	20	3	1
Pandaceae	17	11	5	Monimiaceae	134	6	1
Pandanaceae	1062	15	1	Montiniaceae	4	1	1
Papaveraceae	920	12	1	Myrothamnaceae	2	1	1
Passifloraceae	932	185	25	Pandanaceae	1062	15	1
Pedaliaceae	67	58	20	Papaveraceae	920	12	1
Penaeaceae	45	36	0	Pentadiplandraceae	1	1	1
Pentadiplandraceae	1	1	1	Pontederiaceae	33	7	1
Peridiscaceae	9	8	0	Resedaceae	51	14	1
Phyllanthaceae	2099	332	54	Smilacaceae	261	2	1
Phytolaccaceae	62	11	6	Strelitziaceae	7	5	1
Pinaceae*	255	4	0	Tamaricaceae	79	7	1
Piperaceae	2658	22	3	Tecophilaeaceae	26	16	1
Pittosporaceae	170	6	2	Theaceae	370	1	1
Plantaginaceae	1614	52	6	Typhaceae	65	2	1
Plumbaginaceae	635	50	4	Vahliaceae	5	4	1
Poaceae	11 554	2031	85	Zamiaceae	216	65	1
Podocarpaceae	191	11	2	Ancistrocladaceae	21	13	0
Podostemaceae	250	86	0	Aponogetonaceae	58	22	0
Polygalaceae	1163	344	29	Araucariaceae*	39	1	0
Polygonaceae	1384	105	26	Blechnaceae	219	9	0
Polypodiaceae	1601	30	4	Bromeliaceae	3320	4	0
Pontederiaceae	33	7	1	Bruniaceae	92	84	0
Portulacaceae	258	55	6	Burmanniaceae	163	25	0
Potamogetonaceae	186	7	2	Buxaceae	122	10	0
Primulaceae	2788	56	12	Cabombaceae	6	1	0
Proteaceae	1252	443	6	Casuarinaceae*	91	7	0
Pteridaceae	1226	118	9	Ceratophyllaceae	4	2	0
Rafflesiaceae	22	5	0	Cistaceae	201	7	0
Ranunculaceae	2377	78	14	Ctenolophonaceae	2	1	0
Rapateaceae	95	1	0	Cunoniaceae	245	2	0
Resedaceae	51	14	1	Cupressaceae	166	10	0
Restionaceae	482	354	0	Cymodoceaceae	16	5	0
Rhamnaceae	839	233	21	Davalliaceae	60	1	0
Rhizophoraceae	142	52	7	Dirachmaceae	2	1	0
Rosaceae	4828	270	13	Ephedraceae	70	1	0
Rubiaceae	13 673	2754	318	Eriocaulaceae	1206	130	0
Ruppiaceae	8	1	0	Escalloniaceae	55	2	0
Rutaceae	1730	439	43	Fagaceae*	1101	1	0
Salicaceae	1269	119	23	Geissolomataceae	1	1	0
Salvadoraceae	8	6	3	Gesneriaceae	3122	155	0
Salviniaceae	17	5	0	Gleicheniaceae	136	5	0

Santalaceae	992	307	13	Grossulariaceae	195	3	0
Sapindaceae	1751	263	36	Grubbiaceae	3	3	0
Sapotaceae	1343	239	44	Haemodoraceae	101	9	0
Schizaeaceae	22	2	0	Heliconiaceae	204	8	0
Scrophulariaceae	1576	1045	38	Hydrostachyaceae	19	19	0
Selaginellaceae	404	49	5	Hymenophyllaceae	431	27	0
Simaroubaceae	121	28	9	Isoëtaceae	93	24	0
Simmondsiaceae	2	1	0	Juncaginaceae	35	1	0
Smilacaceae	261	2	1	Lanariaceae	1	1	0
Solanaceae	2678	211	61	Liliaceae	746	1	0
Sphenocleaceae	2	1	0	Loasaceae	314	2	0
Stilbaceae	38	24	4	Marsileaceae	32	24	0
Strelitziaceae	7	5	1	Mayacaceae	6	1	0
Tamaricaceae	79	7	1	Menyanthaceae	55	14	0
Tecophilaeaceae	26	16	1	Myricaceae	53	19	0
Tectariaceae	329	5	0	Neuradaceae	7	7	0
Theaceae	370	1	1	Oleandraceae	19	5	0
Thelypteridaceae	951	42	4	Osmundaceae	16	2	0
Thurniaceae	4	1	0	Penaeaceae	45	36	0
Thymelaeaceae	938	294	26	Peridiscaceae	9	8	0
Triuridaceae	54	7	0	Pinaceae*	255	4	0
Typhaceae	65	2	1	Podostemaceae	250	86	0
Ulmaceae	64	4	2	Rafflesiaceae	22	5	0
Urticaceae	1465	87	24	Rapateaceae	95	1	0
Vahliaceae	5	4	1	Restionaceae	482	354	0
Velloziaceae	278	44	5	Ruppiaceae	8	1	0
Verbenaceae	1035	361	39	Salviniaceae	17	5	0
Violaceae	806	155	10	Schizaeaceae	22	2	0
Vitaceae	985	364	56	Simmondsiaceae	2	1	0
Vochysiaceae	215	4	0	Sphenocleaceae	2	1	0
Welwitschiaceae	1	1	0	Tectariaceae	329	5	0
Woodsiaceae	45	20	0	Thurniaceae	4	1	0
Xanthorrhoeaceae	1236	426	35	Triuridaceae	54	7	0
Xyridaceae	387	66	0	Vochysiaceae	215	4	0
Zamiaceae	216	65	1	Welwitschiaceae	1	1	0
Zingiberaceae	1587	108	17	Woodsiaceae	45	20	0
Zygophyllaceae	211	112	7	Xyridaceae	387	66	0

Appendix 2. Comparison of the results of two regression analyses, with the global total number of plant species per family [Regression 1 – data from The Plant List (2013)] and the total number of Africa taxa [Regression 2 – data from the African Plant Database)] as independent variable, and with the total number of Africa taxa (Regression 1 – data from African Plant Database)] and the total number of medicinal plant species (Regression 2 – data (as summarized and edited) from Neuwinger (2000)] as dependent variable. The 25 families with the highest and lowest residuals are listed; those with residual values exceeding the standard error are shown in bold

Regression 1	Global species	African taxa			Regression 2	African taxa	African medicinal species		
Family		Actual	Predicted	Residual	Family		Actual	Predicted	Residual
Fabaceae	**24 505**	**5220**	**3455**	**+1765**	**Fabaceae**	**5220**	**576**	**440**	**+136**
Aizoaceae	**2271**	**1717**	**347**	**+1370**	**Malvaceae**	**1141**	**202**	**97**	**+105**
Iridaceae	**2315**	**1381**	**353**	**+1028**	**Rubiaceae**	**2754**	**318**	**233**	**+85**
Acanthaceae	**3947**	**1593**	**581**	**+1012**	**Lamiaceae**	**1015**	**142**	**87**	**+55**
Apocynaceae	**5556**	**1741**	**806**	**+935**	**Euphorbiaceae**	**1681**	**197**	**143**	**+54**
Rubiaceae	**13 673**	**2754**	**1941**	**+813**	**Combretaceae**	**259**	**72**	**23**	**+49**
Scrophulariaceae	**1576**	**1045**	**250**	**+795**	**Solanaceae**	**211**	**61**	**19**	**+42**
Euphorbiaceae	**6547**	**1681**	**945**	**+736**	**Annonaceae**	**399**	**72**	**35**	**+37**
Asparagaceae	**2929**	**1169**	**439**	**+730**	**Cucurbitaceae**	**238**	**58**	**21**	**+37**
Cyperaceae	**5784**	**1335**	**838**	**+497**	**Moraceae**	**253**	**59**	**23**	**+36**
Ericaceae	**3554**	**1021**	**526**	**+495**	**Meliaceae**	**130**	**47**	**12**	**+35**
Malvaceae	**4465**	**1141**	**654**	**+487**	**Anacardiaceae**	**270**	**53**	**24**	**+29**
Poaceae	**11 554**	**2031**	**1645**	**+386**	**Menispermaceae**	**117**	**37**	**11**	**+26**
Crassulaceae	**1482**	**531**	**237**	**+294**	**Phyllanthaceae**	**332**	**54**	**29**	**+25**
Restionaceae	**482**	**354**	**97**	**+257**	Vitaceae	364	56	32	+24
Campanulaceae	**2385**	**617**	**363**	**+254**	Sapotaceae	239	44	21	+23
Proteaceae	**1252**	**443**	**204**	**+239**	Convolvulaceae	425	59	37	+22
Geraniaceae	**841**	**374**	**147**	**+227**	Apocynaceae	1741	167	148	+19
Xanthorrhoeaceae	**1236**	**426**	**202**	**+224**	Ebenaceae	157	33	15	+18
Convolvulaceae	**1296**	**425**	**210**	**+215**	Loganiaceae	75	26	8	+18
Vitaceae	**985**	**364**	**167**	**+197**	Burseraceae	172	32	16	+16
Verbenaceae	**1035**	**361**	**174**	**+187**	Amaranthaceae	412	52	36	+16
Commelinaceae	**728**	**318**	**131**	**+187**	Polygonaceae	105	26	10	+16
Rutaceae	1730	439	271	+168	Capparaceae	253	38	23	+15
Combretaceae	480	259	96	+163	Urticaceae	87	24	9	+15
Urticaceae	1465	87	234	−147	Hypoxidaceae	128	4	12	−8
Malpighiaceae	1301	64	211	−147	Bruniaceae	84	0	8	−8
Pandanaceae	1062	15	178	−163	Podostemaceae	86	0	9	−9
Fagaceae	**1101**	**1**	**183**	**−182**	Orobanchaceae	307	18	27	−9

Solanaceae	**2678**	**211**	**404**	**−193**	Asparagaceae	1169	90	100	−10
Araliaceae	**1533**	**49**	**244**	**−195**	Rosaceae	270	13	24	−11
Caryophyllaceae	**2456**	**172**	**373**	**−201**	Brassicaceae	223	8	20	−12
Plantaginaceae	**1614**	**52**	**255**	**−203**	Eriocaulaceae	130	0	12	−12
Dryopteridaceae	**1871**	**78**	**291**	**−213**	Geraniaceae	374	20	33	−13
Polypodiaceae	**1601**	**30**	**253**	**−223**	Santalaceae	307	13	27	−14
Melastomataceae	**4079**	**369**	**600**	**−231**	Gesneriaceae	155	0	14	−14
Ranunculaceae	**2377**	**78**	**362**	**−284**	Oxalidaceae	273	7	24	−17
Arecaceae	**2522**	**79**	**382**	**−303**	**Crassulaceae**	**531**	**19**	**46**	**−27**
Gesneriaceae	**3122**	**155**	**466**	**−311**	**Acanthaceae**	**1593**	**106**	**135**	**−29**
Cactaceae	**2233**	**23**	**342**	**−319**	**Restionaceae**	**354**	**0**	**31**	**−31**
Araceae	**3368**	**177**	**500**	**−323**	**Proteaceae**	**443**	**6**	**39**	**−33**
Lauraceae	**2978**	**108**	**446**	**−338**	**Asteraceae**	**4250**	**314**	**359**	**−45**
Primulaceae	**2788**	**56**	**419**	**−363**	**Campanulaceae**	**617**	**4**	**53**	**−49**
Brassicaceae	**4060**	**223**	**597**	**−374**	**Scrophulariaceae**	**1045**	**38**	**89**	**−51**
Piperaceae	**2658**	**22**	**401**	**−379**	**Cyperaceae**	**1335**	**31**	**114**	**−83**
Asteraceae	**32 913**	**4250**	**4631**	**−381**	**Ericaceae**	**1021**	**2**	**87**	**−85**
Rosaceae	**4828**	**270**	**704**	**−434**	**Poaceae**	**2031**	**85**	**172**	**−87**
Bromeliaceae	**3320**	**4**	**493**	**−489**	**Iridaceae**	**1381**	**16**	**117**	**−101**
Myrtaceae	**5970**	**209**	**864**	**−655**	**Orchidaceae**	**1897**	**34**	**161**	**−127**
Orchidaceae	**27 801**	**1897**	**3916**	**−2019**	**Aizoaceae**	**1717**	**10**	**146**	**−136**

Appendix 3. Results of Bayesian and IDM analyses for African plant families, showing all OVERUSED families (J = 253). Family names in bold are those shown by regression analysis to be overused. [inf. = Inferior 95% probability credible interval; sup. = Superior 95% probability credible interval; margin = difference between the interval of the overall n/t value (0.089, 0.094) and the inferior interval of family n/t values] . The results of an IDM analysis of the composition of the African flora versus the global flora showed that 26 families are over-represented in Africa and 22 families are under-represented (see last column: (+) = over-represented, (−) = under-represented)

Family	Global total	African total	African used	Bayes inf.	Bayes sup.	IDM inf.	IDM sup.	IDM
Myristicaceae	170	14	11	0.519	0.922	0.383	0.962	(−)
Cannabaceae	102	11	8	0.428	0.901	0.289	0.953	
Meliaceae	669	130	47	0.284	0.447	0.273	0.464	
Olacaceae	149	56	21	0.260	0.507	0.236	0.543	(+)
Loganiaceae	351	75	26	0.249	0.460	0.231	0.489	(+)
Irvingiaceae	11	11	7	0.349	0.848	0.230	0.916	(+)
Menispermaceae	448	117	37	0.239	0.405	0.227	0.425	(+)
Solanaceae	2678	211	61	0.232	0.354	0.226	0.365	(−)
Combretaceae	480	259	72	0.227	0.336	0.222	0.345	(+)
Connaraceae	267	18	9	0.289	0.711	0.218	0.782	(−)
Pedaliaceae	67	58	20	0.236	0.474	0.213	0.510	(+)
Musaceae	78	6	5	0.421	0.963	0.212	0.997	
Clusiaceae	1047	63	20	0.216	0.441	0.196	0.476	(−)
Hypericaceae	584	56	18	0.214	0.452	0.192	0.491	(−)
Cucurbitaceae	965	238	58	0.194	0.302	0.188	0.313	(+)
Moraceae	1217	253	59	0.185	0.289	0.180	0.299	(+)
Urticaceae	1465	87	24	0.193	0.378	0.179	0.406	(−)
Phytolaccaceae	62	11	6	0.277	0.789	0.177	0.872	
Dioscoreaceae	653	58	17	0.192	0.421	0.171	0.460	(−)
Polygonaceae	1384	105	26	0.175	0.338	0.164	0.362	(−)
Malvaceae	4465	1141	202	0.156	0.200	0.155	0.203	(+)
Anacardiaceae	701	270	53	0.153	0.248	0.149	0.258	(+)
Ebenaceae	751	157	33	0.154	0.281	0.146	0.298	(+)
Annonaceae	2106	399	72	0.146	0.221	0.143	0.228	(+)
Simaroubaceae	121	28	9	0.179	0.508	0.142	0.578	
Ochnaceae	560	129	27	0.148	0.288	0.139	0.308	(+)
Bignoniaceae	852	67	16	0.153	0.354	0.137	0.391	(−)
Sapotaceae	1343	239	44	0.140	0.238	0.135	0.250	
Oleaceae	688	81	18	0.146	0.325	0.132	0.356	(−)
Burseraceae	649	172	32	0.135	0.251	0.129	0.267	(+)
Pandaceae	17	11	5	0.211	0.723	0.128	0.823	(−)
Melianthaceae	20	16	6	0.184	0.617	0.126	0.711	(+)
Phyllanthaceae	2099	332	54	0.127	0.206	0.123	0.215	
Salicaceae	1269	119	23	0.133	0.274	0.123	0.296	(−)
Lamiaceae	7886	1015	142	0.120	0.163	0.119	0.165	(−)
Vitaceae	985	364	56	0.120	0.195	0.117	0.202	(+)
Primulaceae	2788	56	12	0.127	0.339	0.110	0.384	(−)
Marantaceae	569	63	13	0.125	0.322	0.109	0.364	(−)
Onagraceae	832	31	8	0.137	0.434	0.107	0.505	(−)
Capparaceae	449	253	38	0.112	0.200	0.107	0.211	(+)
Convolvulaceae	1296	425	59	0.109	0.175	0.107	0.182	(+)
Arecaceae	2522	79	15	0.119	0.290	0.106	0.325	(−)
Rubiaceae	13 673	2754	318	0.104	0.128	0.104	0.129	(+)
Euphorbiaceae	6547	1681	197	0.103	0.133	0.102	0.135	(+)
Fabaceae	24 505	5220	576	0.102	0.119	0.102	0.120	(+)
Hernandiaceae	51	9	4	0.187	0.738	0.099	0.848	
Ranunculaceae	2377	78	14	0.110	0.279	0.098	0.315	(−)

Dilleniaceae	219	15	5	0.152	0.587	0.097	0.692	(−)
Sapindaceae	1751	263	36	0.101	0.184	0.097	0.195	
Malpighiaceae	1301	64	12	0.111	0.300	0.096	0.342	(−)
Amaranthaceae	2052	412	52	0.098	0.162	0.095	0.169	(+)
Zingiberaceae	1587	108	17	0.101	0.238			(−)
Icacinaceae	212	92	15	0.102	0.252			(+)
Chrysobalanceae	535	78	13	0.100	0.265			
Costaceae	139	31	7	0.115	0.400			
Nephrolepidaceae	22	5	3	0.223	0.882			
Salvadoraceae	8	6	3	0.184	0.816			(+)
Opiliaceae	33	13	4	0.128	0.581			(+)
Nymphaeaceae	70	14	4	0.118	0.551			
Hydnoraceae	10	7	3	0.157	0.755			(+)
Aristolochiaceae	624	23	5	0.098	0.422			(−)
Overall:				**0.089**	**0.094**	**0.089**	**0.094**	

Appendix 4. Results of Bayesian and IDM analyses for African plant families, showing all UNDERUSED families (J = 253). Family names in bold are those shown by regression analysis to be underused. [inf. = Inferior 95% probability credible interval; sup. = Superior 95% probability credible interval; margin = difference between the interval of the overall n/t value (0.089, 0.094) and the superior interval of family n/t values. The results of an IDM analysis of the composition of the African flora versus the global flora showed that 18 families are over-represented in Africa and 6 families are under-represented (see last column: (+) = over-represented, (−) = under-represented)

Family	Global total	African total	African total used	Bayes inf.	Bayes sup.	IDM inf.	IDM sup.	IDM
Zamiaceae	216	65	1	0.004	0.082			(+)
Xyridaceae	387	66	0	0.000	0.054			
Hypoxidaceae	154	128	4	0.013	0.077			(+)
Bruniaceae	92	84	0	0.000	0.042			(+)
Podostemaceae	250	86	0	0.000	0.042			(+)
Rosaceae	4828	270	13	0.029	0.081			(−)
Geraniaceae	841	374	20	0.035	0.081			(+)
Brassicaceae	4060	223	8	0.019	0.069	0.015	0.085	(−)
Asteraceae	32 913	4250	314	0.066	0.082	0.066	0.083	(−)
Santalaceae	992	307	13	0.025	0.071	0.023	0.082	(+)
Acanthaceae	3947	1593	106	0.055	0.080	0.055	0.082	(+)
Oxalidaceae	601	273	7	0.013	0.052	0.010	0.066	(+)
Eriocaulaceae	1206	130	0	0.000	0.028	0.000	0.065	(−)
Crassulaceae	1482	531	19	0.023	0.055	0.022	0.062	(+)
Gesneriaceae	3122	155	0	0.000	0.023	0.000	0.054	(−)
Poaceae	11 554	2031	85	0.034	0.051	0.034	0.053	(+)
Scrophulariaceae	1576	1045	38	0.027	0.050	0.026	0.053	(+)
Proteaceae	1252	443	6	0.006	0.029	0.005	0.038	(+)
Cyperaceae	5784	1335	31	0.016	0.033	0.016	0.035	(+)
Orchidaceae	27 801	1897	34	0.013	0.025	0.012	0.027	(−)
Restionaceae	482	354	0	0.000	0.010	0.000	0.024	(+)
Campanulaceae	2385	617	4	0.003	0.016	0.002	0.023	(+)
Iridicaceae	2315	1381	16	0.007	0.019	0.007	0.021	(+)
Aizoaceae	2271	1717	10	0.003	0.011	0.003	0.013	(+)
Ericaceae	3554	1021	2	0.001	0.007	0.000	0.011	(+)
Overall:				**0.089**	**0.094**	**0.089**	**0.094**	

Appendix 5. Comparison of the results of two regression analyses, with the global total number of plant species per family as independent variable in both, and with the global number of commercialised medicinal plant species per family [Regression 3 – data from Van Wyk and Wink (2017)] and the number of commonly traded African medicinal plants species per family [Regression 4 – data from Van Wyk (2017)] as dependent variable. The 20 families with the highest and lowest residuals are listed; those with residual values exceeding the standard error are shown in bold

Regression 3	Global species	Global medicinal species			Regression 4	Global species	African medicinal species		
Family		Actual	Predicted	Residual	Family		Actual	Predicted	Residual
Apiaceae	**3257**	**37**	**7**	**+30**	**Fabaceae**	**24 505**	**27**	**10**	**+17**
Lamiaceae	**7886**	**43**	**15**	**+28**	**Apocynaceae**	**5556**	**16**	**3**	**+13**
Rosaceae	**4828**	**28**	**6**	**+22**	**Burseraceae**	**649**	**12**	**1**	**+11**
Fabaceae	**24 505**	**59**	**39**	**+20**	**Commelinaceae**	**728**	**5**	**1**	**+4**
Asteraceae	**32 913**	**63**	**45**	**+18**	**Xanthorrhoeaceae**	**1236**	**5**	**1**	**+4**
Amaranthaceae	**2052**	**21**	**6**	**+15**	**Rubiaceae**	**13 673**	**9**	**6**	**+3**
Apocynaceae	**5556**	**24**	**10**	**+14**	**Euphorbiaceae**	**6547**	**6**	**3**	**+3**
Ranunculaceae	**2377**	**19**	**6**	**+13**	**Rutaceae**	**1730**	**4**	**1**	**+3**
Rutaceae	**1730**	**15**	**5**	**+10**	**Malvaceae**	**4465**	**5**	**2**	**+3**
Solanaceae	**2678**	**15**	**6**	**+9**	**Moringaceae**	**13**	**3**	**0**	**+3**
Scrophulariaceae	**1576**	**12**	**4**	**+8**	**Meliaceae**	**669**	**3**	**1**	**+2**
Burseraceae	649	10	4	+6	**Apiaceae**	**3257**	**4**	**2**	**+2**
Polygonaceae	1384	10	5	+5	**Cucurbitaceae**	**965**	**3**	**1**	**+2**

Cucurbitaceae	965	9	4	+5	**Clusiaceae**	**1047**	**3**	**1**	**+2**
Caprifoliaceae	857	8	4	+4	**Sapotaceae**	**1343**	**3**	**1**	**+2**
Amaryllidaceae	2258	10	6	+4	Amaranthaceae	2052	3	1	+2
Brassicaceae	4060	12	8	+4	Pedaliaceae	67	2	0	+2
Pinaceae	255	7	3	+4	Simaroubaceae	121	2	0	+2
Papaveraceae	920	8	4	+4	Cupressaceae	166	2	0	+2
Malvaceae	4465	12	8	+4	Zygophyllaceae	211	2	0	+2
Oxalidaceae	601	1	3	−2	Orobanchaceae	1613	0	1	−1
Nyctaginaceae	450	1	3	−2	Plantaginaceae	1614	0	1	−1
Fagaceae	1101	2	4	−2	Dryopteridaceae	1871	0	1	−1
Arecaceae	2522	4	7	−3	Cactaceae	2233	0	1	−1
Saxifragaceae	775	1	4	−3	Iridaceae	2315	0	1	−1
Adiantaceae	695	1	4	−3	Ranunculaceae	2377	0	1	−1
Ebenaceae	751	1	4	−3	Campanulaceae	2385	0	1	−1
Acanthaceae	3947	4	7	−3	Caryophyllaceae	2456	0	1	−1
Vitaceae	985	1	4	−3	Arecaceae	2522	0	1	−1
Aizoaceae	2271	1	4	−3	Boraginaceae	2686	0	1	−1
Araceae	3368	4	8	−4	Gesneriaceae	3122	0	2	−2
Urticaceae	1465	1	5	−4	Bromeliaceae	3320	0	2	−2
Annonaceae	2106	1	5	−4	Cyperaceae	5784	1	3	−2
Myrtaceae	5970	7	12	−5	Araceae	3368	0	2	−2
Gesneriaceae	3122	1	7	−6	Myrtaceae	5970	1	3	−2
Bromeliaceae	**3320**	**1**	**8**	**−7**	Ericaceae	3554	0	2	−2
Cyperaceae	**5784**	**4**	**12**	**−8**	**Melastomataceae**	**4079**	**0**	**2**	**−2**
Poaceae	**11 554**	**10**	**20**	**−10**	**Asteraceae**	**32 913**	**10**	**14**	**−4**
Rubiaceae	**13 673**	**13**	**24**	**−11**	**Poaceae**	**11 554**	**0**	**5**	**−5**
Orchidaceae	**27 801**	**4**	**44**	**−40**	**Orchidaceae**	**27 801**	**0**	**12**	**−12**

References

African Pharmacopoeia, 1981, 1986 (vols 1, 2). OAU/STRC Publications Division, Laos.

African Plant Database (version 3.4.0), Conservatoire et Jardin botaniques de la Ville de Genève and South African National Biodiversity Institute, Pretoria. "Retrieved [January 2018]", from. http://www.ville-ge.ch/musinfo/bd/cjb/africa/.

Arnold, T.H., Prentice, G.A., Hawker, L.C., Snyman, E.E., Tomalin, M., Crouch, N.R., Pottas-Bircher, C., 2002. Medicinal and Magical Plants of Southern Africa: an Annotated Checklist. Strelitzia. vol. 13 National Botanical Institute, Pretoria.

Brendler, T., Eloff, J.N., Gurib-Fakim, A., Phillips, L.D. (Eds.), 2010. African Herbal Pharmacopoeia. Association of African Medicinal Plant Standards, Port Louis.

Burkill, H.M., 1985–2004. second ed. The Useful Plants of West Tropical Africa, 6 vols Royal Botanic Gardens, Kew.

Catalogue of the Vascular Plants of Madagascar, 2019. Missouri Botanical Garden. U.S.A. & Antananarivo, St. Louis Madagascar. http://www.tropicos.org/Project/Madagascar, Accessed date: 31 May 2019.

Dobignard, A., Chatelain, C., 2010-2013. Synonymic and Bibliographic Index of North Africa Plants, vols. 1–5 Conservatoire et Jardin botaniques de la Ville de Genève.

Germishuizen, G., Meyer, N.L., 2003. Plants of Southern Africa: an Annotated Checklist. National Biodiversity Institute, Pretoria.

The plant resources of tropical Africa 11(2). In: In: Gurib-Fakim, A., Schmelzer, G.H. (Eds.), Medicinal Plants, vol. 2 CTA PROTA, Wageningen.

Iwu, M.M., 1993. Handbook of African Medicinal Plants. CRC Press, Boca Raton.

Kokwaro, J.O., 1993. Medicinal Plants of East Africa, second ed. East Africa Literature Bureau, Nairobi.

Lebrun, J.-P., Stork, A.L., 1991–2015. Enumération des plantes à fleurs d'Afrique tropicale et Tropical African Flowering Plants: Ecology and Distribution, vols. 1–7 Conservatoire et Jardin botaniques de la Ville de Genève.

Magwede, K., Van Wyk, B.-E., Van Wyk, A.E., 2019. An inventory of Vhavenda useful plants. South Afr. J. Bot. 122, 57–89.

Mhlongo, L.S., Van Wyk, B.-E., 2019. Zulu medicinal ethnobotany: new records from the Amandawe area of KwaZulu-Natal, South Africa. South Afr. J. Bot. 122, 266–290.

Moerman, D.E., 1979. Symbols and selectivity: A statistical analysis of native American medical ethnobotany. J. Ethnopharmacol. 1, 111–119.

Moerman, D.E., 1991. The medicinal flora of native North America: An analysis. J. Ethnopharmacol. 31, 1–42.

Moerman, D.E., 1996. An analysis of the food plants and drug plants of native North America. J. Ethnopharmacol. 52, 1–22.

Moerman, D.E., Pemberton, R.W., Kiefer, D., Berlin, B., 1999. A comparative analysis of five medicinal floras. J. Ethnobiol. 19, 46–67.

Natural Database for Africa, 2011. Version 2.0. NDA Is a Species Based Versatile Database Developed by Ermias Dagne, Ethiopia (edagne@gmail.Com).

Neuwinger, H.D., 2000. African Traditional Medicine – A Dictionary of Plant Use and Applications. Medpharm Scientific Publishers, Stuttgart.

Oliver-Bever, B. (Ed.), 1986. Medicinal Plants of Tropical West Africa. Cambridge University Press, Cambridge.

PROTA, 2010. The Plant Resources of Tropical Africa. Updated List of Species and Commodity Groupings. Backhuys Publishers and CTA PROTA, Wageningen.

The plant resources of tropical Africa 11(1). In: In: Schmelzer, G.H., Gurib-Fakim, A. (Eds.), Medicinal Plants, vol. 1 Backhuys Publishers and CTA PROTA, Wageningen.

The Plant List, 2013. The Plant List. A Working List of All Plant Species. Royal Botanic Gardens, Kew and Missouri Botanical Garden, St Louis version 1.1. http://www.theplantlist.org/.

Watt, J.M., Breyer-Brandwijk, M.G., 1962. The Medicinal and Poisonous Plants of Southern and Eastern Africa, second ed. Livingstone, London.

Weckerle, C.S., Cabras, S., Castellanos, M.E., Leonti, M., 2011. Quantitative methods in ethnobotany and ethnopharmacology: considering the overall flora—hypothesis testing for over- and underused plant families with the Bayesian approach. J. Ethnopharmacol. 137, 837–843.

Weckerle, C.S., Cabras, S., Castellanos, M.E., Leonti, M., 2012. Imprecise probability calculation (IDM) for the detection of over and underused taxonomic groups with the Campania (Italy) and the Sierra Popoluca (Mexico) medicinal flora. J. Ethnopharmacol. 142, 259–264.

Welcome, A.K., Van Wyk, B.-E., 2019. An inventory and analysis of the food plants of southern Africa. South Afr. J. Bot. 122, 136–179.

World Flora Online, 2019. http://www.worldfloraonline.org/, Accessed date: 31 May 2019.

Van Wyk, B.-E., 2008. A broad review of commercially important southern African medicinal plants. J. Ethnopharmacol. 119, 342–355.

Van Wyk, B.-E., 2015. A review of commercially important African medicinal plants. J. Ethnopharmacol. 176, 118–134.

Van Wyk, B.-E., 2017. A review of African medicinal and aromatic plants. In: In: Máthé, Á., Neffati, M., Najjaa, H. (Eds.), Medicinal and Aromatic Plants of the World – Africa, vol. 3. Springer, New York, London, 978-94-024-1119-5, pp. 19–60.

Van Wyk, B.-E., Moteetee, N.A., 2019. Ethnobotanical research in sub-Saharan Africa – documenting and analysing indigenous knowledge about medicinal, edible and other useful plants. Editorial: South Afr. J. Bot. 122, 1–2.

Van Wyk, B.-E., Wink, M., 2015. Phytomedicines, Herbal Drugs and Poisons. Kew Publishers, Kew and University of Chicago Press, Chicago.

Van Wyk, B.-E., Wink, M., 2017. Medicinal Plants of the World, second ed. CABI, London.