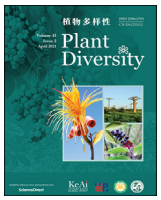
Plant Diversity 43 (2021) 134–141

Contents lists available at ScienceDirect

Plant Diversity

journal homepage: http://www.keaipublishing.com/en/journals/plant-diversity/
http://journal.kib.ac.cn



Research paper

Native useful vascular plants of China: A checklist and use patterns

Huifu Zhuang [a, b], Chen Wang [b], Yanan Wang [a], Tao Jin [a], Rong Huang [a], Zihong Lin [a], Yuhua Wang [b, *]

[a] Service Center for Information Technology, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, 650201, China
[b] Yunnan Key Laboratory for Wild Plant Resources, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, 650201, China

ARTICLE INFO

Article history:
Received 15 May 2020
Received in revised form
28 August 2020
Accepted 5 September 2020
Available online 12 September 2020

Keywords:
Useful plants
Ethnobotany
Plant diversity
Traditional knowledge
China

ABSTRACT

Of all types of interactions between humans and plants, the utilization of plants by people is the most direct and influential. China has a long history of using native plants and a large body of recorded knowledge on uses. Here, we present an inventory of plant uses in China based on an extensive survey of the literature. Twelve categories of usage are recognized (medicinal, edible, etc.), these categories being chosen according to an integration of various current standards. A total of 50,521 use-citations were recorded, covering 10,808 species and infraspecies, representing 28% of the Chinese flora. Additional information is included in the dataset on taxonomy and endangerment status. Analysis of the data reveals that the eight plant families with the greatest numbers of species used in China, namely Asteraceae, Fabaceae, Rosaceae, Ranunculaceae, Poaceae, Lamiaceae, Orchidaceae, and Liliaceae, are also the top eight most species-rich Chinese plant families. However, there are some families that are over-represented or under-representation in certain use categories, compared with their relative abundance in the total flora. There are indications that rare and endangered species are being subject to some degree of over-exploitation. A disproportionately high number of used species are Chinese endemics (3552 species, representing over 33% of used species). A total of 20% of used species have been classified as threatened nationally or globally, according to at least one of the various threat assessments that have been made for the Chinese flora. This comprehensive inventory of the useful plants of China, with relevant ethnobotanical information included, provides a baseline for further studies of plant resources. It will be useful in follow-up research. The scientific dataset it contains will be useful for the protection and sustainable utilization of plant resources in China.

1. Introduction

1.1. The importance of useful plants

Useful plants play a significant role in human living (Smekalova, 2012). Since antiquity, humans have used a great diversity of wild plants for food, medicines, fuel and many other purposes (Prance and Nesbitt, 2005; Tardio et al., 2006). Some plants discovered to be used in traditional medicine through ethnobotanical research have proved useful for the development of new drugs used for treating cancer, malaria, Alzheimer disease, HIV/AIDS and other diseases (Lentini, 2000; Butler, 2004; Newman et al., 2003). Currently, more than 50% of all approved drugs contain natural products or their derivatives (Marrelli et al., 2015; Ovadje et al., 2015). There has been growing interest in finding the health functions from traditional medicines and wild fruits (Chen et al., 2006; Saleem et al., 2002; Leonti et al., 2006; Pieroni et al., 2002). Nowadays, the effective use of genetic resources of the planet is considered as a key factor in the pursuit of sustainable development around the world.

1.2. Close use relationship between humans and plants in China

China is among the world's richest countries in terms of plant biodiversity. One estimate is that there are some 33,000 vascular plant species (Jordi et al., 2006), but, according to our statistics, there are 39,174 species and infraspecies) recorded in all. There are 55 officially recognized ethnic minorities in China, more than 80%

* Corresponding author.
E-mail address: wangyuhua@mail.kib.ac.cn (Y. Wang).
Peer review under responsibility of Editorial Office of Plant Diversity.

https://doi.org/10.1016/j.pld.2020.09.003

of them having their own traditional medicinal knowledge systems (Jia and Li, 2005). In addition to plants used in traditional medical systems in China, many ethnic minorities use a diversity of species in their folk medical traditions. Anthropological and ethnobotanical studies in China, initiated by Professor Pei Shengji in the 1980s (Zhang et al.,2018), have resulted in the compilation of much detailed information about the types and uses of native plants. There has been a concentration of such studies in those areas with the greatest indigenous and ethnic diversity, especially within Yunnan, Guizhou, Guangxi, Hainan, Inner Mongolia, Xinjiang, Tibet, Hunan and others areas (Table S3). There has also been much progress in follow-up scientific assessments and development of applications. Assessments through bioassays of the chemical molecules responsible for the traditional uses of plants have been undertaken from the 1950s (KIB, 2009) and, in consequence, a large number of compounds have been identified with potential for use in the pharmaceutical, cosmetic, food, agricultural and other industries. Many new drugs have been developed, such as artemisinin, total saponins of *Panax notoginseng* (Xueshuantong for injection), and so on have been successfully developed in China (Tu et al., 2015).

Of all types of interactions between human beings and plants, ethnobotanical studies of how plants are used has the most practical implications. Studies of useful plant can potentially progress through three research stages – field investigations and cataloguing, scientific assessment, and development of applications (Pei and Huai, 2007). The cataloguing of the field investigations is an important part of the first stage, which is also important for providing support for assessing and developing the management of plant resources.

1.3. Dispersed state of knowledge on plant uses and database construction

While information about the plant resources of China and their traditional and current uses has been documented for some areas, it is vastly dispersed and inadequately integrated. Due to the professional characteristics of scientific publications, most of the literature has only been published in small publication runs, many publications only being available to members of small research groups involved in diverse research fields such as botany, biology, chemistry, conservation biology and others (Javiera et al., 2019). Furthermore, some publications, such as unpublished theses and dissertations, are not widely accessible. Hence, the scattered nature of the data has prevented a full understanding of the current state of knowledge about the uses made plants in China. Previous analyses have been concerned with only subsets of the total potential dataset.

Since 2008, the *Scientific Data Project* of the Chinese Academy of Sciences has funded a program of digitization and database construction for the Chinese flora. This has included the cataloguing and integrating of information on uses. Although the online databases that have been compiled through this program have played an important role in the rapid spread of plant-related knowledge in China, further integration of useful plant information is needed.

While many publications about the Chinese flora have been produced over the years, the scientific names used for the same species can differ between them, as understandings of taxonomic relationships and the delimitations of species have changed. Many scientific names of plant species were revised during the preparation of the latest edition of *Flora of China* in English. The true identity of plants for which traditional uses have been recorded can become lost, leading to a loss of traditional knowledge in disguise (Ai, 2019; Qin and Tian, 2014). Therefore, research on the identity of useful plants is becoming a hot issue in China. We need a complete catalogue of useful plants matched to the latest taxonomic treatments and associated nomenclature. This will help promote a better understanding of value of biodiversity in China and enhance its usefulness for its protection and sustainable utilization.

Here, we present our results, providing: (1) a complete checklist of the useful plants of China, catalogued according to the nomenclature used in the latest edition of the *Flora of China*; (2) an analysis according to categories of usage, showing the general patterns of use of the Chinese flora; and (3) discussing the potential influence of plant use patterns on plant diversity in China.

2. Material and methods

2.1. Baseline checklists of Chinese plant diversity used in this study

The Chinese flora, according to *Flora of China* (2018), contains 39,174 vascular plant species and infraspecies belonging to 312 families. Generally, flora of China records the native plants in China. However, it also contains a small number of alien plant species closely related to human life, such as some crops. In this study, we take all the plants recorded in *Flora of China* as baseline of native Chinese plant diversity. These, listed with their synonyms, constituted the baseline checklist used in the present study. For endemism and conservation status information, we employed the *Scientific Database of Chinese Plant Species* (KIB, 2010), developed by Kunming Institute of Botany, and the *Information System of Chinese Rare and Endangered Plants*, developed by the Institute of Botany, Chinese Academy of Sciences(IB, 2013), both include information on conservation status according to the *National Red Data List of Chinese Plants* (SCPRC, 1999a, 1999b), *Red List of Biodiversity in China* (Higher Plants) (MEP and CAS, 2013), CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), IUCN (International Union for Conservation of Nature) and PSESP (Plant Species with Extremely Small Populations) (IB, 2013). Some of these are for global conservation status (IUCN, CITES, and PSESP) and the other specifically for China.

2.2. Data sources, literature mining and databases construction

A useful plant in our study is defined as a plant used by people, following Hill (1937). We use the term “use-citation” for mention of a specific use of a particular plant species in a specific source (Javiera et al., 2019). Each use-citation includes a plant name, taxonomic information, usage and references. To begin our study, we consulted authoritative books about useful plants, such as the *Pharmacopoeia of the People's Republic of China* (CPC, 1953-2015), *Chinese Materia Medica* (SATCM, 1999), *Economic Flora of China* (BLWP, 1961), etc. (Table S3), and digitalized the information into a structured data table. We followed up with literature searches of journal articles, reviews and theses on Chinese ethnobotany, as available in China. We used relevant keyword combinations, such as “ethnobotany”, “Chinese traditional knowledge”, “useful plant”, “medicinal plant”, “edible plant”, etc., to retrieve information online from a total of 23 theses and 99 research articles (Table S3) to enter into our database. A taxon names indexing tool named Taxonfinder (http://taxonfinder.org) was used to detect scientific names in thousands of digital texts. Next plant usage terms, such as “medicine”, “edible”, etc., were used to interrogate the dataset on species used for different purposes.

2.3. Classification of uses and statistical analyses

Categories used for the recording of plant uses have changed with the progression of plant science. According to traditional economic values and uses, plants used as resources are divided into

roughly 10–20 categories (BLWP, 1961; Zhu, 2004; Wang and Li, 2014; Chen et al., 2014). Wishing to refer to both these categories and the usage categories that are used in modern economic botanical and ethnobotanical studies, we decided to recognize 12 usage categories in total (Table 1.). Ours is a modified version of the classifications of use found in the *Economic Flora of China* (BLWP, 1961) and *Plant Resources in China* (Zhu, 2004). We entered the information on plant uses gathered from the literature into these 12 categories in our database. Statistical analyses were then carried out on the data in the database to determine the characteristics of the plants used, the frequencies of use of different species, the parts of the plants used, the numbers of use-citations per species and the frequencies of plant parts used. Linear regression was used to determine the relationship between the numbers of plant species used for any purpose and overall numbers of species per family and also, separately in the case of the use-categories of medicinal plants, edible plants and ornamental plants, to determine whether there were significant statistical differences in species used per family in these cases.

3. Results

A total of 50,521 plant use-citations was extracted from the literature on Chinese vascular plants. These were categorized into species, using nomenclature and current taxonomic understandings as in the *Flora of China*. Taking account of synonymies and misspellings, a total of 10,808 useful species was determined (28% of flora of China), belonging to 2276 genera and 284 families (Table S1). The number of useful species per use category was 9772 for medicinal uses, 2061 for edible uses, 1102 for ornamental or planting uses, 767 as industrial raw materials, 779 for timber, 692 for fiber, 547 with oilseeds, 752 for fodder, 183 for pesticides, 149 for religious or cultural uses, 129 for dyeing and 352 with other uses (classifiable into the foregoing categories (used as green manures, for handicrafts, toys, hobbies, tobacco, etc. (Table 1).

Of the useful plant species and infraspecies, 3552 (33%) are endemic to China, 1353 are included in at least one of the national threatened plant lists available for China and 1356 are included in at least one list of globally threatened species, such as those of IUCN and CITES. In all, 2106 of the species and infraspecies (20%) are included in at least one list of threatened plants, which is equivalent to a large proportion (30%) of the total number of Chinese threatened plant species. All use-categories contain rare and endangered species, the greatest number being for that of medicinal plants. A total of 3159 medicinal plant species are endemic, 418 are recorded in the Chinese Plant Red Data list (accounting for 19% of the total Red Data list), 315 on CITES and 1154 have been Red-Listed by IUCN (Table 2).

Table 1
Use-categories used for categorizing uses of the Chinese useful flora, with definitions of each category, numbers of species and use-citations per species and the percentages of the total Chinese used flora belonging to each category.

Usage	Abbr.	Classification criteria	No. of species or infraspecies	No. of use-citation	% of total Chinese used flora
Medicine	MD	Species reported as medicinal in pharmacopeias, medicine books or through ethnobotanical research, or prescribed for the treatment of certain diseases.	9772	37,523	90.41
Edible	ED	Species reported as used for vegetable, fruit, cereal, or condiment; or used as sources of tea and drinks.	2061	5163	19.07
Ornamental or greening plants	OP	Species reported as used in gardens and parks, used as greenery, used as for soil and water conservation, and sand fixation.	1102	1570	10.20
Industrial raw materials	IN	Species reported as used in industrial materials, such as rubber, resin, tanning material, essential oil, etc.	767	1103	7.10
Timber or construction material	TC	Species reported as sources of timber and building material.	779	1212	7.21
Fiber	FB	Species reported as sources of fiber in ethnobotanical studies or used by people to make textiles, baskets, ropes, or mattress in botanical texts.	692	1089	6.40
Oilseeds	OI	Species reported as sources of oilseed.	547	724	5.06
Fodder	FO	Species reported as used for forage, bee keeping, or used as veterinary medicine.	752	1145	6.96
Pesticide	PE	Species used for pesticide.	183	216	1.69
Religious or cultural uses	RC	Species of religious significance, or reported as used by people in certain ceremonies, rituals.	149	180	1.38
Dyeing or pigment	DP	Species used for Dyeing.	129	206	1.19
Others	OT	Species that could not be classified in the previous categories, such as species used as green manure, hobby, tobacco, toys, etc.	352	390	3.26

Table 2
Endemism and conservation status of useful plants.

Endemic/conservation status*	ED^N	RD^N	RLBC^N	CITES^G	IUCN^G	PSESP^G
Total species number of each status category in Chinese flora	13,960	2330	6468	1512	7470	117
All uses	3552	476	1186	341	1353	24
Medicine	3159	418	998	315	1154	16
Edible	548	60	154	19	174	1
Ornamental or planting	264	71	131	50	147	7
Industrial raw materials	180	27	66	5	78	4
Timber or construction material	234	51	125	3	134	9
Fiber	165	5	26	3	29	0
Oilseeds	138	27	49	3	56	4
Fodder	103	8	18	1	22	0
Pesticide	21	2	5	0	5	0
Religious or cultural uses	33	8	16	5	20	0
Dyeing or pigment	22	3	5	0	6	0
Others	75	8	21	3	24	0

*Abbreviations: ED (Endemic); RD (Red Data List of Chinese Plants); RLBC (Red List of Biodiversity in China, Higher Plant); CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora); IUCN (International Union for Conservation of Nature); PSESP (Plant Species with Extremely Small Populations). The superscript abbreviations "N"and "G" refer to national and global respectively.

The number of useful species in a plant family and the total number of species in that family are significantly related in China (Fig. 1). Those families with higher species richness are likely to have higher numbers of useful plants. Tests on the relationships between the number of species per family and the use-categories of 'medicine', 'edible' and 'ornamental or planting' as the dependent variable revealed all to be significantly related (Adjusted R Square > 0.5, $P < 0.05$).

Table S2 shows the numbers of species in each use category for each family. Table 3 shows the data for the top five most species-rich families in each use category. Table 4 summarizes the results of regression analyses for 'all uses', 'medicine', 'edible' and 'ornamental or planting'. The families included are those that contain much higher or lower numbers of useful species (over 3.00 or under −3.00; $P < 0.01$) than predicted by chance.

Of the total of 39,174 plant species and infraspecies in the *Flora of China,* 28,366 (72%) have no recorded uses, 7494 (19%) have one recorded type of use, 1692 (4.3%) have two, 821 (2%) have three and the remaining 801 (2%) have more than three recorded types of use. There is an approximately negative exponential function model between the numbers of used species to use categories (Fig. 2).

There are significantly more use-citations for species in the 'medicinal' and 'edible' categories than for species in the other categories of use (Fig. 3).

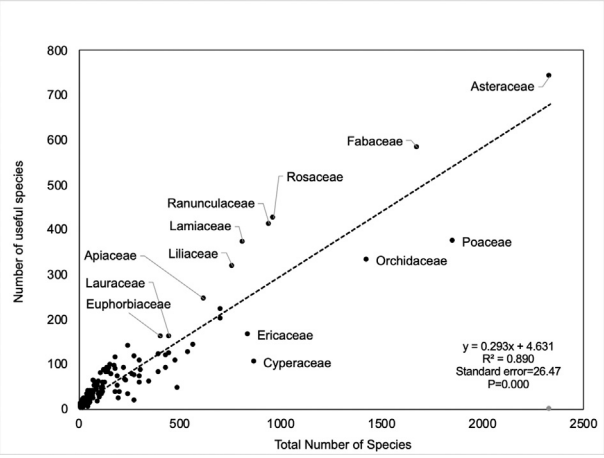


Fig. 1. Scatterplot of the families of vascular plants in China, comparing total numbers of species with the numbers of useful species.

Of the total of 50,521 use-citation records assembled, the most commonly used parts of plants are root, stem, whole plant and leaf, all with more than 11,000 records of use (Fig. 4). Fruits, flowers, seeds and above-ground parts are used to lesser extents.

4. Discussion

4.1. High number of plant species used in China

The total number of Chinese species and infraspecies of vascular plants used is 10,808, the corresponding percentage of the total flora (28%) being similar to that recorded for countries such as Chile (23%), Mexico (23%) and Ecuador (30%) (Javiera et al., 2019). Of the total for all uses, 9772 species and infraspecies have been recorded as medicinal. After adjusting for taxonomic revisions, this figure is not dissimilar to the early estimates of nearly 11,000 species reported to have been used since the Paleolithic period (Hamilton, 2004), the estimated 12,000 species estimated to have been used by Academician Xiao Pigen (Li, 2008) and the about 8000 species recorded as medicinal in the ten volumes of Chinese Materia Medica (1999). For edible plant resources, Ministry of Agriculture (1995) reported that China had at least 400–500 wild species of vegetables and more than 200 wild species of starch or sugar plants. Our summary found that totally 2061 plants were recorded with edible usages (Table 1), including at least 1090 vegetables and 203 staple foods. Our study listed a similar number of wild plants that can be used as staple foods, but a greater number of wild plants that can be used as vegetables. Apart from staple and vegetables, 404 edible plants were used for fruits, 197 substitutes for tea drinking, and 243 edible plants used for spices, condiments or snacks. (A detailed dataset of edible plants with subdivisions will be translated to English and published in our follow-up work). Our study listed a similar number of wild plants that can be used as staple foods, but a greater number of wild plants that can be used as vegetables. The State Environmental Protection Administration of China (1998) has estimated that as many as 2200 ornamental species originated in China. Our statistics show that only 1102 species of ornamental plants have been used in China. These figures suggest that there is potential for more species of native Chinese plants to be used within China for ornamental and planting purposes. We note that, for wild species only, Zhu (2004) has listed 379 species of wild oil plants in China, and 394 wild species of fiber plant. Those categories of used plants were augmented and detailed in our research, 547 plants are used for oilseed and 692 for fiber

Table 3
Families with the highest numbers of useful plants in China (top 5) for each use category.

Use category	Number of families	Top 5 families	Numbers of useful species
All uses	283	Asteraceae	743
		Fabaceae	583
		Rosaceae	426
		Ranunculaceae	413
		Lamiaceae	373
Medicine	275	Asteraceae	716
		Fabaceae	542
		Ranunculaceae	413
		Rosaceae	383
		Lamiaceae	369
Edible	203	Rosaceae	153
		Poaceae	126
		Asteraceae	114
		Fabaceae	102
		Liliaceae	91
Ornamental or greening plants	170	Poaceae	107
		Fabaceae	93
		Rosaceae	52
		Orchidaceae	43
		Asteraceae	35
Fodder	115	Poaceae	138
		Fabaceae	96
		Asteraceae	56
		Lamiaceae	27
		Rosaceae	25
Timber or construction material	106	Poaceae	79
		Fabaceae	59
		Lauraceae	46
		Fagaceae	39
		Pinaceae	37
Industrial raw materials	125	Rosaceae	45
		Asteraceae	43
		Lauraceae	41
		Lamiaceae	41
		Fagaceae	39
Fiber	100	Poaceae	130
		Fabaceae	55
		Urticaceae	34
		Moraceae	32
		Tiliaceae	32
Oilseeds	113	Lauraceae	50
		Theaceae	14
		Sapindaceae	11
		Rutaceae	19
		Rosaceae	20
		Pinaceae	13
Pesticide	62	Fabaceae	38
		Ranunculaceae	16
		Asteraceae	13
		Euphorbiaceae	11
		Solanaceae	8
Sacrifice or culture	70	Poaceae	9
		Fabaceae	7
		Cupressaceae	7
		Rutaceae	6
		Salicaceae	5
Dyeing or pigment	51	Fabaceae	17
		Rubiaceae	8
		Asteraceae	6
		Euphorbiaceae	5
		Anacardiaceae	5
Others	103	Poaceae	39
		Fabaceae	30
		Rosaceae	13
		Euphorbiaceae	12
		Polygonaceae	12

(Table 1). Our own inventory of useful plants has the advantage, compared with previous inventories, of including all published information available in China on uses of plants in China, which should be useful for those making efforts to achieve sustainable utilization of the plants.

4.2. The endemic and threatened status of plant species used in China

Overexploitation is a major threat to plant diversity (Corlett, 2016) and thus a special conservation concern with respect to

Table 4
Plant families in China with the highest and lowest residual values in regression analyses of numbers of useful species against total number of species.

Family name	Number of useful species	Predicted number	Standardized residual
All uses			
Rosaceae	426	287	5
Ranunculaceae	413	281	5
Lamiaceae	373	242	5
Liliaceae	317	228	3
Fabaceae	583	496	3
Athyriaceae	18	86	−3
Ericaceae	165	250	−3
Orchidaceae	332	423	−3
Dryopteridaceae	47	149	−4
Cyperaceae	104	259	−6
Poaceae	374	548	−7
Medicine			
Ranunculaceae	413	252	5
Lamiaceae	369	217	5
Rosaceae	383	257	4
Asteraceae	716	615	3
Fabaceae	542	444	3
Liliaceae	291	204	3
Dryopteridaceae	47	134	−3
Ericaceae	130	224	−3
Cyperaceae	89	232	−5
Poaceae	182	490	−10
Edible			
Rosaceae	153	49	10
Liliaceae	91	40	5
Moraceae	49	9	4
Fagaceae	54	17	3
Poaceae	126	94	3
Scrophulariaceae	8	36	−3
Ranunculaceae	16	49	−3
Cyperaceae	3	45	−4
Orchidaceae	14	73	−5
Ornamental or Planting			
Poaceae	107	56	8
Fabaceae	93	50	7
Clusiaceae	33	3	5
Rosaceae	52	29	4
Arecaceae	21	3	3
Cupressaceae	19	2	3
Lamiaceae	8	25	−3
Scrophulariaceae	3	21	−3
Cyperaceae	7	26	−3
Ranunculaceae	7	29	−3
Asteraceae	35	70	−5

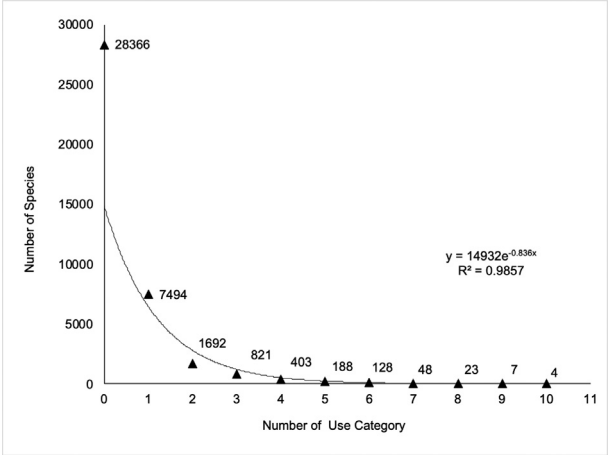


Fig. 2. Numbers of species in the Chinese flora having records of use for different numbers of use categories, as recognized in this study. For example, 28,366 species have no records of use of any type and 7494 species have one known types of use.

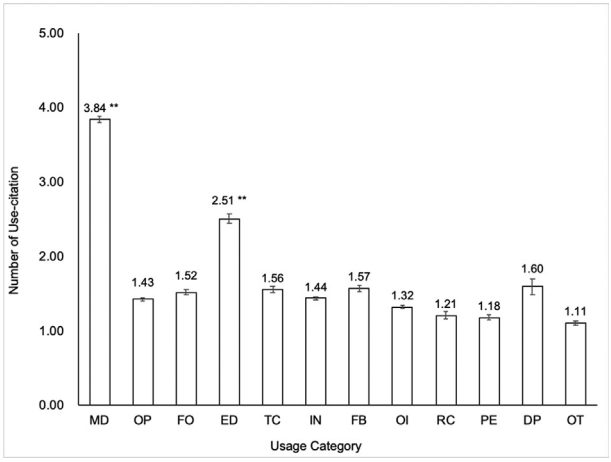


Fig. 3. Number of plant use-citation of each species in different use category. Abbreviated codes refer to Table 1. Medicinal and edible plants have significantly more use-citations than other category of plants. Asterisks indicate significant differences between each two usage categories determined by Student's t-test (**, $P < 0.01$). Error bars are ±SE.

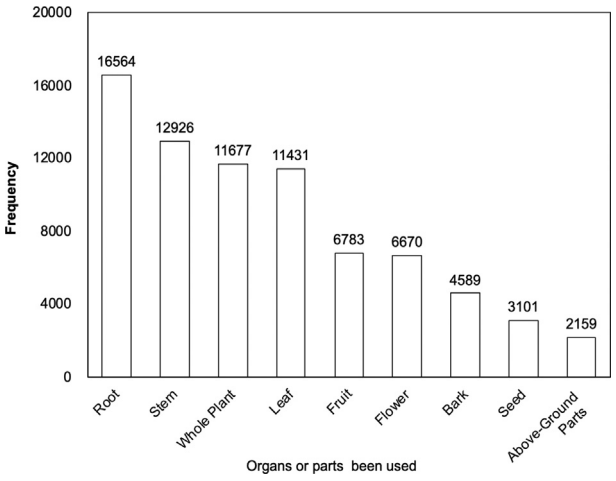


Fig. 4. Number of use-citations per use-category for plants in the Chinese flora. The total number of use-citations for all use-categories is 50,521.

used species and especially for species that are national endemics. Our figure for the total number of endemic species used medicinally (3159) (Table 2) is roughly similar to that of 3510 reported earlier by Li et al. (2017). However, the result from our own inventory that about 19% of species included on the Chinese National Red Data List are medicinal is greatly different from the estimate of Huang et al. (2011) that 60–70% of Chinese endangered species are of medicinal value. The explanation may be that the lists of endangered plants given in different sources are not the same and that there are differences of opinion about which plants are medicinal. In general, a notable proportion (25% of endemic plant, and 18%–22% of each endangered category) of the rare and endangered plants species have been used in China, that indicate that rare and endangered species are being subject to some degree of overexploitation. We suggest that before endangered species are utilized, especially before commercial operations, more research on domestication and cultivation should be carried out. Sustainable utilization of plant resources requires coordination of protection and development.

4.3. Overall use patterns of plants in China

Globally, families of plants with greater species richness are more likely to have more useful plants (Javiera et al., 2019). Linear regression confirms this is the case for China (Fig. 1). The dominant families of Chinese flora, such as Poaceae, Asteraceae, Fabaceae, Liliaceae, Ranunculaceae and Chenopodiaceae contain a greater number of used plants. Our statistics show that most plant species used in China are used for only one or two categories of use (Fig. 2), whereas a few plants species have multiple usages, such as for medicine, food, ornamental, construction material, etc. The latter, which include *Betula platyphylla, Ulmus macrocarpa, Ficus microcarpa, Vitex negundo, Cinnamomum camphora, Broussonetia papyrifera, Sophora japonica* and *Bischofia javanica*, have greater overall potential for utilization and development and should be given more attention in follow-up studies. The fact that the number of used species per use-category confirms approximately to a negative exponential function indicates that most of published floras for China (which are often for only limited area) are deficient in how many species are actually used. We are still at a relatively initial stage in compiling a full list of used plants at the national scale.

We recorded a total of 50,521 use-citations. The most used parts of plants (each with over 11,000 citations) are roots, stems, whole plants and leaves. The first three of these collection modes will cause considerable damage to the plants, which has a certain pressure on the sustainable utilization of wild plant resources (Zhuang and Wang, 2009).

Wild medicinal and edible plant resources are widely used in China, especially in ethnic areas. In our inventory, medicinal and edible plants were the two main use categories, using respectively, 90% and 19% of all species in the Chinese used flora (Table 1).

4.4. Rich diversity of medicinal and edible plant species in China

Benefiting from the inheritance of traditional Chinese medicine (TCM), China uses more plant species as medicines (9772) than any other country. The proportion of the national flora used medicinally (25%) is greater than has been recorded for other countries, such as Chile (12%; Javiera et al., 2019), Argentina (14%; Barboza, 2009), Mexico (7%; Javiera et al., 2019) and the USA (13%; Moerman, 1991).

Medicinal and edible plants have significantly more numbers of use-citations (3.62 and 2.21) than other categories of plant use (Fig. 3). The richness of traditional knowledge about medicinal plants and edible plants in China has been quantitatively confirmed in this study. Of the total of 50,521 use-citations of all uses, 37,523 (74%) are for medicinal use and 5163 (10%) for edible. It also suggests that researchers mainly focus on these two categories of resource plants, and we should pay more attention to other types of plant resources in the future.

4.5. Over-representation of some taxa in certain use-categories

Many studies have found that useful plants are not randomly distributed across floras. (Forest et al., 2007; Lulekal et al. 2011; Weckerle et al., 2011, 2012). Our study reveals that the same is true of China (Table 4).

Of the about 312 plant families present in the flora of China, the most over-represented in terms of useful species are Rosaceae, Ranunculaceae, Lamiaceae, Liliaceae and Fabaceae. They have the highest residual values in regression analyses (Table 4). Conversely, Poaceae, Cyperaceae, Athyriaceae, Dryopteridaceae, Orchidaceae and Ericaceae have lowest residual values such analyses, indicating that they have the lowest proportions of used plants.

In addition to regression analyses of family representation regarding all uses, separate regression analyses undertaken for particular uses reveal that Ranunculaceae, Lamiaceae, Rosaceae, Asteraceae, Fabaceae and Liliaceae are over-represented for use as medicines, Rosaceae, Liliaceae, Moraceae, Fagaceae and Poaceae for use as foods and Poaceae, Fabaceae, Clusiaceae, Rosaceae, Arecaceae and Cupressaceae as ornamentals.

5. Conclusions

Our main finding is that China has a large number of useful vascular plants. Our research into the literature has revealed that a total of 10,818 species and infraspecies have been used, with quantitative information now available on details about patterns of use. The close utilization relationship between the Chinese people and the Chinese flora is confirmed. More species have been used medicinally than in any other country. Those plant families that are richer in species in China contain a higher number of used plants, but there is over- or under-representation for certain use-categories, which suggests that, in these cases, the selection of species for use is non-random. Data are provided on the proportions of rare and endangered plants used. We have presented the first comprehensive ethnobotanical for Chinese plants. This will provide a baseline for further studies and provide insights into the

selection of plant species for research, including to support scientific efforts made to protect and sustainably use the plants of China.

Author contributions

YHW contributed to the conception of the study. HFZ performed the data analyses and wrote the manuscript. YNW contributed to the dataset integration and database construction. CW, RH, JT and ZHL contributed to the ethnobotanical data collection.

Declaration of competing interest

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

Acknowledgement

We thank the Scientific data center of Kunming Institute of Botany for dataset and digitization supporting. This study was supported by Strategic Priority Research Program of Chinese Academy of Sciences (No. XDA20050204, XDA19050301), National Natural Science Foundation of China (Grant No. 32000261) and the 13th Five-year Informatization Plan of Chinese Academy of Sciences (No. XXH13506, XXH-13514).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pld.2020.09.003.

References

Ai, T.M., 2019. Some suggestions on compiling of Chinese Pharmacopoeia 2020 edition. Chin. Tradit. Herb. Drugs 50, 1281–1284.
Barboza, G., 2009. Medicinal plants: a general review and a phytochemical and ethnopharmacological screening of the native Argentine Flora. Kurtziana 34, 7–365.
Bureau of Local Products and Waste Products (BLWP), 1961. Ministry of Commerce of the People's Republic of China. Science Press, Beijing China. Economic Flora of China.
Butler, M.S., 2004. The role of natural product chemistry in drug discovery. J. Nat. Prod. 67, 2141–2153.
Chen, P.N., Chu, H.L., Chiou, H.L., et al., 2006. Mulberry anthocyanins cyaniding 3-rutinoside, exhibited and inhibitory effect on the migration and invasion of a human cancer cell line. Canc. Lett. 235, 248259.
Chen, S.K., Wang, Y.H., Zhuang, H.F., 2014. Important and Useful Plants in Northwest Yunnan. Yunnan Science and Technology Press, Kunming, China.
Corlett, R.T., 2016. Plant diversity in a changing world: status, trends, and conservation needs. Plant Divers. 38, 15–22.
Chinese Pharmacopoeia Commission (CPC), 1953-2015. The Pharmacopoeia of the People's Republic of China. Each edition of 1953-2015.
Forest, F., Grenyer, R., Rouget, M., et al., 2007. Preserving the evolutionary potential of floras in biodiversity hotspots. Nature 445, 757–760.
Hamilton, A.C., 2004. Medicinal plants, conservation and livelihoods. Biodivers. Conserv. 13, 1477–1517.
Hill, A.F., 1937. Economic Botany: A Textbook of Useful Plants and Plant products. McGraw Hill Book Company, Inc, New York.
Huang, L.Q., Xiao, P.G., Wang, Y.Y., 2011. Investigation on Resources of Rare and Endangered Medicinal Plants in China. Shanghai Science and Technology Press, Shanghai, China, p. P11.
Institute of Botany (IB), CAS, 2013. Information system of Chinese rare and endangered plants. http://www.iplant.cn/rep/protlist.
Javiera, D.F., Pedro, L.L., Marticorena, A., et al., 2019. Native useful plants of Chile: a review and use patterns. Econ. Bot. 73, 112–126.
Jia, M.R., Li, X.W., 2005. Ethnomedicine of China. China Medical Science and Technology Press, Beijing.
Jordi, L.P., Zhang, F.M., Ge, S., 2006. Plant biodiversity in China: richly varied, endangered, and in need of conservation. Biodivers. Conserv. 15, 3983–4026.
KIB, 2009. The state key laboratory of photochemistry and plant resources in west China. http://phytochem.kib.cas.cn/sysgk/201607/t20160701_341 316.html.
Kunming Institute of Botany (KIB), CAS, 2010. Scientific database of Chinese plant species. http://db.kib.ac.cn.
Lentini, F., 2000. The role of ethnobotanics in scientific research. State of ethnobotanical knowledge in Sicily. Fitoterapia 71, 883–888.
Leonti, M., Nebel, S., Rivera, D., Heinrich, M., 2006. Wild gathered food plants in the European Mediterranean: a comparative analysis. Econ. Bot. 60, 130–142.
Li, Y.H., 2008. Sustainable development of medicinal plant resources must be emphasized. China Pharmaceut 17, 6–7.
Li, H.T., Hui, S., Xiao, B., Li, Z., Huang, Y.J., Ma, L.Q., 2017. Endemic plants for medicine use in China. China J. Chin. Mater. Med. 42, 4329–4335.
Lulekal, E., Asfaw, Z., Kelbessa, E., Van Damme, P., 2011. Wild edible plants in Ethiopia: a review on their potential to combat food insecurity. Afr. Focus 24, 71–121.
Marrelli, M., Cristaldi, B., Menichini, F., Conforti, F., 2015. Inhibitory effects of wild dietary plants on lipid peroxidation and on the proliferation of human cancer cells. Food Chem. Toxicol. 86, 16–24.
Ministry of Environmental Protection (MEP) and Chinese Academy of Sciences (CAS), 2013. Red List of Biodiversity in China (Higher Plant). http://www.mee.gov.cn/gkml/hbb/bgg/201309/t2013 0912_260061.htm.
Ministry of Agriculture, 1995. China: Country Report to the FAO International Technical Conference on Plant Genetic Resources (Leipzig, 1996). Ministry of Agriculture, Beijing.
Moerman, D.E., 1991. The medicinal flora of native North America: an analysis. J. Ethnopharmacol. 31, 1–42.
Newman, D.J., Cragg, G.M., Snader, K.M., 2003. Natural products as sources of new drugs over the period 1981-2002. J. Nat. Prod. 66, 1022–1037.
Ovadje, P., Roma, A., Steckle, M., Nicoletti, L., Arnason, J.T., Pandey, S., 2015. Advances in the research and development of natural health products as mainstream cancer therapeutics. Evid. Base. Complement Altern. Med. 2015, 751348 https://doi.org/10.1155/2015/751348, 12 pages.
Pei, S.J., Huai, H.Y., 2007. Ethnobotany. Shanghai Scientific & Technical Publishers, Shanghai, China.
Pieroni, A., Janiak, V., Durr, C.M., Ludeke, S., Trachsel, E., Heinrich, M., 2002. In vitro antioxidant activity of non-cultivated vegetables of ethnic Albanians in southern Italy. Phytother Res. 16, 467–473.
Prance, G.T., Nesbitt, M., 2005. The Cultural History of plants. Routledge (Taylor and Francis), New York.
Qin, M.J., Tian, M., 2014. Proposal for standardized authors' s name citing in original plant Latin name listed in the Chinese Pharmacopoeia. China J. Chin. Mater. Med. 39, 1743–1748.
Saleem, A., Husheem, M., Hakonen, P., Pihlaja, K., 2002. Inihibition of cancer cell growth by crude extract and the phenolics of *Terminalia chebula* Retz. fruit. J. Ethnopharmacol. 81, 327–336.
State Administration of traditional Chinese Medicine (SATCM), 1999. Chinese Materia Medica, vol. 1–10. Shanghai Science and Technology Press.
State Council of the People's Republic of China (SCPRC), 1999a. National Red Data List of Chinese Plants (Vol.1). http://www.forestry.gov.cn/yemian/minglu1.htm.
State Council of the People's Republic of China (SCPRC), 1999b. National Red Data List of Chinese Plants (Vol.2). http://www.iplant.cn/rep/protlist/2.
State Environmental Protection Administration (SEPA), 1998. China's Biodiversity: A Country Study. China Environmental Science Press, Beijing.
Smekalova, T.N., 2012. Development of Strategy of Conservation of Wild Relatives of Cultivated Plants of Russia in Situ. Vavilov's Institute RAS. http://www.vir.nw.ru/files/ppt/02.04.2012/15.
Tardio, J., Pascual, H., Morales, R., 2006. Ethnobotanical review of wild edible plants in Spain. Bot. J. Linn. Soc. 152, 27–71.
Tu, P.F., Yong, J., Xiao, Y.G., 2015. Discovery, research and development for innovative drug of traditional Chinese medicine under new situations. China J. Chin. Mater. Med. 40, 3423–3428.
Wang, K.L., Li, L.F., 2014. Resources Botany. Science Press, Beijing, China.
Weckerle, C.S., Cabras, S., Castellanos, M.E., et al., 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. https://doi.org/10.1016/j.jep.2011.07.002.
Weckerle, C.S., Cabras, S., Castellanos, M.E., et al., 2012. An imprecise probability approach 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.
Zhang, L., Zhuang, H.F., Zhang, Y., et al., 2018. Plants for health: an ethnobotanical 25-year repeat survey of traditional medicine sold in a major marketplace in North-west Yunnan, China. J. Ethnopharmacol. 224, 119–125.
Zhu, T.P., 2004. Plant Resource in China. Science Press, Beijing.
Zhuang, H.F., Wang, Y.H., 2009. An analysis model for the sustainable use of medicinal plants. Acta Bot. Yunnanica 31, 520–528.