

Article

A Survey and Analysis of the History of Ernest Henry Wilson's Specimen Collections in China

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Abstract: Since the mid-17th century, Western plant collectors have explored Asia, particularly China, to collect native species for economic and botanical development. Ernest Henry Wilson (1876–1930) stands among the foremost figures in this pursuit. He conducted five plant collections in China between 1899 and 1918, gaining recognition for numerous valuable ornamental species. However, precise details such as the total number of specimens, a comprehensive species list, and the collection locations remained elusive, hindering a thorough assessment of his scientific contributions. To address this gap, we compiled data from various online databases and relevant publications, constructing a comprehensive dataset encompassing species names, collection dates, locations, and additional pertinent information. Employing Python, we organized and translated the species names and locations, facilitating analysis of families, genera, species, and the completeness and preferences of his collection. The conclusions drawn from the available data include 19,218 specimens, with 11,884 collection numbers, belonging to 200 families, 1046 genera, and 3794 species (including 342 infraspecific taxa). Wilson exhibited a preference for woody and flowering plants, resulting in a collection completeness of 25%. His collection spanned seven provinces, 28 prefecture-level cities, and 38 county-level areas, underscoring his significant contributions to the global dissemination of Chinese plant knowledge. This study conducts a comprehensive analysis of the plant specimens collected by Wilson in China, investigating their taxonomy, distribution, and historical context and evaluating Wilson's contribution to plant dissemination. The findings serve as a valuable reference for subsequent biodiversity research endeavors.

Keywords: China; specimen collection; plant diversity; plant collection history; Ernest Henry Wilson



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1. Introduction

Steady progress has been made in Botanical research since the advent of modern science. Botanical herbarium specimens have emerged as valuable materials for studying plant resources and the environment in diverse countries. Concurrently, the dissemination of botanical resources has gradually become globalized [1–3]. Therefore, a thorough investigation into plant dissemination, including the study of dissemination materials, like specimens [4]; dissemination methods, e.g., transnational collection; disseminators, such as plant collectors; and the history of modern plant dissemination in China will contribute to raising awareness for the protection of local plant resources. During the rapid development of capitalism, Western countries, leveraging long-term practical production experience, established specialized botanical research institutions to promote economic development [5]. With the swift progress of both botany and the economy, the demand for plant resources expanded even further [6], giving rise to the profession of plant collectors

in Western countries. Engaging in plant surveys, collection, and introduction worldwide, particularly in Asia, these plant collectors focused on China, recognized as one of the most biologically diverse countries [7,8]. Plant resources from China have been drawing Western interest since the 16th century [9] and became the focus of professional collection from the 17th century onwards [10]. Especially in the 19th century, Western botanists exhibited a higher frequency of collection in China [11,12]. After the Opium Wars (1840), Westerners gained greater freedom of action in China, making collection activities more accessible for collectors [13]. Ernest Henry Wilson stands out as one of the most renowned plant collectors during this period.

Between 1899 and 1911, Wilson undertook two plant explorations in China on behalf of the British Nursery Firm of Veitch and Sons and three times for The Arnold Arboretum of Harvard University in the United States. He collected a substantial number of plant specimens, representing diverse species in Hubei (Hupeh), Sichuan (Szechuan), and Taiwan (Formosa) [14,15]. Initially, James Herbert Veitch (1869–1907) of Veitch and Sons was inspired by the specimens of *Davidia involucrata* Baill. (Nyssaceae) collected by the Irish botanist Augustine Henry (1856–1930) in China, expressing a keen interest in hiring a plant collector to collect this species. Wilson was the chosen candidate. Employed by Veitch, Wilson embarked on his first botanical expedition to mainland China in 1899. In 1903, he returned to China to search for *Meconopsis integrifolia* (Maxim.) Franch. (Papaveraceae), completing the collection task and returning to England in 1905 [16]. The thousands of herbarium specimens brought back from the two collections (1899–1905) caught the attention of Charles Sprague Sargent (1841–1927), the director of the Arnold Arboretum at that time [17]. On behalf of the Arnold Arboretum, Sargent invited Wilson for a third expedition to China [18]. The goal of the third expedition (1907–1909) was to increase knowledge of Chinese woody plants and collect and introduce as many plants as possible [16]. However, due to the poor growth of conifer seeds collected from Western China during the third expedition, which were nonetheless of significant research value, Wilson returned to China for a fourth botanical expedition in 1910. In 1918, Wilson conducted further collections in Taiwan, introducing a variety of rare plants such as *Abies kawakamii* (Hayata) T. Itô (Pinaceae), *Taiwania cryptomerioides* Hayata (Cupressaceae), and *Pseudotsuga wilsoniana* Hayata (Pinaceae) [15]. His collections surpassed those of other collectors of the same period in terms of the number of ornamental species. Wilson's contributions have been highly praised by later generations, with the acknowledgment that “hardly a garden exists without plants introduced by him” [19].

According to previous research accounts, however, Wilson collected approximately 65,000 specimens [20–22] and thousands of species in China. These figures are derived from studies published in *Arnoldia*, but no one has verified or systematically counted the exact number of specimens and species he collected. Moreover, in past studies, there has been limited mention of the specific collection locations on his journey [18,23–25], such as Yichang (Ichang), Kangding (Tachienlu), and Chengdu (Chengtu), among others, and the timeline of his journeys remains unclear. In essence, most studies rely on studies without robust data support and based on a single source, lacking quantification of species and numbers. As diversity and collection preferences are not analyzed, a scientific and comprehensive evaluation of Wilson's contributions to diversity is challenging. In this study, building upon previous research, we adopted a multi-channel approach to collect specimen data, including digital specimens and publications. In the context of global digitization, digital specimens are more easily accessible, and combining them with publications allows cross-verification and supplement collection information. We utilized Python to further process the dataset, obtaining a catalog of collected species and lists of collection times and locations. Through these methods, this study seeks to address questions about the quantity and diversity of the specimens and species collected by Wilson in China, his collection preferences and completeness, and the publication of new species based on his collections. Ultimately, this research aims to evaluate Wilson's significant contributions to botany and diversity studies.

2. Materials and Methods

2.1. Data Compilation

We extensively reviewed the literature and publications related to Wilson, including biographies, obituaries, and archives, to gain insights into his personality and life. These materials were instrumental in understanding the historical context of plant exploration and the global impact and value of Wilson's collection achievements. Some publications were authored by Wilson himself, such as *A Naturalist in Western China with Vasculum and Gun*, while others were written by later scholars, such as the material published in *Arnoldia*. Among these studies and publications, *Plantae Wilsonianae* [26–28] and Field Notes documented information about plant specimens collected by Wilson. The former recorded some species collected throughout his life, while the latter specifically noted plant species collected by him in China. However, Field Notes are considered as a reference only because only collection time and collection number information can be reliably extracted.

In addition to publications, we gathered digital specimen data using keywords like “Wilson”, “China”, and “Formosa” on five comprehensive database websites: Integrated Digitized Biocollections, IDIGBio [29]; Global Biodiversity Information Facility, GBIF [30]; National Specimen Information Infrastructure (NSII, <http://www.nsii.org.cn/2017/home.php>, accessed on 29 July 2022); Chinese Virtual Herbarium (CVH, <https://www.cvh.ac.cn/>, accessed on 29 July 2022); Specimen Resource Sharing Platform for Education (SPSPE, <http://mnh.scu.edu.cn/>, accessed on 29 July 2022), and individual specimen museum websites (Table 1) [31,32]. This approach was taken as the data from comprehensive databases are more extensive, while data from individual herbariums are frequently updated and more complete.

Table 1. The herbaria and countries in which Wilson's specimens are stored.

No.	Country	Herbarium Name	Herbarium Code	Number
1	Australia	Royal Botanic Gardens and Domain Trust	NSW	8
2	Austrian	Universität Wien	WU	3
3	Botswana	University of Botswana	UCBG	1
4	Brazilian	Herbario da Universidade Estadual de Ferira de Santana	UFES	2
5	Canada	Canadian Museum of Nature	CMN	2
6	China	Xiamen University	AU	2
7	China	Wuhan Institute of Botany	HIB	3
8	China	South China Botanical Garden	IBSC	535
9	China	Kunming Institute of Botany, Chinese Academy of Sciences	KUN	64
10	China	Lushan Botanical Garden	LBG	1
11	China	Institute of Botany, Chinese Academy of Sciences	PE	165
12	China	Zhongshan (Sun Ya-tsen) University	SYS	680
13	China	Institute of Botany, Jiangsu Province and Chinese Academy of Sciences	NAS	15
14	China	Nanjing University	N	1
15	China	Nanjing Agricultural University	NAU	1
16	China	Herbarium of Taiwan Forestry Research Institute	TAIF	3
17	France	Muséum National d'Histoire Naturelle	P	911
18	German	ZE Botanischer Garten und Botanisches Museum, Freie Universität Berlin	B	211

Table 1. Cont.

No.	Country	Herbarium Name	Herbarium Code	Number
19	The Netherlands	Naturalis Biodiversity Centre, formerly Leiden University	L	50
20	The Netherlands	Naturalis Biodiversity Center	WAG	5
21	The Netherlands	Naturalis Biodiversity Center	U	2
22	Sweden	Lund University	LD	4
23	Sweden	Swedish Museum of Natural History	S	82
24	Sweden	Museum of Evolution	UPS	2
25	Russia	Komarov Botanical Institute of RAS	LE	340
26	USA	Herbarium of the Arnold Arboretum, Harvard University Herbaria.	A	3767
27	USA	Economic Herbarium of Oakes Ames (ECON) & Orchid Herbarium of Oakes Ames	AMES	127
28	USA	Gray Herbarium	GH	419
29	USA	Bernice Pauahi Bishop Museum	BISH	10
30	USA	California Academy of Sciences	CAS	111
31	USA	Carnegie Museum of Natural History	CM	1
32	USA	Academy of Natural Sciences	PH	1
33	USA	Missouri Botanical Garden	MO	368
34	USA	Morton Arboretum	MOR	16
35	USA	New York Botanical Garden	NY	186
36	USA	Smithsonian National Museum of Natural History	US	5675
37	USA	University of South Florida	USF	2
38	USA	University of Vermont	VT	2
39	USA	University of Washington	WTU	1
40	USA	The University of Texas at Austin	LL	2
41	USA	Brown University	BRU	3
42	UK	The Natural History Museum	BM	739
43	UK	Royal Botanic Garden Edinburgh	E	1340
44	UK	Royal Botanic Gardens, Kew	K	2082

2.2. Data Processing

2.2.1. Data Preprocessing

Standardizing File Formats

To address inconsistencies in data sources, formats, and completeness, we manually standardized the disparate data formats. Specifically, date entries, such as “1901年5月” or “190105”, were unified to the format “1901/05.” Additionally, we harmonized the formats for herbarium barcodes, species names, collection times, and other data to ensure uniformity, thereby facilitating smooth data processing.

Removing Duplicate Data

To ensure data integrity, we used barcodes as reference points and eliminated duplicate entries from different databases but corresponding to the same herbarium and collection number. However, a special case arose at the Smithsonian National Museum of Natural History (US), where a barcode was duplicated, but indeed there were two distinct specimens. In such instances, duplicate entries were retained. Similarly, we removed items with duplicate collection numbers from both *Plantae Wilsonianae* and database websites.

2.2.2. Plant Species Names

In the realm of global plant authority databases, we used Plants of The World Online (POWO, <https://powo.science.kew.org/>, accessed on 2 August 2022) [33]. For Chinese plant authority databases, we gave precedence to IPlant (<http://www.iplant.cn/>, accessed on 2

August 2022), Species 2000 China Node (<http://www.sp2000.org.cn>, accessed on 2 August 2022), and Flora of China (<http://www.efloras.org/>, accessed on 2 August 2022).

We employed the ipypd biodiversity processing framework in Python and utilized the IPlant database for translating botanical names [34].

We manually verified species names using IPlant, Species 2000 China Node, and Flora of China, which were supplementarily verified on Plants of the World Online.

The verified species names were subjected to various taxonomic verification tools, including the Taxonomic Name Resolution Service (TNRS, <https://tnrs.biendata.org/>, accessed on 10 August 2022) with data from Tropicos, Global Compositae Checklist, USDA Plants, and NCBI Taxonomy [35,36], Species 2000 China Node (http://www.sp2000.org.cn/names_match_services, accessed on 14 August 2022), and the 2022 China Plant Species List (<http://www.iplant.cn/pnc>, accessed on 14 August 2022), ensuring the validation of accepted species names. The dates for these verifications are 10 August 2022 for TNRS and Species 2000 China Node and 14 August 2022 for the 2022 China Plant Species List.

2.2.3. Recoding Collection Numbers

When Wilson collected specimens for Veitch and the Arnold Arboretum, he utilized collection numbers in both. Consequently, there are instances where the same collection number corresponds to different species. We performed the following processes.

If the number of specimens with the same collection number was greater than 5 and they belonged to the same family but 1–2 specimens had different species names, we considered this a misidentification issue among different herbaria. Following the principle of majority rules, we adopted the species name with the highest frequency, counting it as one species.

If we found an instance of the same collection number but belonging to different botanical families and, after verifying the original specimen information, it was confirmed that the two specimens represent distinct species, we assigned a separate number for the additional species, counting it as two species.

2.2.4. Collection Dates

Collection time was supplemented by checking handwritten records on specimen photographs (because handwritten information on specimens was not fully entered in the specimen information of some herbaria).

(1) Referencing *Plantae Wilsonianae* and Field Notes.

We utilized information from *Plantae Wilsonianae* and Field Notes to update the collection location and collection time details associated with the collection number.

(2) Supplementing collection time information based on the principle that when the collection number and species are identical, the collection time is also identical.

2.2.5. Collection Location

(1) Transcription of Wade–Giles text to Pinyin

In the late 19th and early 20th centuries, Wade–Giles played a crucial role in global language exchange. Both digitized specimen data and *Plantae Wilsonianae*-recorded location information were gathered using the Wade–Giles system. We utilized the ipypd tool in Python to transcribe location names recorded in the Wade–Giles system to Pinyin.

(2) Referring to publications about Wade–Giles [14,37–39], conducting an internet search on Chinese early specimen collection place names' examination (CVH, <https://www.cvh.ac.cn/topics/counties.php>, accessed on 25 August 2022), and using Google, we refined locality information through comparisons of names in both Wade–Giles and modern Pinyin.

(3) Comparison with Wilson's Contemporary Photographs

Wilson also captured photographs during specimen collection, using a camera provided by the Arnold Arboretum. The available photographs only date from 1907 onwards.

(4) Adhering to the Principle of the Same Collection Time in the Same Location

(5) Adhering to the Principle of the Same Collection Number and Same Year in the Same Location.

3. Results

3.1. The Herbarium of Collection

We compiled specimens from 44 herbaria (Table 1), utilizing both comprehensive and independent herbarium databases. These herbaria are distributed across 13 countries [31]. Statistical analysis revealed that digital specimens are predominantly hosted in four countries. The United States contains 16 herbaria with 10,691 specimens, the United Kingdom has 3 herbaria with 4161 specimens, China has 11 herbaria with 1470 specimens, and France houses 1 herbarium with 911 specimens. These figures account for 55.63% (USA), 21.65% (UK), 7.65% (China), and 4.74% (France) of the total specimens, respectively. Among these countries, the US, A, K, and E herbaria harbor more than 1000 specimens each, constituting 29.53%, 19.60%, 10.83%, and 6.97% of collections, respectively.

3.2. Family and Genus

There are 18,853 identified plant specimens belonging to 200 families, constituting approximately 41% of the total families in China. Figure 1 illustrates those families with more than 500 specimens collected (red color range) and those families with more than 500 specimens collected (blue–purple color range). Notably, the families with the highest specimen counts are Rosaceae (2711 specimens), Pinaceae (1199 specimens), Ericaceae (1049 specimens), Fabaceae (764 specimens), Sapindaceae (760 specimens), Ericaceae, Pinaceae, and Rosaceae. On the other hand, fewer than 10 specimens were collected for 80 families. In the overview of Wilson's collections, seven families accounted for 40% of the total specimens, with 500 to 2711 specimens each. Furthermore, the proportional representation of each family aligns with Wilson's specific collecting priorities, indicating a certain bias in Wilson's collection, characterized by a broad scope and strong preferences.

Wilson's collection comprises 1046 genera and 3794 species (including 342 infraspecific taxa) in the File S1, constituting about 22% and 10% of China's plant genera and species, respectively. Notably, Wilson published 296 new species. Among the collected genera, 80 families are monogeneric, while the others vary from 1 to 74 genera. The families with the highest genera counts include Fabaceae (74 genera), Asteraceae (61 genera), Rosaceae (41 genera), Lamiaceae (39 genera), Orchidaceae (38 genera), Rubiaceae (22 genera), Ranunculaceae (22 genera), and Apocynaceae (20 genera).

To assess Wilson's collection completeness, the quantitative relationship between families and genera was considered. Wilson's collection completeness was determined by comparing the genera he collected within a family to the total number of genera distributed in China in that family based on the *List of Plant Species in China* (2022 Edition) [40]. For instance, if Wilson collected specimens from 41 genera in Rosaceae, and there are a total of 59 genera distributed in China in Rosaceae according to the *List of Plant Species in China* (2022 Edition), then Wilson's collection completeness for Rosaceae is 69.49%. If the collection completeness exceeds 60%, it is considered relatively complete. Excluding cases where a single genus is distributed in China within a single family (37 families), there are 42 families with relatively complete collections. Among them, 13 families have a collection completeness of 100%. As shown in Table 2, Fagaceae (83.33%), Berberidaceae (81.82%), Taxaceae (80%), Cactaceae (75.00%), Lardizabalaceae (75.00%), Sabiaceae ((75.00%), Vitaceae (73.33%), Pinaceae (72.73%), Cannabaceae (71.43%), and Rosaceae (69.49%) have the highest collection completeness. Families with collection completeness below 60% are considered to have incomplete collections, applying to a total of 121 families. Therefore, Wilson's overall collection completeness in China is 25%.

Acanthaceae	Actinidiaceae	Adoxaceae	Altingiaceae	Amaranthaceae	Amaryllidaceae
Anacardiaceae	Annonaceae	Apiaceae	Apocynaceae	Aquifoliaceae	Araceae
Araliaceae	Arecaceae	Aristolochiaceae	Asparagaceae	Asphodelaceae	Aspleniaceae
Asteraceae	Athyriaceae	Balanophoraceae	Balsaminaceae	Begoniaceae	Berberidaceae
Betulaceae	Bignoniaceae	Bixaceae	Blechnaceae	Boraginaceae	Brachytheciaceae
Brassicaceae	Bryaceae	Buxaceae	Cactaceae	Calycanthaceae	Campanulaceae
Cannabaceae	Capparaceae	Caprifoliaceae	Cardiopteridaceae	Caryophyllaceae	Celastraceae
Cercidiphyllaceae	Chloranthaceae	Clethraceae	Colchicaceae	Combretaceae	Commelinaceae
Convolvulaceae	Coriariaceae	Cornaceae	Crassulaceae	Cucurbitaceae	Cupressaceae
Cyatheaceae	Cycadaceae	Cyperaceae	Cystopteridaceae	Daphniphyllaceae	Dennstaedtiaceae
Diapensiaceae	Dioscoreaceae	Dipentodontaceae	Droseraceae	Dryopteridaceae	Ebenaceae
Elaeagnaceae	Elaeocarpaceae	Ephedraceae	Ericaceae	Eucommiaceae	Euphorbiaceae
Eupteleaceae	Fabaceae	Fagaceae	Garryaceae	Gentianaceae	Geraniaceae
Gesneriaceae	Ginkgoaceae	Gleicheniaceae	Goodeniaceae	Grimmiaceae	Grossulariaceae
Hamamelidaceae	Helwingiaceae	Hydrangeaceae	Hylocomiaceae	Hymenophyllaceae	Hypericaceae
Icacinaeae	Iridaceae	Iteaceae	Juglandaceae	Juncaceae	Juncaginaceae
Lamiaceae	Lardizabalaceae	Lauraceae	Lentibulariaceae	Liliaceae	Linaceae
Linderniaceae	Lindsaeaceae	Loganiaceae	Loranthaceae	Lycopodiaceae	Lythraceae
Magnoliaceae	Malvaceae	Mazaceae	Melanthiaceae	Melastomataceae	Meliaceae
Menispermaceae	Moraceae	Myricaceae	Myrtaceae	Nartheciaceae	Nephrolepidaceae
Nitrariaceae	Nyctaginaceae	Nyssaceae	Oleaceae	Oleandraceae	Onagraceae
Ophioglossaceae	Opiliaceae	Orchidaceae	Orobanchaceae	Osmundaceae	Oxalidaceae
Paeoniaceae	Pandanaceae	Papaveraceae	Passifloraceae	Paulowniaceae	Pentaphragmataceae
Pentaphyllaceae	Penthoraceae	Phrymaceae	Phyllanthaceae	Phytolaccaceae	Pinaceae
Piperaceae	Pittosporaceae	Plagiogyriaceae	Plantaginaceae	Plumbaginaceae	Poaceae
Podocarpaceae	Polemoniaceae	Polygalaceae	Polygonaceae	Polypodiaceae	Primulaceae
Proteaceae	Pteridaceae	Ranunculaceae	Rhamnaceae	Rhizophoraceae	Rosaceae
Rubiaceae	Rutaceae	Sabiaceae	Salicaceae	Santalaceae	Sapindaceae
Sapotaceae	Saururaceae	Saxifragaceae	Schisandraceae	Schoepfiaceae	Scrophulariaceae
Selaginellaceae	Simaroubaceae	Smilacaceae	Solanaceae	Stachyuraceae	Staphyleaceae
Stemonaceae	Styracaceae	Symplocaceae	Tamaricaceae	Tapisciaceae	Taxaceae
Tectariaceae	Theaceae	Thelypteridaceae	Thymelaeaceae	Tofieldiaceae	Torricelliaceae
Trochodendraceae	Ulmaceae	Urticaceae	Verbenaceae	Violaceae	Vitaceae
Woodsiaceae	Zingiberaceae				

Legend

The 200 families of specimens represented in the Wilson collections are listed in A-Z order. The darker the color, the more sheets are collected.



Figure 1. The Families represented in the Wilson collections.

Table 2. Top 60 families regarding Wilson's collection completeness.

No.	Family	Genera Collected by Wilson	Genera Distributed in China	Collection Completeness	No.	Family	Genera Collected by Wilson	Genera Distributed in China	The Collection Completeness
1	Actinidiaceae	3	3	100.00%	31	Nephrolepidaceae	1	1	100.00%
2	Aquifoliaceae	1	1	100.00%	32	Oleandraceae	1	1	100.00%
3	Begoniaceae	1	1	100.00%	33	Paeoniaceae	1	1	100.00%
4	Betulaceae	6	6	100.00%	34	Paulowniaceae	1	1	100.00%
5	Bixaceae	1	1	100.00%	35	Pentaphragmataceae	1	1	100.00%
6	Buxaceae	3	3	100.00%	36	Penthoraceae	1	1	100.00%
7	Capparaceae	2	2	100.00%	37	Phytolaccaceae	1	1	100.00%
8	Cercidiphyllaceae	1	1	100.00%	38	Pittosporaceae	1	1	100.00%
9	Clethraceae	1	1	100.00%	39	Plagiogyriaceae	1	1	100.00%
10	Coriariaceae	1	1	100.00%	40	Schisandraceae	3	3	100.00%
11	Cornaceae	2	2	100.00%	41	Schoepfiaceae	1	1	100.00%

Table 2. Cont.

No.	Family	Genera Collected by Wilson	Genera Distributed in China	Collection Completeness	No.	Family	Genera Collected by Wilson	Genera Distributed in China	The Collection Completeness
12	Cycadaceae	1	1	100.00%	42	Selaginellaceae	1	1	100.00%
13	Daphniphyllaceae	1	1	100.00%	43	Simaroubaceae	3	3	100.00%
14	Ebenaceae	1	1	100.00%	44	Smilacaceae	1	1	100.00%
15	Elaeagnaceae	2	2	100.00%	45	Stachyuraceae	1	1	100.00%
16	Elaeocarpaceae	2	2	100.00%	46	Staphyleaceae	3	3	100.00%
17	Ephedraceae	1	1	100.00%	47	Tapisciaceae	1	1	100.00%
18	Eucommiaceae	1	1	100.00%	48	Tectariaceae	1	1	100.00%
19	Eupteleaceae	1	1	100.00%	49	Tofieldiaceae	1	1	100.00%
20	Garryaceae	1	1	100.00%	50	Torriceiliaceae	1	1	100.00%
21	Ginkgoaceae	1	1	100.00%	51	Trochodendraceae	2	2	100.00%
22	Grossulariaceae	1	1	100.00%	52	Fagaceae	5	6	83.33%
23	Helwingiaceae	1	1	100.00%	53	Berberidaceae	9	11	81.82%
24	Iteaceae	1	1	100.00%	54	Taxaceae	4	5	80.00%
25	Juncaceae	2	2	100.00%	55	Cactaceae	3	4	75.00%
26	Juncaginaceae	1	1	100.00%	56	Lardizabalaceae	6	8	75.00%
27	Lentibulariaceae	2	2	100.00%	57	Sabiaceae	3	4	75.00%
28	Myricaceae	1	1	100.00%	58	Vitaceae	11	15	73.33%
29	Nartheciaceae	1	1	100.00%	59	Pinaceae	8	11	72.73%
30	Actinidiaceae	3	3	100.00%	60	Cannabaceae	5	7	71.43%

3.3. Collection Data

Between 1899 and 1918, Wilson consistently collected flowering plants in China, meticulously documenting the locations of the gathered species. He returned in different seasons to collect various reproductive materials for his sponsors. We separately recorded his collection volumes in different years, months, and seasons (Figure 2). The results of the third expedition are particularly noteworthy because Wilson was required to expand the collection range and plant species, considering the different reproductive materials produced by plants in different seasons. The collection volumes in the spring, summer, and autumn were relatively balanced and substantial, with slightly more collections in the summer and the least in the winter (Figure 2f). Horizontal comparisons across the other four expeditions revealed distinct seasonal characteristics in the collection work. For instance, the first two collections, executed during Wilson's tenure with Veitch and focused on ornamental species, were concentrated in the spring and summer. This alignment with the seasonal nature of plants allowed for the collection of flowers and leaves in the spring and summer, while fruits could be gathered in the autumn. Given Veitch's emphasis on ornamental aspects, particularly for commercial purposes, the focus on the spring and summer aligns with their priorities. Furthermore, the timing of each expedition adhered to this pattern, with the first three primarily concentrated on the period from April to August. The fifth expedition deviated somewhat from this pattern, as Wilson was not in Taiwan during this period.

3.4. Collection Location

Based on specimen records and the literature, we compiled Wilson's collection sites in China. Between 1899 and 1918, Wilson conducted five comprehensive plant collections. During the first expedition (1899–1902), Wilson, employed by the British Nursery Firm of Veitch and Sons, visited Hubei Province and collected a flowering tree known as *Davidia involucrata* (Figure 3a,b). The second expedition (1903–1905) took Wilson, still in the employ of Veitch, to Sichuan Province, where he collected a high-altitude herbaceous plant, *Meconopsis integrifolia* [41,42]. In the subsequent expeditions (1907–1909 and 1910–1911), Wilson was employed by Harvard University's Arnold Arboretum [43]. During these periods, he extensively collected and documented trees, shrubs, and herbaceous plants in Hubei and Sichuan. In 1918, Wilson, still under the employment of the Arnold Arboretum, focused on gathering data in coastal areas of Asia, including the collection of coniferous species in Taiwan, China. Wilson's botanical expeditions in China spanned approximately 12 years, covering a diverse range of species and a broad geographical area. His collection efforts reached seven provinces or municipalities, 28 prefecture-level cities, and 38 county-level regions.

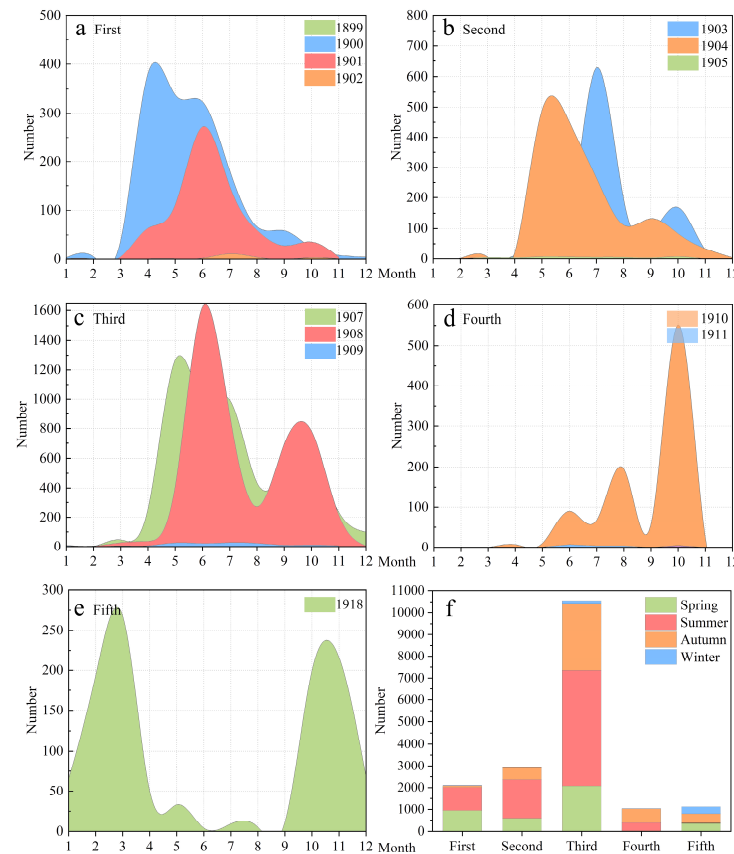


Figure 2. The quantity and month variation of Wilson's specimens over five expeditions (a–e), and the quantity and seasons Variation of Wilson's five expeditions (f).

In 1899, Wilson embarked on a journey from England to China. Wilson arrived in Yichang City, Hubei Province, in 1900 to collect specimens of *Davidia involucrata* [44]. His collection extended to Badong (Patung), Xingshan (Hsing-shan), Changyang, Fengjie, Wushan, Fang, Baokang counties, Jianshi, Shiyan cities, and Enshi Tujia and Miao Autonomous Prefecture, especially the Shennongjia area [45,46]. In Hubei and the surrounding area, Wilson also discovered a fruit with exceptionally high economic value: kiwifruit (*Actinidia chinensis* Planch. (Actinidiaceae)) [47]. In 1902, Wilson departed from Yichang to Shanghai and subsequently returned directly to England. During this expedition, Wilson collected *Davidia involucrata* and numerous other plants, sending them back to Veitch with collection numbers ranging from 1 to 2800 [13].

In 1902, Wilson went back to China for an extended investigation of more plant resources, ranging from Hubei to Chongqing (Chungking) and Sichuan to collect a rare alpine plant—*Meconopsis integrifolia* [16]. Sailing westward along the Yangtze River, he passed through Wushan and Fuling (Fulin) counties and Chongqing and Yibin (Sui Fu) cities, eventually docking in Leshan (Kiating) city. To locate *Meconopsis integrifolia*, Wilson traversed the wilderness of central Sichuan, reaching as far north as Songpan (SungpanTing), Mao, Wenchuan, and Xiaojin counties; the cities of Dujiangyan and Chengdu; and Aba Tibetan and Qiang Autonomous Prefecture. He also ranged as far south as Hongya (Hungya), Luding, and Baoxing counties and the cities of Emeishan, Ya'an, and Kangding. In the vicinity, Wilson discovered *Meconopsis integrifolia*, *Meconopsis punicea* Maxim. (Papaveraceae) (Figure 3c,d). Wilson kept numerous specimens and returned to England in 1905.



Figure 3. The photographs of plants that aroused Wilson’s great interest in China: (a) *Davidia involucreata* (photo taken by Wilson in 1907 in Xingshan Hsien, Hubei Province); (b) *Davidia involucreata* (photo taken by Hai Yan on 9 May 2023 in Sichuan Province); (c) *Meconopsis punicea* (photo taken by Renwu Wu on 20 July 2022 in Aba, Sichuan Province); (d) *Meconopsis georgei* Taylor (Papaveraceae) (photo taken by Renwu Wu on 17 July 2022 in Kangding, Sichuan Province).

In 1906, Charles S. Sargent (1841–1927) explicitly instructed Wilson to document the collection with photographs, focusing particularly on coniferous trees [16]. In 1907, Wilson expanded the collection in Fang, Xingshan, and Wufeng Tujia Autonomous County (Chang-le County). Wilson focused on the Three Gorges [48] and collected *Primula sinensis* Sabine ex Lindl. (Primulaceae) (Figure 4c). Traveling from Fengjie (Kuichou Fu), Yunnan, Wanzhou, and Jiangjin counties to Yibin, in 1908, his expedition covered Mianzhu, Danba, Hanyuan, Jinkouhe counties, and Chendu [37], Guanghan, Xichang cities. In this expedition, Wilson explored the transition zone west of the Chengdu Plain (Figure 4a1–b2) around Zheduo Mountain (Cheto-shan), Balang Mountain (Pan-lan-shan), Niutou Mountain, Daxue Mountain, and Dapao Mountain (Ta pao shan). This expedition was unprecedentedly rich, not only expanding the collection scope but also significantly increasing the quantity of specimens gathered. In April 1909, he packed his collections in Yichang, left

China, and traveled from Shanghai to Beijing, Moscow, St. Petersburg, and Berlin, and then stopped in Paris before arriving to London in May 1909.



Figure 4. Wilson's photographs of a pavilion in China: (a1) China—Chengdu Qing Yang Temple. Photo taken by Wilson on 18 August 1908. Source: <http://id.lib.harvard.edu/images/olvwork177710/catalog>, accessed on 14 December 2022. (a2) The same place on 14 July 2022 (photo taken by Renwu Wu). (b1) China—Chengdu City. Entrance to Zhaojue Temple 3 miles outside the north gate of Chengdu City. Source: <http://id.lib.harvard.edu/images/olvwork287154/catalog>, accessed on 14 December 2022. (b2) The same place on 14 July 2022 (photo taken by Renwu Wu). (c) *Primula sinensis*, Sanyou Dong, Ichang. Photo taken by Wilson on 5 March 1908. Source: <http://id.lib.harvard.edu/images/olvwork289290/catalog>, accessed on 14 December 2022.

To secure an ample supply of gymnosperms, Wilson initiated his fourth expedition in September 1909 [20]. In this expedition, Wilson charted a new course starting from Hubei, Wushan, Wuxi, Kai, and Yunyang counties; ranging to the cities of Dazhou (Suiting Fu), Bazhong, and Langzhong (Pa Chou); and moving from Yilong county to Sichuan. Here, he focused more on the northern part of China, including Anzhou, Beichuan, and Pingwu counties and Aba Tibetan Autonomous Prefecture. Expressing a particular fondness for Songpan, he discovered *Lilium regale* E. H. Wilson (Liliaceae) (Figure 5a,b) in the Min River Gorge [39]. He returned in 1911 to collect numerous seeds and bulbs of this lily [16,49]. In March 1911, Wilson departed from Leshan, traveled along the Yangtze River, passed through Chongqing and Hubei, and finally arrived in Boston.

Embarking on his fifth botanical expedition in East Asia, Wilson aimed to collect plants from the coastal regions of Japan, the Republic of Korea, and Taiwan. He set sail

from Yokohama, Japan, navigating through Okinawa to the Republic of Korea and eventually reaching Taiwan in January 1918. His initial surveys focused on Taipei City around Ali Mountain. There, Wilson was pleasantly surprised by the abundance of subtropical coniferous trees [50]. On this mountain, he discovered *Taiwania cryptomerioides* and *Abies kawakamii*. After leaving Taiwan in April, he returned in September specifically to collect labeled *Pseudotsuga wilsoniana* [50]. The fifth collection in Taiwan spanned only seven months, and, due to incomplete specimen record information, reconstructing details on the types and quantities of the collected plants and accurate collection data poses a challenge.

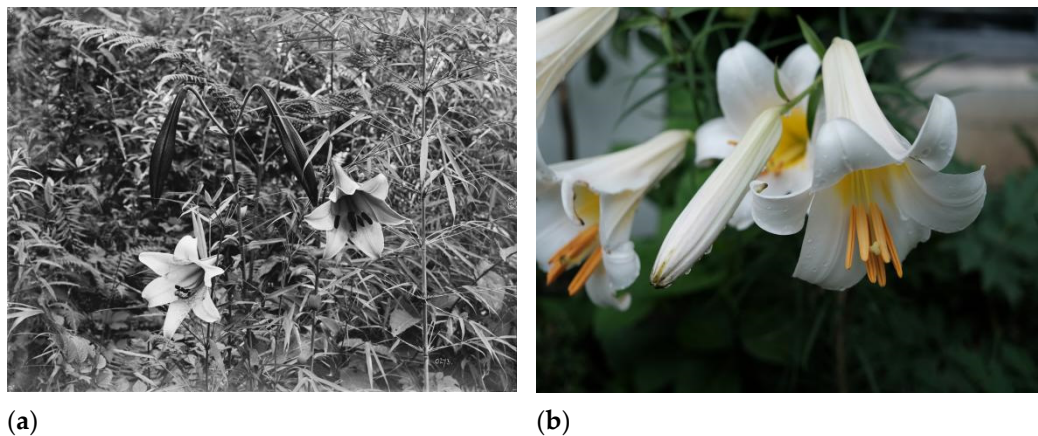


Figure 5. The photographs of plants that aroused Wilson’s great interest in China: (a) *Lilium brownii* F. E. Br. ex Mieliez. (Liliaceae) Northwestern Szechuan, China. Photo taken by Wilson on 16 August 1910. Source: <http://id.lib.harvard.edu/images/olvwork293603/catalog>, accessed on 14 December 2022; (b) *Lilium regale* (photo taken by Renwu Wu on 13 June 2022).

4. Discussion

4.1. Collection Preference

Influenced by collector preferences and objective environmental factors, Wilson’s collection completeness at the family level is relatively low [51]. Employing the criterion of specimen quantity exceeding 20 specimens in the database, we selected 132 species (4136 specimens) as examples to study Wilson’s collection preferences. Among these, 72 species are woody plants (2506 specimens, accounting for 61%), outnumbering herbaceous, liana, and shrub species. The preferences indicate Wilson’s inclination towards collecting woody plants over herbaceous and shrubby ones. Specifically, he focused on 66 species of flowering plants (1902 specimens), 66 species of plants with ornamental leaves (2325 specimens), and 48 species of plants with ornamental fruits (1718 specimens). Concerning collection completeness, 29 families (including those with a single genus or a single family) are relatively complete, while 171 families are incomplete. The completeness of collection at the family level is influenced by plant characteristics. Research indicates that plants with certain aesthetic features, such as vibrant colors and tall stature, are more likely to attract scholars’ attention [1]. Similarly, plants with aesthetically pleasing characteristics were more likely to capture Wilson’s attention, leading to their collection. Although Wilson aimed to collect as many different plant species as possible, historical, cultural, scientific, and educational influences may have contributed to the unevenness in the number of plant species collected. Notable examples include *Rhododendron* L. (828 specimens), *Acer* L. (690 specimens), *Prunus* L. (646 specimens), and *Pinus* L. (514 specimens), which possess aesthetically pleasing features in terms of flower type [52], leaf shape, leaf color, and fruit appearance, resulting in variations in the number of specimens collected by Wilson.

4.2. Collection Location

Wilson’s collection routes in China were primarily concentrated in Sichuan and Hubei provinces. In the book *A Naturalist in Western China: with Vasculum, Camera, and Gun*, Wil-

son combined these four routes on a map, using the Wade–Giles system to label place names. Scholars have continuously studied these routes and sites. Hu Xiuying [14] depicted two simplified collection routes by Wilson from 1907 to 1911, providing rough pinyin translations for some collection locations. Scholars such as Yin Kaipu [39] and Flanagan [23], representing those who revisited Western China a century later, retraced Wilson’s footsteps, witnessing the changes in landscapes a hundred years later. The descriptions of the scenery along the way have sparked the interest of scholars worldwide, who recognize this precious cultural heritage.

In the post-COVID-19 era, we advocate for outdoor activities to enhance physical fitness. By organizing Wilson’s collection locations (Figure 6a1–c2), which feature breathtaking natural and cultural landscapes with rich plant diversity, these locations can be gradually developed into tourist routes. Different “Wilson Trails” can be established based on his collection routes, allowing travelers to choose routes according to their preferences. Similarly, “Wilson Trails” can be incorporated into the construction of urban botanical gardens, creating specialized or cultural botanical gardens and showcasing regional culture, plant culture, and historical heritage [53,54]. Everyone can experience a century of changes along these collection routes or in urban botanical gardens, allowing the appreciation of the beauty of the landscapes, cultural sentiments, and the charm of the plants. By retracing Wilson’s path, we can also raise awareness of environmental and plant conservation, contributing to the valuable legacy that Wilson has left behind.

4.3. Differences between Wilson and Contemporaneous Plant Collectors

Wilson’s collecting expedition exhibited several notable characteristics: extensive collection, rich species diversity, wide-ranging exploration, a high frequency of visits, and exposure to hazardous outdoor environments. Over 11 years, Wilson made five trips to China, covering seven provinces, 28 prefecture-level cities, 38 counties, and numerous mountainous forest areas. Unlike Frank Meyer and Joseph Rock, who conducted linear plant surveys covering 18 and 5 provinces, Wilson’s collections were more geographically distinct, often avoiding urban areas and focusing on wild mountainous regions.

He extensively collected ornamental alpine herbs in locations such as Zheduo Mountain, Balang Mountain, Niutou Mountain, and their surrounding areas. For instance, he discovered *Meconopsis integrifolia* and *Meconopsis punicea*, and more specimens, on cliffs near Kangding. Many species collected by Wilson were published as new ones, reflecting the harsh and remote conditions of these wilderness areas. This contrasts with George Forrest’s collections, which often occurred in previously explored areas, resulting in fewer discoveries of new species. In addition, unlike Floyd Alonzo McClure, Wilson did not confine himself to collecting specific plant taxa. While McClure focused primarily on the collection and study of bamboo species in China, Wilson extensively collected species with high ornamental value. Therefore, Wilson’s collection volume and diversity of species far exceeded those of contemporaneous collectors.

Wilson’s passion for botany drove him to courageously seek out plant specimens, prioritizing plant collecting and meticulously documenting native flora through written accounts and photography. In contrast, others, such as Rock, pursued more diversified interests. Locke’s endeavors extended beyond plant collecting, utilizing his intervals between collections to document the culture and lifestyle of the locales he explored. Wilson took over 2400 photos, stored in the Arnold Arboretum’s library, with some being accessible online. Starting in 1907, under Sargent’s guidance, Wilson simultaneously collected plants and photographed landscapes and habitats. Ancient trees were a particular focus for Wilson, who captured large photos in Hubei, Sichuan, and Taiwan and documented these areas. These photos became valuable resources for ancient tree research, supporting studies on plant distribution and providing historical evidence for phytogeography. Wilson’s photography facilitated botanical history research, ancient tree preservation efforts, and advancements in plant geography by providing robust evidence for plant distribution and historical insights into geographical patterns.

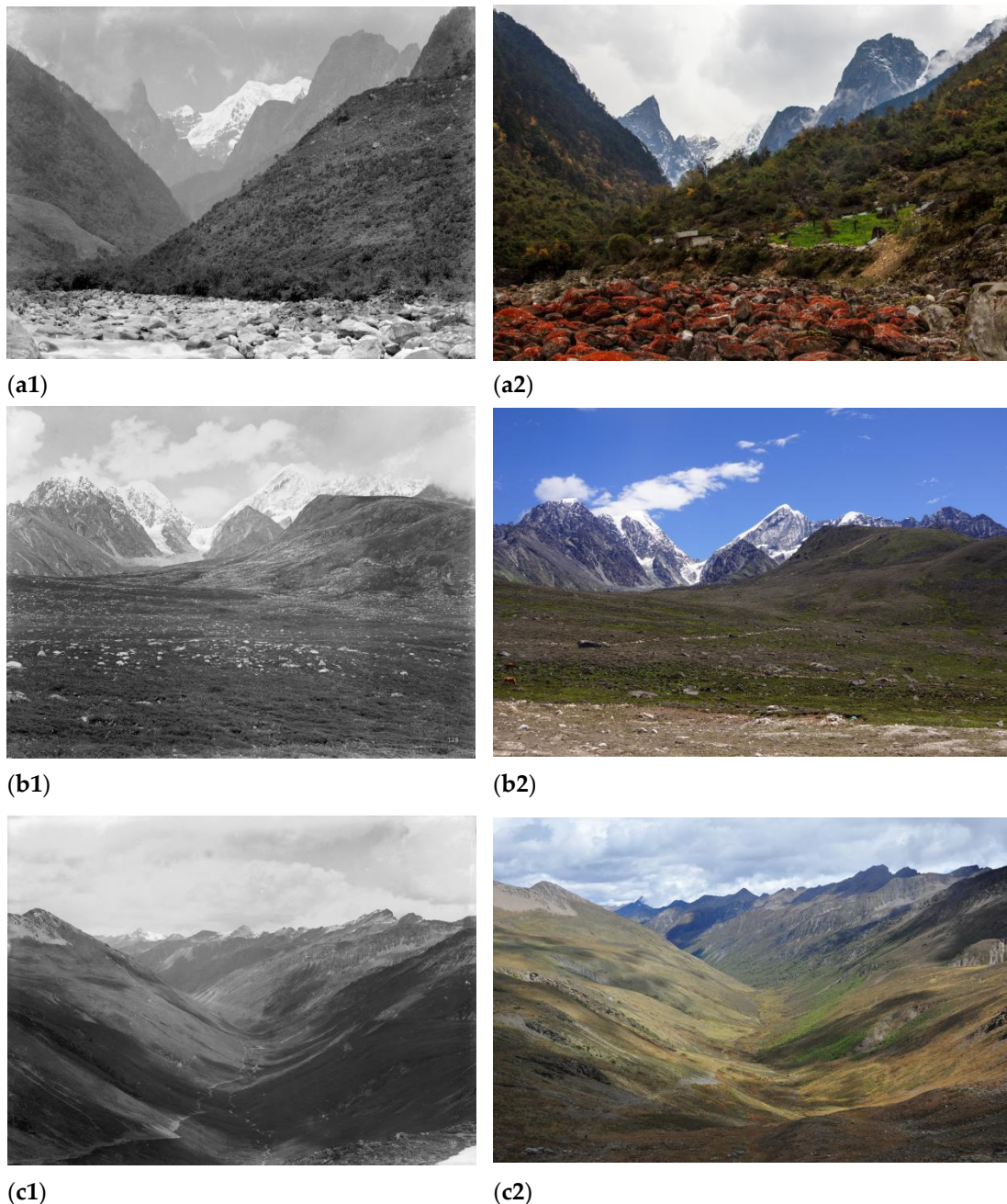


Figure 6. Wilson's photographs of beautiful mountain scenery in Sichuan: (a1) View of the snow-clad peak in Nan Men Guan Gully, s. e. of Kangding, Sichuan Province. Photo taken by Wilson on 17 July 1908. Source: <http://id.lib.harvard.edu/images/olvwork287999/catalog>, accessed on 14 December 2022. (a2) The same place in Kangding, with the red rocky landscape and beautiful snow-capped mountains in the distance (photo taken by Yunfei Ding on 23 July 2017). (b1) Ya-jiageng, near Kangding, Sichuan Province; photo taken by Wilson on 19 July 1908. Source: <http://id.lib.harvard.edu/images/olvwork288009/catalog>, accessed on 14 December 2022. (b2) The same place near Kangding, with a combination of the snowy mountains in the distance and the meadows nearby by Yongbang Huang, Guangjun Sun, in 29 October 2019. (c1) Alpine meadows of the Ta-p'ao-shan Range from a pass northeast of Kangding (photo taken by Wilson on 7 July 1908). Source: <http://id.lib.harvard.edu/images/olvwork287982/catalog>, accessed on 14 December 2022; (c2) The same place in Kangding, with alpine meadows stretching as far as the eye can see; photo taken by Kaipu Yin on 21 September 2021.

4.4. Value and Impact of Wilson's Collection in China

Wilson's plant-collecting endeavors significantly enhanced the Western understanding of China as containing the most diverse and abundant plant life in temperate countries [55]. The plant specimens he collected provided the West with new insights into China's germplasm resources, particularly wild plant resources. Before China's emphasis on plant resource conservation, many of these resources were taken to Western countries for research purposes. Examples include the *Acer griseum* (Franch.) Pax in Engler (Sapindaceae) [56], *Meconopsis integrifolia*, and *Taiwania cryptomerioides* [24]. This resulted in China losing its edge in plant resource research. We surveyed the plant species collected by Wilson in China, identifying 296 new plant species classified, named, and published by Western botanists. For Western countries, especially the UK and the US, plant specimens were not only taken for preservation but also served as research subjects. This fostered the development of plant taxonomy, identification, and geography, providing a broader range of resources for plant applications.

For China, the collected plant specimens provided the basis for studying native plants. His specimens are still studied by many scholars, with a new species, *Cotoneaster nantouensis* J. Fryer & B. Hylmö (Rosaceae), published in May 2009. One remarkable discovery is *Euonymus aquifolium* Loesener & Rehder (Celastraceae) collected by Wilson in Sichuan in 1908. After 110 years, it remained unseen until August 2021 when researcher Hu Jun re-discovered it in the cliffs of western Sichuan. Wilson's collections and photographs from over a century ago not only help to explore species that once existed in China but also aid in identifying current species.

The success of Wilson's collection work holds significant importance for the advancement of world botany and serves as a reminder for China to protect its native plant resources, improve specimen collection procedures, and standardize specimen management and preservation for better plant resource conservation. Wilson's collection experiences became known to Chinese botanists, inspiring them to make efforts to collect domestic plant specimens and advance their botanical studies. Notably, botanists like Hu Xiansu (1894–1968) and Chen Huanyong (1890–1971) were deeply influenced by him. Hu Xiansu often lectured on books like "A Naturalist in Western China" in his classes, aiming to broaden students' horizons and motivate them to study diligently for the development of China's botanical endeavors.

Numerous outstanding plant collectors, chiefly represented by Wilson, have conducted extensive species collection and resource surveys worldwide, especially in China. Wilson's five expeditions to China have provided abundant research materials for Western countries' studies on Chinese plant resources, as well as for Chinese scholars researching native plant resources a century later. This contribution is of great importance. In future research on plant dissemination and biodiversity conservation, if a collaborative effort can be made to gather outstanding researchers, botanists, taxonomists, and others from both domestic and international arenas to share such specimen data or other data and establish a centralized sharing website, it would not only expand the scope of research influence but also facilitate breakthroughs in the field, proving beneficial without causing harm.

4.5. Digitization of Specimens

Plant collection and specimen digitization play crucial roles in historical research [57]. The key to specimen data lies in comprehensive digitization covering all specimen and keyword information. Since physical specimens are mostly dispersed worldwide, collecting them can be challenging, making global specimen digitization the simplest way to share data. Arnold Arboretum compiled statistics on the number of plant specimens collected by Wilson in China. From 1899 to 1903, Wilson collected about 5000 specimens for Veitch [17,21,22]. From 1907 to 1911, he collected around 4700 collection numbers for Arnold Arboretum, totaling 65,000 specimens [16,17,21,22,49]. However, incomplete digitization information in some herbaria and the low digitization levels of many spec-

imens have led to discrepancies between Wilson's specimen data collected through on-line platforms and literature records. This has somewhat affected research results [58]. Large herbaria like the Arnold Arboretum, Kew, and Edinburgh Royal Botanic Garden are highly digitized and well-managed in terms of specimen classification, management, and keyword supplementation. However, most small herbaria have yet to achieve specimen digitization, and incomplete keyword information bindings make the results of keyword searches less than ideal, posing significant challenges in collecting specimen data. During the collection and data-screening processes, we observed that the data information accompanying the specimens was still lacking details, as shown, for example, in instances where the collection location was noted as HUPHEI in photos, with Hubei information in digital form missing. We had to cross-reference with the specimen photos to complete the corresponding information.

In conclusion, specimens are essential research materials for preserving plant diversity, demonstrating the history of plant distribution, and advancing botanical studies. However, building upon previous research, we can offer some recommendations for future studies and further exploration in this field: 1. Foster digitization conditions, and improve keyword information to allow for ease of retrieval and utilization. 2. Promote better management and maintenance of specimens by institutions. 3. Preserve valuable historical data for future research. Additionally, combining our research methodology with intelligent software will aid in data processing and analysis to a certain extent. We look forward to future studies employing more scientific and intelligent methods to drive data collection for research, thus diversifying data collection more widely and enriching research content. Vigorously advancing specimen information digitization, improving information systems, innovating research methods, and more comprehensively studying the history of plant distribution can contribute to enhancing the protection of biodiversity. Biodiversity is a necessary condition for human survival, and plant diversity is the foundation of biodiversity, serving as a fundamental guarantee for national and global ecological security [59–61]. Studying the history of plant collection can help us to understand the origin and development of plant diversity, contributing to future ecological conservation efforts. We will continue to delve into research, promote the development of botanical studies, and facilitate the implementation of biodiversity protection efforts.

5. Conclusions

Considering that plant specimens have played a pivotal role in the history of plant dissemination, they have positive implications for biodiversity conservation today. This study delves into the botanical collection endeavors of the renowned 20th-century plant collector Ernest Henry Wilson in China. The collection comprises 19,218 specimens and 11,884 collection numbers, spanning 200 families, 1046 genera, and 3794 species (include 342 infraspecific taxa), with 296 newly published species. Wilson's preference for woody and flowering plants is evident, resulting in a collection completeness of 25%. His collections span seven provinces, 28 prefecture-level cities, and 38 county-level areas and made significant contributions to the global dissemination of Chinese plant knowledge. This study analyzes species collected by Wilson in China, investigating their collection timelines and geographic distribution. By conducting such an analysis, we aimed to elucidate the authentic historical context from a century ago, thereby facilitating further botanical exploration and research. The objective was to provide valuable insights and references for subsequent research endeavors.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/f15030475/s1>. Supplementary File S1: The list of species collected by Wilson.

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