Himalayan Apiaceae - A comprehensive ecological and ethnobotanical evaluation

Aadil Abdullah Khoja, Mahpara Hamid, Bilqeesa Hamid, Muhammad Waheed, Muhammad Azhar Jameel, Rainer W. Bussmann and Shiekh Marifatul Haq

Correspondence

Aadil Abdullah Khoja[1], Mahpara Hamid[1], Bilqeesa Hamid[2*], Muhammad Waheed[4], Muhammad Azhar Jameel[5], Rainer W. Bussmann[5,6] and Shiekh Marifatul Haq[5*]

[1]Department of Botany, Glocal University Saharanpur-247121 (U.P)
[2]Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences &Technology of Kashmir, Benhama, Ganderbal, J&K-191201. India
[3]Department of Chemistry, University of Kashmir Srinagar, Srinagar 190006, India
[4]Department of Ethnobotany, Institute of Botany, Ilia State University, 0162 Tbilisi, Georgia
[5]Department of Biology, Texas A&M University, College Station-77843, USA
[6]Department of Botany, Institute of Life Sciences, State Museum of Natural History, Karlsruhe, Germany

*Corresponding Author: bhatbilqees94@gmail.com; snaryan17@gmail.com

Ethnobotany Research and Applications 27:42 (2024) - http://dx.doi.org/10.32859/era.27.42.1-18
Manuscript received: 09/07/2024 – Revised manuscript received: 23/09/2024 - Published: 24/09/2024

Research

Abstract

Background: Taxonomic patterns of ethnobotanical uses of plants support the hypothesis that families with the most species richness will have a large number of valuable species. However, certain plant families (e.g., Apiaceae) with specific bioactive characteristics are underrepresented due to changes in the cultural relevance of native plant species. Thus, developing a biocultural conservation strategy may benefit from an awareness of plant usage patterns.

Methods: Ethnoecological data was collected through interviews and group discussions using semi structured and close-ended questionnaires. The data was subjected to hierarchical cluster analysis and ordination techniques (Principal Component Analysis) using multivariate software. Use value (UV), was quantitative indicators used to assess the homogeneity of the ethnobotanical data.

Results: The present investigation documented a total of 18 plant species used by local communities for multipurpose. Majority of plants were used for medicinal purposes followed by fodder, and spices. Amongst the parts of plants, roots were the most utilized plant part with 28% of usage followed by leaves (25%). Gastro-intestinal disorders were treated with most species (32%), followed by musculoskeletal (17%). Most of the plant species are consumed in the form of infusion (31%) followed by decoction (25%). A heat map showed two distinctly separated clusters based on the degree of intensity of flowering timing of the flora and month. Out of 18 medicinal plants reported 15 medicinal plants were used for different ethnoecological uses other than medicinal values. We recorded only three species (*Angelica glauca*, *Angelica archangelica*, and *Elwendia persica*) used as flavoring agents especially in the local traditional cuisine. Highest UV was reported for *Foeniculum vulgare* (0.72), *Elwendia persica* (0.62).

Conclusion: The study found plant uses were primarily medicinal and food-related; however other uses are also relevant. Our findings indicate that the most accessible or locally abundant plant species were the most beneficial to local residents.

Keywords: Apiaceae; Ethnoecology; Flowering; Nativity; Phytochemistry; Himalaya

Background

Apiaceae (syn. Umbelliferae) is one of the largest angiosperm families. It includes 300 genera (3000 species) globally and 81 genera (280 species) in India (Wei *et al.* 2019). Apiaceae plants have been widely used in healthcare, nutrition, the food industry, and other fields (Yuan 1999). Currently, 55 genera (230 species) of Apiaceae plants have been used as medicinal plants worldwide (Zhao and Yan 2020). Extensive studies have demonstrated that Apiaceae medicinal plants (AMPs) present a variety of pharmacological properties for the treatment of gastrointestinal disorders, musculoskeletal disorders, cardiovascular, and respiratory system diseases, amongst others (Cai 2011). These pharmacological activities are largely associated with metabolites such as polysaccharides, alkaloids, phenylpropanoids (simple phenylpropanoids and coumarins), flavonoids, and polyene alkynes (Li *et al.* 2022; Liu *et al.* 2002).

The management and utilization of biological resources is central to the history of human culture and civilization, and human communities have used resources, particularly bioresources, during all times of human evolution (Gras *et al.* 2021). Plant resources are essential to human cultures and have been used to support wellbeing for thousands of years. Many cultures around the world continue to use plants as their major source of treatment and have built their own medicinal systems based on their own theories, beliefs, and experiences (WHO 2012). Indigenous communities have garnered extensive ecological knowledge and are frequently reliant on wild plants for food, fodder, medicine, and other purposes (Gairola *et al.* 2014). Indigenous and traditional medical systems are especially common in rural communities across the world including in the Himalayan region (Haq *et al.* 2023). Diverse ethnic communities in the Himalayan region have their own local indigenous healthcare systems, and medicinal plant applications often differ depending on geography and ecology (Haq *et al.* 2023a).

The comparison of global production statistics of Apiaceae crops is difficult as the data tracked by the Food and Agriculture Organization of the United Nations (FAO) is recorded under the crops belonging to other families. The only Apiaceae family crops recorded by FAO are grouped as “carrots and turnips” and “Anise, badian, fennel and coriander”. Production of anise, badian, fennel, and coriander were recorded to be 1.97 million MT in 2019 with the highest quantity from Asia (87.6%) especially from India (1.4 MT) (Thiviya *et al.* 2021). Apiaceae family consists of economically important aromatic plants and are commonly used as food, flavors (spices, condiments), and medical purposes (Shelef 2003). Some of the Apiaceae are spices, which have been used as a flavoring, seasoning and coloring especially in India, China and many other southeastern countries. Many species of family Apiaceae have been commonly used in household medicinal remedy for various health complications traditionally (Saleem *et al.* 2017;Khare 2008).

Over the last decades, ethnobotany has experimented with new methods while maintaining the dual goal of documenting and preserving ancient human uses of plants, to describe and attempting to enhance human lifestyle (Pardo-de-Santayana *et al.* 2015). As a result, ethnobotanical study is dominated by the collection of plant applications related to health, particularly medical and food uses, while other uses are also relevant. Taxonomic patterns of ethnobotanical uses of native plants support the assumption that families with the highest species richness will have a large number of valuable species (Palchetti *et al*. 2023). However, certain plant families (e.g., Apiaceae) with distinct traits are underrepresented due to changes in the cultural relevance of native plant species. The goal of this work was to shed light on the role of Himalayan Apiaceae, depicting in the relationships between humans and uses of vascular plants in the Northern part of the Kashmir Himalayas. This study focused on a comprehensive assessment of the useful plant species of family Apiaceae from the Kashmir Himalaya to achieve the following objectives: (1) to understand the ethnoecological knowledge about Apiaceae (2) elucidate major diseases cured and the mode of remedy preparation by indigenous communities, and (3) to study phenological spectra and nativity status of documented plants. (4), finally, the study reviewed the published bioactive metabolites of the document plants.

Material and Methods

Study area

The district Kupwara lies in the Northern part of the Kashmir valley (India), between 34°45 N and 75°20 E. The Kashmir valley is endowed with rich diversity of plants. Around 2300 species of land plants, bryophytes, pteridophytes, gymnosperms, and angiosperms, have been identified in this region. According to Haq *et al.* (2023b), 153 (8%) angiosperm taxa found in Kashmir are endemic exclusively to this region. The district Kupwara has a total geographical area of 2379 km2 with 367 villages (https://kupwara.nic.in/demography/). The region is characterized by dense forests (Himalayan dry-temperate to subalpine forest types) (Haq *et al.* 2023c), is rich in floral diversity and home to many medicinal plants. The majority of the population lives in rural, and the official literacy rate is 66.92% (https://kupwara.nic.in/demography/). For the present study, eight villages (Manchater, Gabra, Keran, Bungus valley, Sadnatop, Rashanpora Dutt, Budnamal and Farkin) which lie in the frontier area was selected (Figure 1).

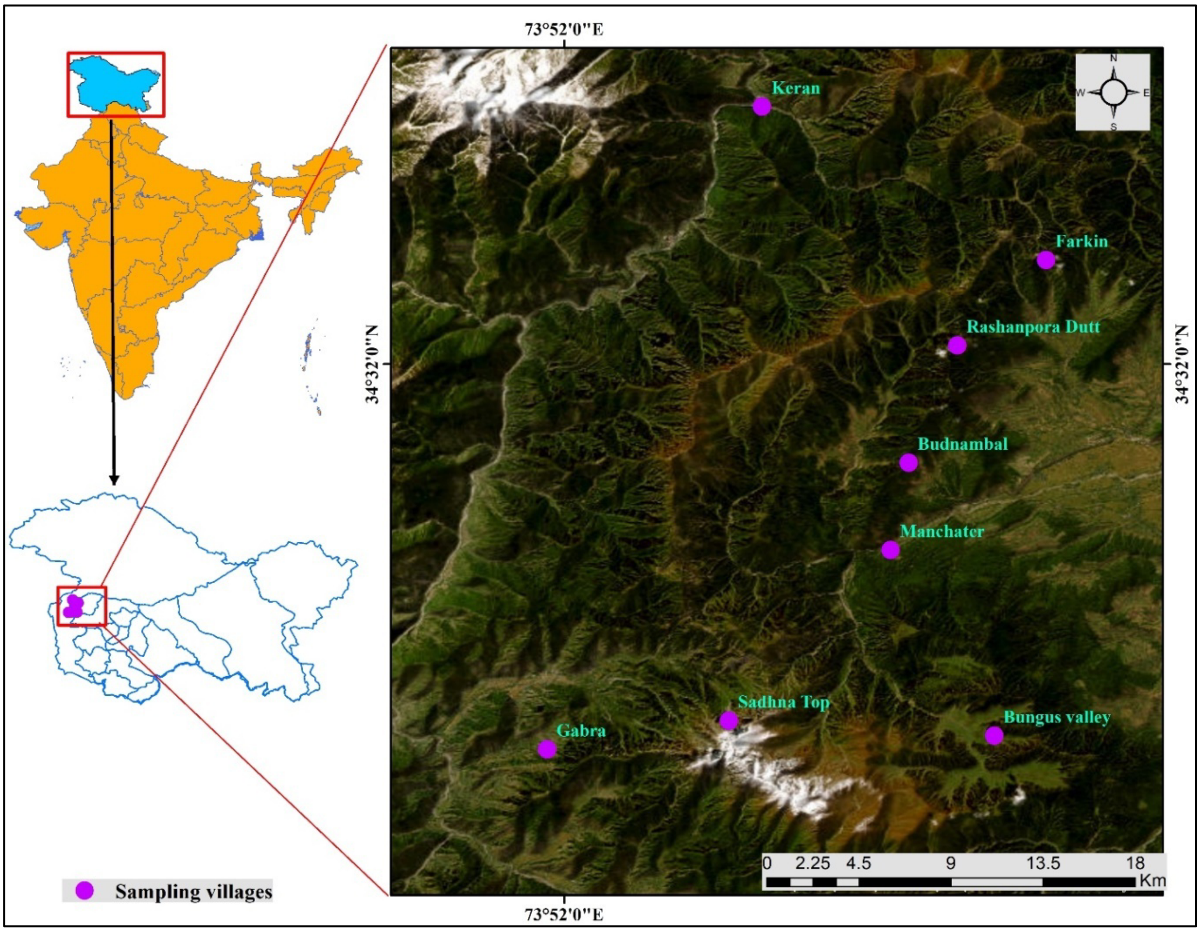

Figure 1. Study area map showing the locations of surveyed villages in Jammu & Kashmir India.

Ethnobotanical data collection

The study was carried out in 2022-2023. Field surveys were conducted frequently in different seasons following standard protocols (Haq *et al.* 2020). The ethnoecological data was collected through face-to-face semi structured interviews and discussions, after obtaining prior informed consent form the participants (Asif *et al.* 2021). Before each interview, participants provided verbal agreement after being fully informed, and the ethical guidelines outlined by the International Society of Ethnobiology (ISE, 2008) were followed. Additionally, one person from each indigenous community, who was well familiar with the traditions and norms of the community, was taken as a guide during all the field surveys. The interviews were carried out in native language Kashmiri, and Gujari, with one of the authors being proficient in the language. Subsequently, the interviews were translated into English. The information collected was also crosschecked with the available literature (Gaiorola *et al.* 2014; Haq *et al.* 20123c). The field studies coincided with the growing seasons of plants in the study area. During field sampling, detailed field observations on ecological traits such as flowering for each species were recorded following standard literatures (Haq *et al.* 2023a), and voucher specimens were collected. The interviews were centered on the utilization of the indigenous plants for medical, religious, cultural, and culinary purposes. The informants were shown both photographs and live plants to identify them and obtain local names (Figure 2).

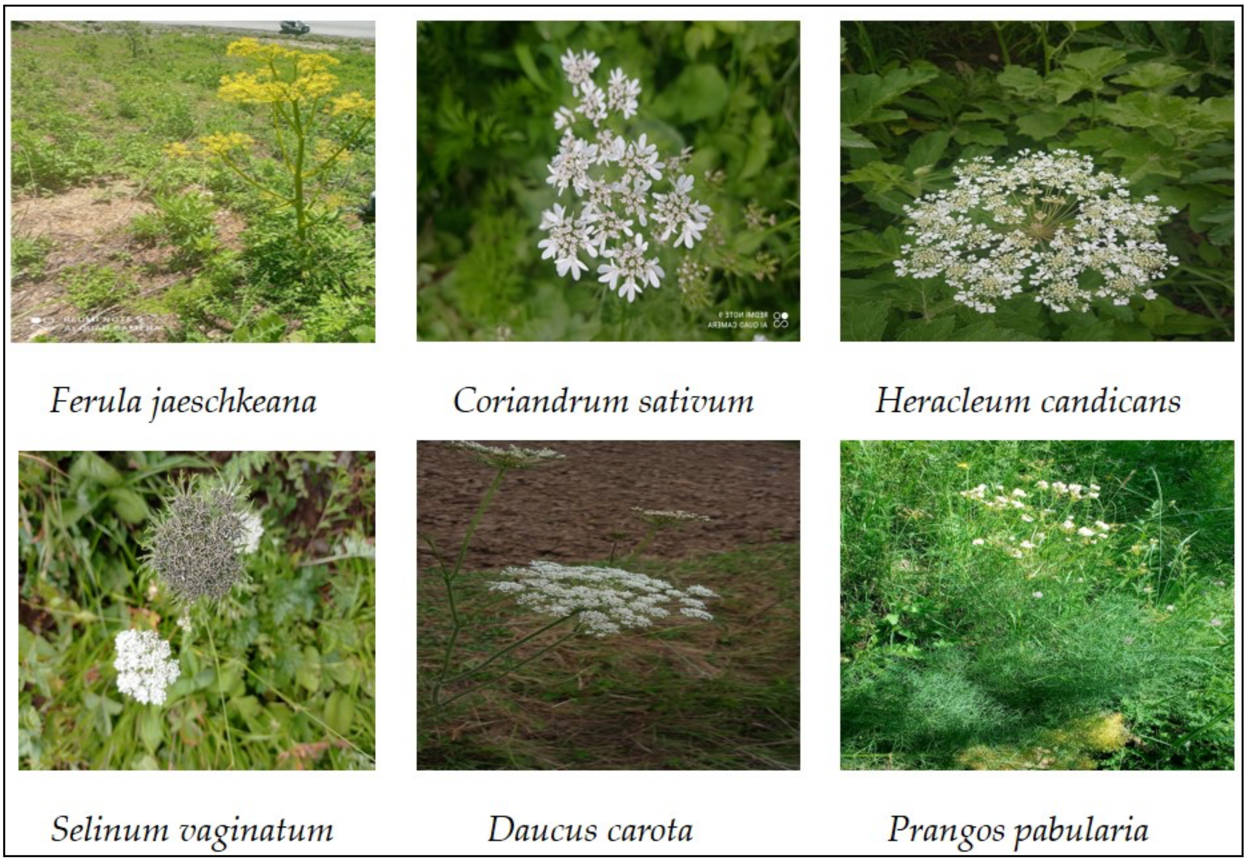

Figure 2. Representative plants used among the people living in the study area.

Plant Identification

Plant specimens were collected from different sites during the field survey and were properly coded/tagged. Specimens were identified with the help of taxonomists at the CBT Lab, University of Kashmir, Srinagar (J&K), by comparing with herbarium specimens at the KASH herbarium and local floras (Haq *et al.* 2024; Khoja*et al.* 2022). Nomenclature and botanical families of all the specimens were further authenticated using The Plant List (www.plantsoftheworldonline.org/).

Use value

To measure the significance of species, Philips and Gentry (1993) proposed the UV index. The formula described by (Albuquerque *et al.* 2006) is used to compute UV.

$$UV = \sum Ui/N$$

Where Ui is the total number of uses for a specific species that were mentioned by all of the informants, and N is the total number of informants.

Data analysis

A Principal Component Analysis (PCA) was conducted to visualize the utilization of disease categories. The function of fact was extra was used to illustrate the PCA biplot, contribution plot, and even values corresponding to the variance described by each principal component. To show the relation between medicinal preparation, plant part used and traditional use categories of plant species, chord diagram was prepared in Origin Pro software (version 9.95) (Haq *et al.* 2023b). The heat map was produced using the presence/absence data to show species distribution, and cluster analysis showed species that shared the same flowering time. The Sorensen's similarity coefficient, based on presence/absence data, was used to identify significant differences among diverse flowering times and months (Sorensen 1948; Sajad *et al.* 2021).

Results and Discussion

Demography of respondents

A total of 47 respondents (29 men, 18 women) were interviewed. The uneven ratio of men and women was because women are restricted mainly to their homes and are not allowed to go to distant areas (Haq *et al.* 2023; Khoja *et al.* 2022a). Data was obtained from three ethnic groups Gujjar (40.43%), Pahari (31.91%) and Kashmiri (27.66%) among which Cultivator/agricultural laborer accounted for 31.93%, herders 19.15%, Traditional healers and shopkeepers 17% each, housewives 10.64% and govt. employees (6.38%). The most important knowledge holders were old people (44.70%) followed by middle aged (38.30%) and young (17.00%). In the rural area's elders have higher traditional knowledge as compared to the younger once, the reason behind this is younger generation is not interested and have faith on tradition medicine as compared to generic medicine. Most respondents were illiterate (45.57%), whereas 27.66% of the participants had primary education, 17.00% secondary level and only 12.77% higher education. It was noted that the illiterate population had more knowledge of traditional medicine, which may be explained by the fact that educated participants are expected to have exposure to the developed world and mostly rely on current medications rather than alternative one (Khoja *et al.* 2024). Gujjar, Pahari and Kashmiri languages were spoken by the Gujjar, Pahari and Kashmiri people respectively. All the ethnic groups were Muslims (Table 1).

Table 1. Demography of the respondents from the study area.

Variable	Categories	Number of people	Percentage (%)
Informant category	Traditional healer	7	14.9
	Other local participants	40	85.1
Gender	Male	29	61.7
	Female	18	38.3
Age group	Young (20-40 years)	8	17
	Middle (41-64 years)	18	38.3
	Old (65+ years)	21	44.7
Education Level	Illiterate	20	45.57
	Primary education	13	27.66
	Secondary education	8	17
	Higher education	6	12.77
Profession	Traditional healers	7	14.9
	Cultivator/agricultural laborer	15	31.93
	Herders	9	19.15
	Housewives	5	10.64
	Govt. Employees	3	6.38
	Shopkeepers	8	17
Religion	Islam	47	100
Ethnic Groups & Language	Gujjar	19	40.43
	Pahari	15	31.91
	Kashmiri	13	27.66

Floristic composition

In the current study a total of 18 plant species belonging to 14 genera which have various uses, including medicinal, salad, spice, fodder and vegetable (Table 2). Regions with more diverse floras usually have more useful wild plant species for locals to report. The premise is that a broader choice of available species results in a correspondingly greater number being used (Haq *et al.* 2024). The way a species is used greatly depends on the socioeconomic conditions in the area, and distribution patterns might vary from location to location (Khoja *et al.* 2022a). The research revealed a notable dependence on a range of forest resources for medicinal applications. In the Jammu region (Thakur *et al.* 2021) reported 18 plant taxa, (Ahmad *et al.* 2017) reported 7 plant taxa from Pakistan, (Amiri and Joharchi 2016) reported 70 plant taxa from Turkey, (Redouan *et al.* 2020) reported 31 taxa belonging to 16 genera from Talassemtane national park (Northern Morocco).The phytochemicals (Table 2) includes information regarding all the 18 plants. Our findings show that, with respect to the number of species of medicinal use, *Angelica* and *Chaerophyllum* are the richest genus, having two species reported to be useful medicinally as well as other ethnoecological usage, while as the remaining genus were monotypic.

Table 2. List of plant species recorded from the study area with detail ethnobotanical uses.

Botanical name/Code	**Common name**	**Part used**	**Prep**	**Adm**	**Disease treated**	**Other uses**	**Flowering period**	**Nativity**	**UR**	**UV**	**Phytochemical**	**Ref**
Anethum graveolens L. 4123-KASH	Soe, Sowa-dil	Whole plant	Infusion, poultice	Oral as well as topical	Abdominal pain, colic, arthritis	-------	July-September	Exotic	9	0.19	Alkaloid, terpenoids and flavonoids	Chahal *et al.* 2017.
Angelica archangelica L. 3336-KASH	Choure	Roots	Paste, infusion	Oral as well as topical	Wound healing, abdominal pain	Spice	June-August	Native	21	0.45	α-pinene, δ-3-carene, limonene, and α-phellandrene	Fratern*et al.* 2014
Angelica glauca Edgew. 4110-KASH	Choure	Leaves, roots	Cooked, powder	Oral	Fatigue, constipation and dyspepsia stomachache, obesity pinch of powder for toothache	Spice	June-August	Native	15	0.32	α-phellandrene, trans-carveol, β-pinene, β-caryophyllene, and β-caryophyllene oxide.	Irshad *et al.* 2011
Anthriscus nemorosa (M.Bieb.) Spreng. 4135-KASH	leayh-gass	Whole plant	Decoction poultice, paste	Oral as well as topical	Rheumatism, Joint swelling, Rashes	Fodder	June-August	Native	10	0.21	Isogeranol, crystathenyl acetate and farnesene	Naeini *et al.* 2017.
Berula erecta (Huds.) Coville 4216-KASH	Lais-gass	Whole plant, leaves, roots	Powder, paste	Oral as well as topical	Rheumatism, muscular pain, joint swelling toothache	-------	August-September	Native	13	0.28	Monoterpene, sesquiterpene, (Z) falcarinol and γ-terpinene.	Kaya *et al.* 2018.
Bupleurum falcatum L. 4237-KASH	Bair-mooj	Root, Whole plant	Infusion, paste	Oral as well as topical	Fatty liver, abdominal pain, Wound healing	Fodder	June-July	Exotic	11	0.23	Saikosaponins (a, c, and d)	Lu *et al.* 2011; Ma *et al.* 2011.
Carum carvi L. 4139-KASH	Kosnyot, Gosnyod	Seeds	Infusion, decoction	Oral	Abdominal bloating, diarrhea	Spice	June-August	Native	14	0.3	Carvone, limonene, and dihydrocarvone	Pang and Cui 2020.

Chaerophyllum reflexum var. *acuminatum* (Lindl.) Hedge &Lamond 4321-KASH	Cher-gass	Whole plant	Infusion, decoction	Oral as well as topical	Indigestion, fever	Fodder	June-August	Native	16	0.34	Santene,γ-terpinene, p-cymene, myristicin, 1,8-cineole, α-terpineol and hydroxymyristic acid.	Ashraf *et al.* 1979.
Chaerophyllum villosum Wall. ex DC. 4186-KASH	Youngu	Leaves, whole plant	Decoction, paste	Oral as well as topical	Urinary tract infection, wound healing	Fodder	June-August	Native	19	0.4	γ-terpinene, p-cymene, terpinolene and β-pinene	Joshi and Mathela 2013.
Coriandrum sativum L. 6246-KASH	Dainwall	Leaves	Cooked, decoction	Oral	Indigestion, fever	Spice, salad	June-August	Exotic	24	0.51	Petroselinic acid, linoleic acid, and oleic acid	Mandal *et al.* 2015.
Daucus carota L. 4254-KASH	Gazar	Leaves, roots	Infusion, cooked	Oral	Dysentery, fatigue, defective lactation	Vegeta ble, salad	June-October	Native	26	0.55	α-pinene, isophorone oxide, and quercetrin	Cui *et al.* 2020.
Elwendia persica (Boiss) Pimenov & Kljuykov 2974-KASH	Kala-zeera	Seeds	Infusion, cooked	Oral	Urinary tract infection, diarrhea, cough and cold	Spice, salad, herbal tea	April-July	Native	29	0.62	γ cumin aldehyde, α-terpinene-7-al, γ-terpinene-7-al, γ-terpinene, ρ-cymene and β-Pinene	Thawkar *et al.* 2023
Eryngium billardierei F.Delaroche 4247-KASH	Dawa-mool	Roots	Fresh	Oral	Jaundice, urinary tract infection	Fodder	June-August	Native	17	0.36	Isofencho, germacrene D and gurjunene	Sardari *et al.* 2024
Ferula jaeschkeana Vatke 4276-KASH	Jangliheeng	Leaves, whole plant, roots	Paste, decoction, infusion	Oral as well as topical	Headache, fever, sore throat, abdominal pain	-------	April-July	Native	22	0.47	Jaeschkeanadiol, α-pinene, and β-pinene	Yang 2018.

Foeniculum vulgare Mill. 4321-KASH	Baidyaan	Whole plant, flowers	Decoction, infusion	Oral	Sore throat, urinary tract infection, constipation, piles proper digestion	Spice, salad	June-August	Native	34	0.72	Trans-anethole, estragole, and anisaldehyde	Pavela *et al.* 2017.
Heracleum candicans Wall. ex DC. 3446-KASH	Mirkull	Leaves, Flowers	Infusion	Oral	Fatigue, abdominal pain, calcium deficiency	Fodder	May-July	Native	20	0.43	Bergapten, heraclenin, and imperatorin	Gao *et al.* 2011.
Prangos pabularia Lindl. 4761-KASH	Plande	Flower, seeds	Decoction, powder	Oral as well as topical	Fever, skin irritation, kidney inflammation leukoplakia, diabetes	Fodder	June-July	Native	15	0.32	α-pinene, δ-3-carene, limonene, germacrene D and bicyclogermacrene	Razavi 2012.
Selinum vaginatum C.B. Clarke 3811-KASH	Bud-jath	Roots	Infusion, decoction	Oral	Abdominal pain, intestinal worms, rheumatism	Fodder	July-September	Native	23	0.49	bornyl acetate, limonene, elemol, camphene, α-pinene	Chaudhary *et al.* 2020.

Where; Prep: Preparation, Adm: Administration, UR: Use Report, UV: Use Report, Ref: Reference

Plant part used

Amongst the parts of plants, roots were most utilized with 28% of usage, followed by leaves (25%), whole plant (22%), seeds (16%) and flowers (9%), (Figure 3). Roots are often the most favored part of plants used as they often comprise a higher concentration of bioactive constituents (Khoja *et al.* 2023; Haq *et al.* 2020;2023). Excessive usage of roots or whole plants, especially in the case of threatened species, should however be discouraged because it can have a serious negative influence on population and growth, and can lead to extinction (Khoja *et al.* 2024). In addition to roots, leaves are commonly used for food and medicines due to the high content of bioactive constituents (Haq *et al.* 2024a). Our results are similar to the ethnobotanical surveys completed in diverse regions of the Himalaya (Singh *et al.* 2009).

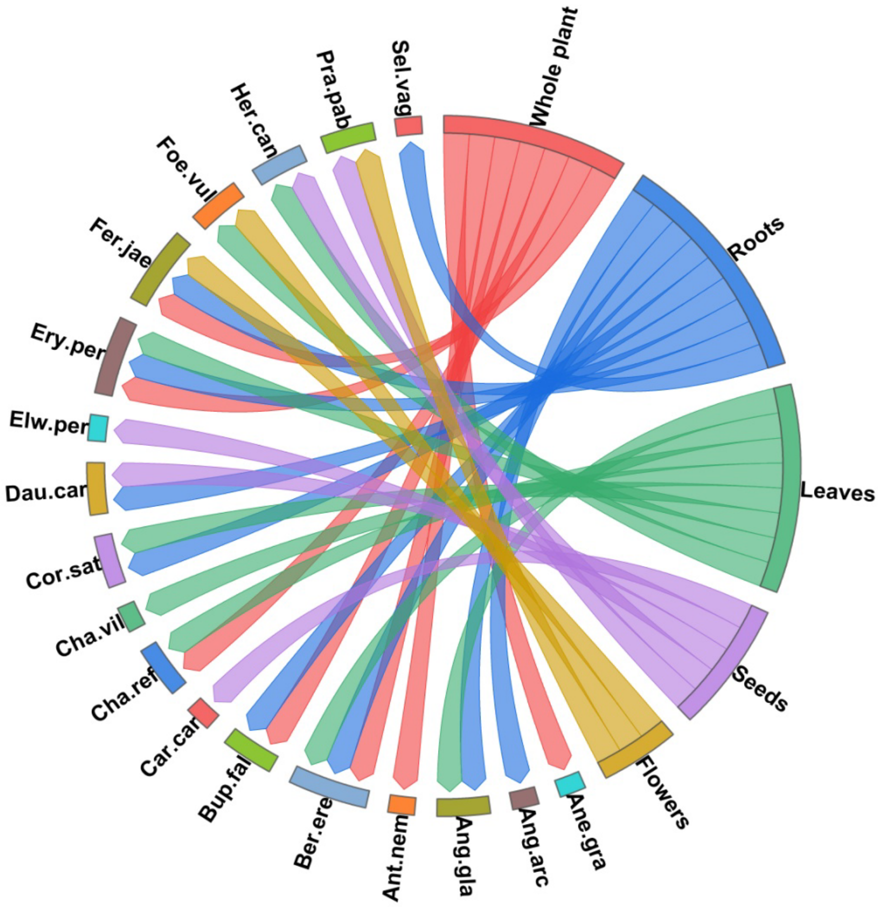

Figure 3. Distribution of plant species across various plant part categories used in the region. The direction of the lines indicates which plant species is associated with each plant part, while the thickness of each bar reflects the extent of use for each part within the categories. Full species names are provided in Table 2.

Method of Preparation

The most popular methods for preparations included using infusion (31%) followed by decoction (25%), paste (17%), cooked (11%), powder (5%) and raw (3%) (Figure 4). Numerous ethnobotanists, such as (Khoja *et al.* 2023) from the Kashmir Himalayas, (Emiru *et al.* 2011) from Northern Ethiopia, and (Uniya *et al.* 2006) from tribal areas in the Western Himalaya, reported similar findings. The most common and viable strategies of traditional recipe preparations include using raw, drying the plants, crushing and grinding to fine powder, boiling to obtain decoction, making tea and infusion, poultice, cooked, and paste making. Most of the plant species are collected in the autumn season and depending upon the availability, forest inhabitants were aware of various plant species' collecting seasons, modes of collection, and frequency of collection.

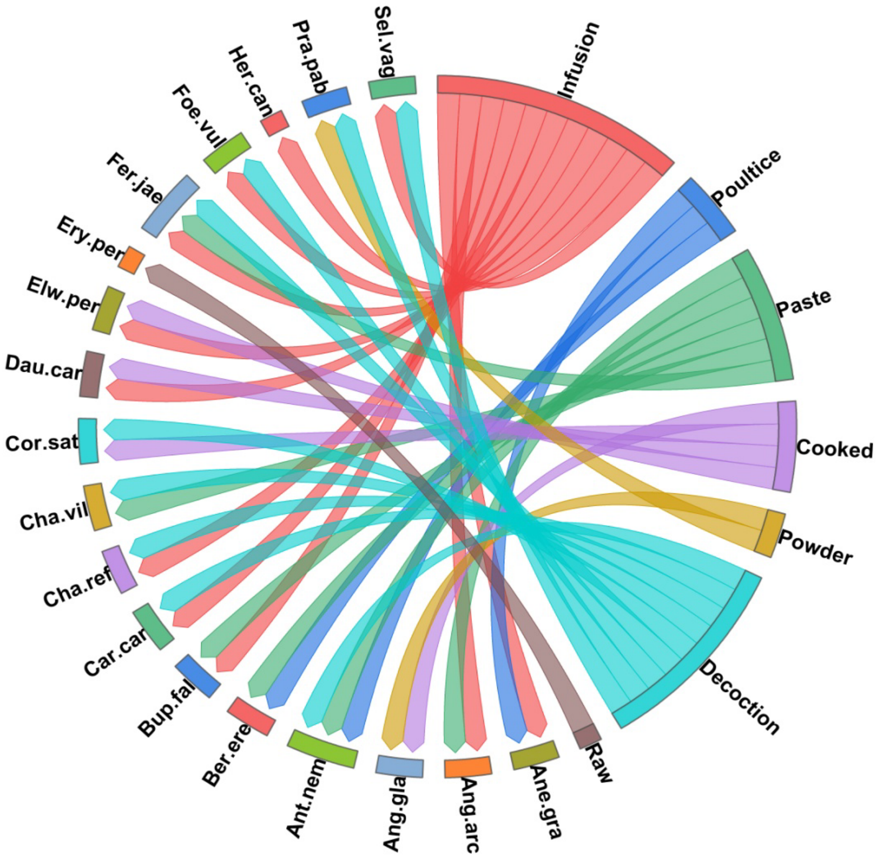

Figure 4. Distribution of plant species across various preparation categories used in the region. The direction of the lines indicates which plant species is associated with each plant part used, while the thickness of each bar represents the extent of use for each part within the categories. Full species names are provided in Table 2.

Disease cured

Plants are a potent and rich source of different phytochemicals (Avato & Argentieri 2015). Gastro-intestinal disorders were treated with most species (32%), followed by musculoskeletal (17%), dermatological and renal (12% each), hepatic and fever (7% each), gynecological and dental (5% each) and respiratory (3%). The results could be explained by the fact that gastrointestinal disorders are frequent in these regions as a result of poor sanitation, malnutrition, and a lack of clean water. This distribution of applications is in accordance with other studies, e.g., Kaur *et al.* (2020), Miya *et al*. (2020) from the Indian sub-continent and Monigatti *et al.* (2013) reported from Peru. The PCA analysis identified nine distinct groups based on changes in the preferences for using plant parts. The biplot revealed 9 clusters of disease categories based on species presence or absence, including Gastro-intestinal, musculoskeletal, dermatological, renal, hepatic, gynecological, dental, fever and respiratory. PC1 and PC2 described 51.1% of the disease categories in the biplot (Figure 5).

Traditional use categories

The majority of plants were used for medicinal purposes (N-18, 49%), followed by fodder (N-8, 21%), spices (N-6, 16%), salad (N-4, 11%) and vegetables (N-1, 3%) (Figure 6). This shows that the resources from medicinal plants are important in many dimensions of life for people who live in distant places, notably for of meeting their basic needs for food and healthcare. The area is suitable for use as a cattle rangeland, as evidenced by the second biggest use of plants in the research area: as fodder. Combining extensive grazing with overharvesting of wood for medicine and fuel has resulted in open, degraded forests. Additionally, 15 plant species that are used as fodder, spices, salad and vegetables were found during the survey; however, these species have showed a decreasing tendency in recent years due to overexploitation. Similar findings were also observed by several other studies from different Himalayan locations, including the high-altitude Himalaya (Haq *et al*. 2023b), Kashmir Himalayas (Khoja *et al.* 2022), and District Reasi (Haq and Singh 2020). People frequently choose to utilize traditional medicine due to its accessibility, affordability, and perceived lack of side effects, perceived lack of complexity in administration, and the increasing importance of medicinal plants frequently used in folk medicine (Kasole *et al.* 2019).

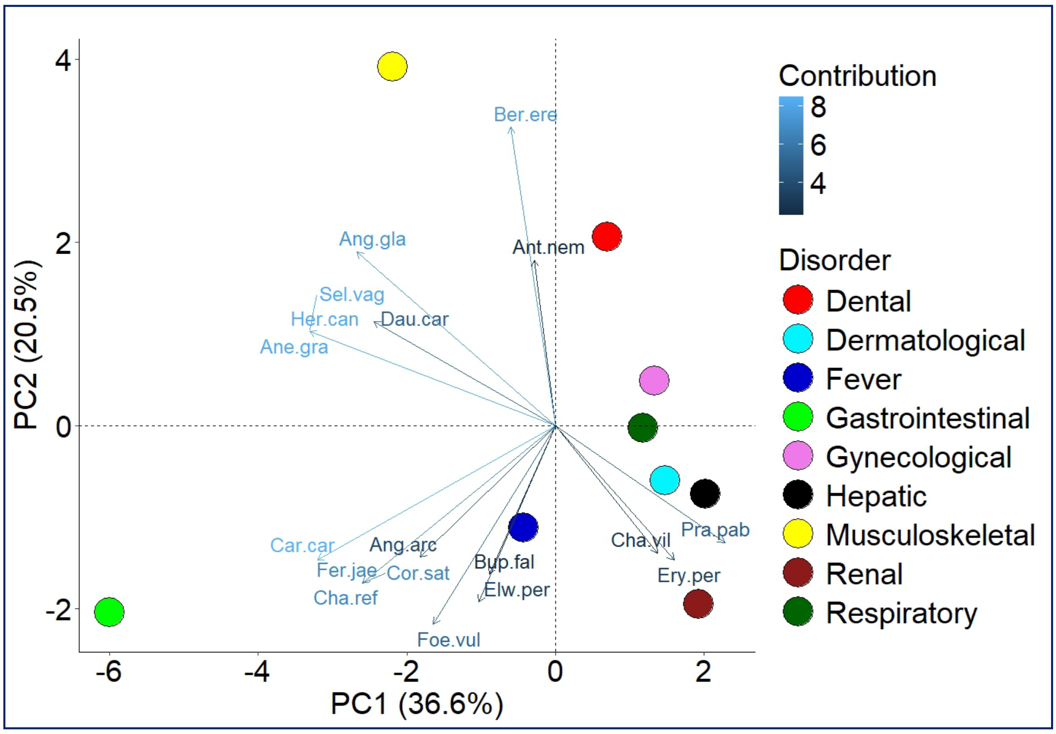

Figure 5. Principal Component Analysis (PCA) biplot of disease categories in the Kupwara district of Jammu and Kashmir, India. Full species names are provided in Table 2.

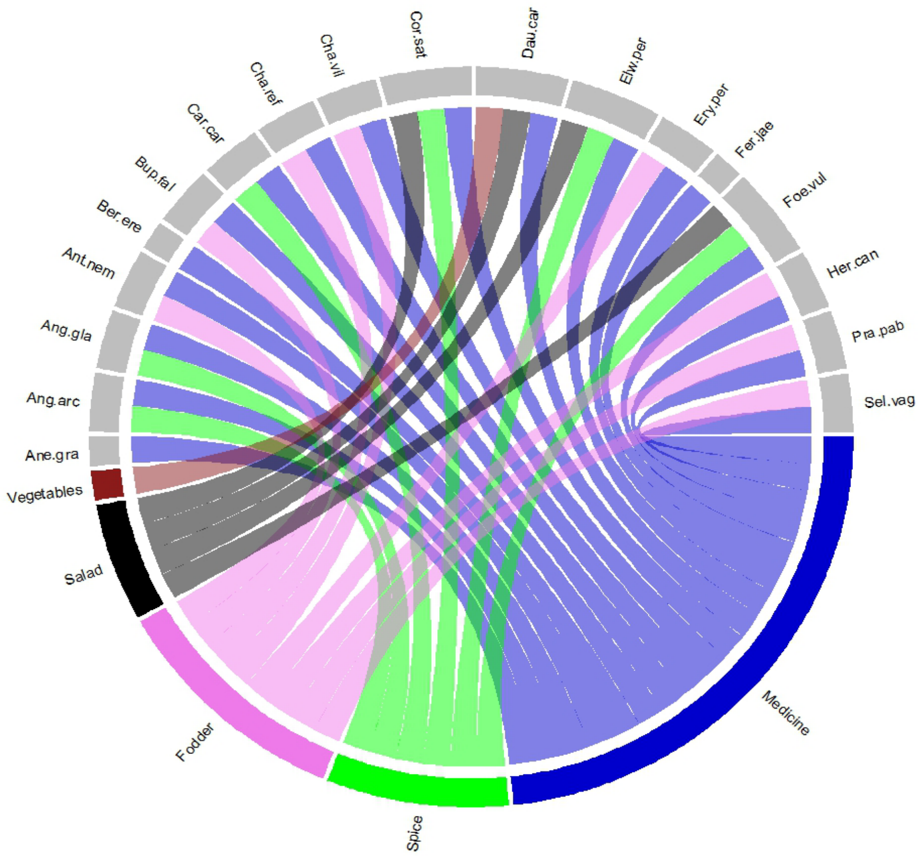

Figure 6. Distribution of plant species across various use categories in the region. The direction of the lines indicates the ethnobotanical usage linked to each plant species, while the thickness of each bar represents the extent of plant usage within each category. Full species names are provided in Table 2.

Phenological spectrum

The phenological spectrum of a flora depicts the flowering period of each species. In the present study, the flora showed flowering periods from April to October, most of the plant taxa are in full bloom in the month of June, July and August (e.g., *Angelica glauca, Anthriscus nemorosa, Bupleurum falcatum, Chaerophyllum villosum, Foeniculum vulgare, Heracleum candicans*, and *Selinum vaginatum*). In January, February, March, November and December in family Apiaceae no flowering was seen because of harsh winters in the study area. Similar results were shown by (Khoja*et al.* 2022a) in Northern Himalaya of Kashmir. These findings are in line with those of (Malik and Malik 2014; Haq *et al.* 2019;2021) who also reported two flowering seasons in other parts of the Himalayan region. A heat map for all months of a year was generated to get the overall picture of month-wise classificatory association with the number of species at flowering stage (Figure 7). The dendrogram showed two distinctly separated clusters based on the degree of intensity of flowering of the vascular flora, in which June to August formed one cluster and rest of months formed second cluster.

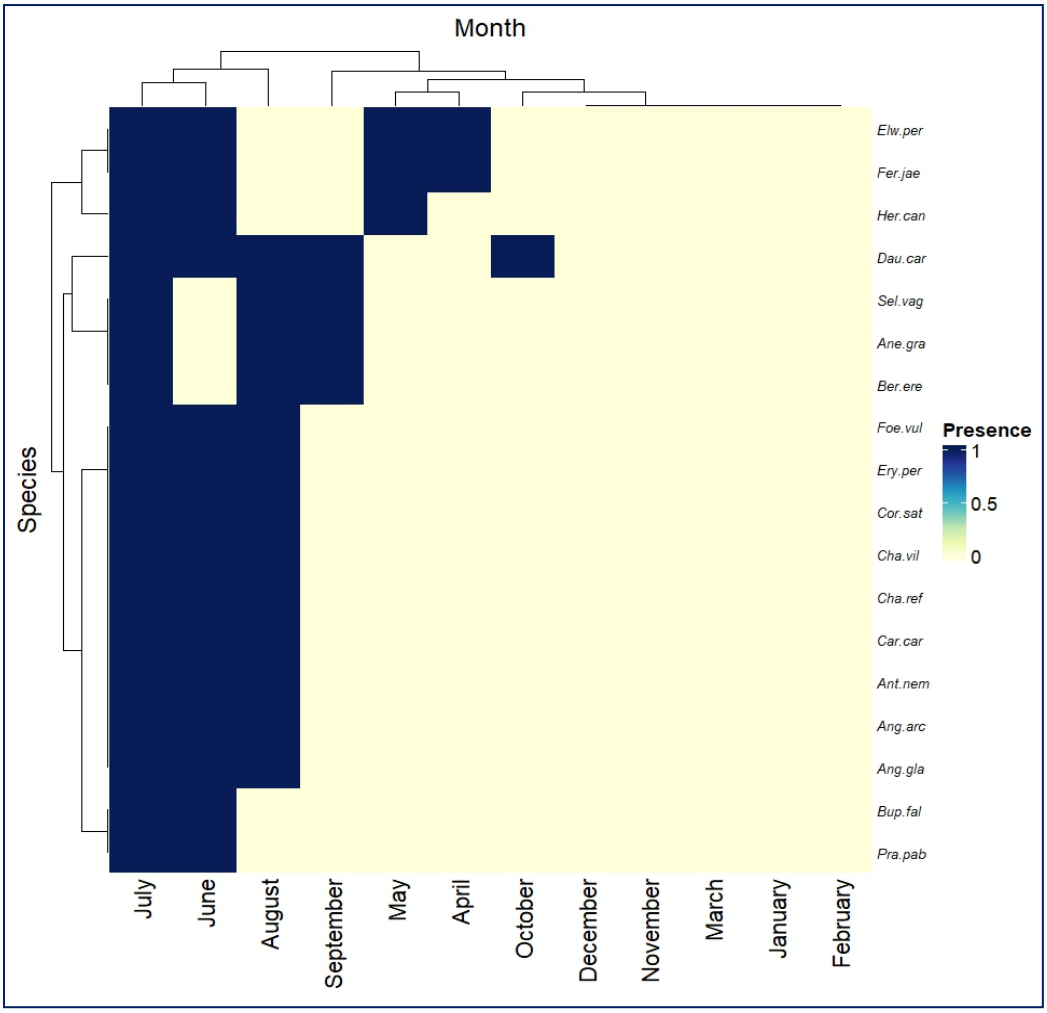

Figure 7. Heat map with clustering dendrogram based on phenological responses across different months. The color scheme indicates mean values, with darker shades (blue) representing higher values and lighter shades (yellow) indicating null values, as shown in the figure. Full species names are provided in Table 2.

Nativity Status

Approximately (N-15, 83%) of the 18-plant species surveyed were native to Asia or the Himalayas, while (N-3, 17%) were introduced and partly invasive (Haq *et al.* 2023c). *Coriandrum sativum* is the only reported species that were grown in fields and gardens. Some invasive species included *Anethum graveolens* and *Bupleurum falcatum* (Table 2). Species like *Coriandrum sativum* and *Foeniculum vulgare* are cultivated in the home gardens because of their multiple usages and boost the economy of the local people, the use of these species as spice in the local cuisine. In the present study we recorded only three species (*Angelica glauca*, *Angelica archangelica*, and *Elwendia persica*) used as flavoring agents especially in the local traditional cuisine. It is important to note that *Angelica glauca* and *Angelica archangelica* were especially used for flavoring beans and beef by Kashmiri ethnic group whereas Gujjars and Pahari use it to flavor it to other wild vegetables. All these species are native and due to their over exploitation, all these species are categorized in IUCN threatened list of plants. Overuse or overharvest of these species endangers biodiversity and the community's capacity to use them for traditional medicine. Overharvesting of subsurface components or entire plants should be avoided, especially when it comes to endangered species, as this practice reduces the plant's wild population (Haq *et al.* 2024). The market value of *Elwendia persica* varies between 3500-5000/kg in the local market similarly the market value of *Angelica glauca* and *Angelica archangelica* varies between 500-800/kg. The plant taxa with multiple uses should be identified and can be used to boost species recovery, such as modifying structure through enhanced species regeneration and planting native species. The native plant taxa tolerate extreme climatic and environmental conditions and indicate that these species may be used as pioneer species particularly degraded landscape modifying the habitat for other species, thus be promoted for future forest restoration in the landscape particularly denuded area.

Use value

The UV indices of the species observed in this study ranged from 0.19 to 0.72 (Figure 8). The highest UV index was recorded for *Foeniculum vulgare* (0.72), *Elwendia persica* (0.62), *Daucus carota* (0.55), *Coriandrum sativum* (0.51), while the lowest UV index was recorded for *Anethum graveolens* (0.20). The relative importance of botanical taxa used for treating particular types of ailments is indicated by the UV. The most important, well-liked, and valuable plant species that locals used as medicine were typically those with the highest UV. An insight of how a species is used can be gained from the use value calculation. Species with higher UV levels are usually well-known and preferred due to their reputation as natural treatments with less adverse effects (Ojha *et al.* 2020). The medicinal plants in the study area with high UV levels were generally widely known in the region (Farooq *et al.* 2019; Haq *et al.* 2024). Similar results were reported by (Redouan *et al.* 2020) from Talassemtane National Park (Northern Morocco).The plant taxa with the greatest URs are those that were most collected for medical preparation because these medicinal taxa have multiple uses, i.e., medicinal as well as other uses. Therefore, it is important to prioritize their conservation and careful management to ensure their sustainable use. According to the highest use report, there is a greater need for these medicinal plants to treat a variety of disorders, which raises their surplus demand and is the primary factor driving their extinction in their natural habitat. Multiple studies have highlighted the importance of certain plants in the Himalayas and their traditional medicinal uses among various tribal communities in the region (Haq *et al.* 2024a; Khoja *et al.* 2024).

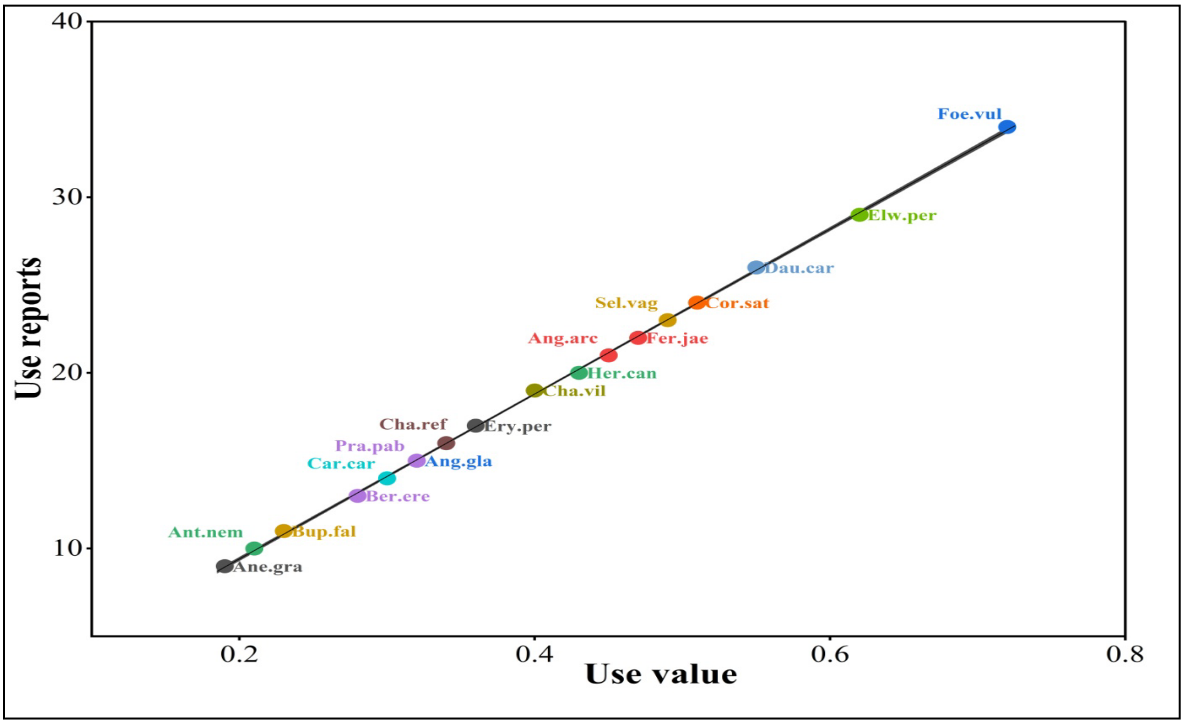

Figure 8. Relationship between Use Value (UV) and Use Reports (Ui). Full species names are listed in Table 2.

Phytochemistry of family Apiaceae

A total of fifty-three of bioactive metabolites have been identified from the 18 members of family Apiaceae (Table 1). Based on their chemical structures, these metabolites can be categorized into five main classes: (1) polysaccharides, (2) alkaloids, (3) phenylpropanoids, (4) flavonoids, and (5) terpenoids (Figure 4). Polysaccharides are the largest components of biomass and account for ca. 90% of the carbohydrates in plants (BeMiller 2019). Studies have demonstrated that polysaccharides in medicinal plants are indispensable bioactive compounds, presenting uniquely pharmacological effects such immunomodulatory, hypoglycemic, antitumor, anti-diabetic, and antioxidant, amongst others with few side effects or adverse drug reactions (Zheng *et al.* 2019). About 27,000 alkaloids presenting as water-soluble salts of organic acids, esters, and combined with tannins or sugars have been found in plants (Kukula-Koch and Widelski 2017). Many alkaloids are valuable medicinal agents that can be utilized to treat various diseases, including malaria, diabetes, cancer, cardiac dysfunction, blood clotting-related diseases etc. (Khan 2016; Perviz *et al.* 2016). Phenylpropanoids are a large class of secondary metabolites biosynthesized from amino acids, phenylalanine, and tyrosine (Deng and Lu 2017). Over 8000 aromatic metabolites of the phenylpropanoids have been identified in plants. These include simple phenylpropanoids (propenyl benzene, phenylpropionic acid, and phenylpropyl alcohol), coumarins, lignins, lignans, and flavonoids (Bottger *et al.* 2018). Ferulic acid, one of the phenylpropionic acids, is an important bioactive metabolite of Apiaceae; it mainly exists in *Angelica* and *Ferula* (Wang *et al.* 2012; Wen *at al.* 2018). Flavonoids are a group of the most abundant secondary metabolites in plants (Deng 2017). Generally, flavonoids can be further categorized into eight subgroups, including flavones (e.g., apigenin, luteolin, and baicalein), flavonols (e.g., kaempferol, quercetin, and myricetin), flavanones (e.g., naringenin, hesperitin, and liquiritigenin), flavanonols (e.g., dihydrokaempferol, dihydromyricetin, and dihydroquercetin), isoflavones (e.g., daidzein, purerarin, and peterocarpin), aurones, anthocyanidins, and proanthocyanidins (Ballard *et al.* 2019; Kim *et al.* 2006). About 25,000 terpenoids have been reported in plants; they are diverse secondary metabolites containing three subgroups, including monoterpenoids, sesquiterpenes, and triterpenoids (Yonekura-Sakakibara and Saito 2009). In Ferula (Xing *et al.* 2012), and 13 triterpenoids (e.g., ranuncoside, oleanane, and barrigenol) in *Hydrocotyle sibthorpioides* Lam. (Xu *et al.* 2013). Specifically, saikosaponin triterpenes constitute the main class of secondary metabolites in the genus *Bupleurum*, with more than 90 saponins (e.g., saikosaponin a, b, and c) isolated (Pan 2006).

Conclusion

The purpose of this research was to highlight the significance of Himalayan Apiaceae in the Kashmir Himalayas by presenting the links between human and plant uses . A total of 18 plant species belonging to 14 genera with various uses, including medicinal, salad, spice, fodder and vegetable were documented. Roots were most utilized followed by leaves. Gastro-intestinal disorders were treated with most species (32%), followed by musculoskeletal (17%), dermatological. A total of fifty-three of bioactive metabolites have been identified from the 18 members of family Apiaceae. The study shed light on how Himalayan Apiaceae contributes to useful insights into therapeutic properties, ecological functions, and cultural relevance population in the study area.

Declarations

Ethics approval and consent to participate: The current study relies solely on a field survey rather than animal or human experiments. As a result, ethical approval and agreement to participate are not required. Informants' formal consent for data collection and release was obtained informally. Furthermore, the International Society of Ethnobiology's (http://www.ethnobiology.net/) ethical rules were strictly observed.

Data availability statement: Data will be made available on request.

Competing interests: The authors declare that they have no competing interests.

Author Contributions: S.M.H conceptualized and supervised this research work. A.A.K; M.H; B.H; surveyed the study sites and collected the required information from informants. M.W; S.M.H.; data analysis with the help of software. The original draft written by A.A.K; M.H; B.H; M.A.J; M.W; R.W.B; S.M.H.: data validation and editing the original draft.

Acknowledgements

We must express our gratitude to the local communities of District Kupwara for sharing their knowledge and for participating in the surveys and interviews. The researchers are appreciative of everyone who contributed to the study, whether directly or indirectly.

Literature cited

Albuquerque UP, Lucena RFP, Monteiro JM, Florentino ATN, Almeida CFCBR. 2006. Evaluating two quantitative ethnobotanical techniques. Ethnobotany Research and Applications 4:51-60.

Amiri MS, Joharchi MR. 2016. Ethnobotanical knowledge of Apiaceae family in Iran: A review. Avicenna Journal of Phytomedicine. 6(6):621-635.

Ashraf M, Aziz J, Bhatty MK. 1979. Studies on the essential oils of Pakistani species of the family Umbelliferae. Part 32. *Chaerophyllum reflexum*, Lindl (Kangoo) essential oil of the whole plant. Pakistan Journal of Scientific and Industrial Research 22:260-261.

Asif M, Haq SM, Yaqoob U, Hassan M, Jan HA. 2021. Ethnobotanical study of indigenous knowledge on medicinal plants used by the tribal communities in tehsil "Karnah" of District Kupwara (Jammu and Kashmir) India. Ethnobotany Research and Applications 21:1-14.

Avato P, Argentieri MP. 2015. Brassicaceae: a rich source of health improving phytochemicals. Phytochemistry reviews 14(6):1019-1033.

Ballard CR, Maróstica MR. 2019. Chapter 10—Health Benefits of Flavonoids Health Benefits of Flavonoids. In Bioactive Compounds; Campos, M.R.S., Ed.; Woodhead Publishing: Cambridge, UK. 185-201.

BeMiller JN. 2019. Polysaccharides: Occurrence, Structures, and Chemistry. In Carbohydrate Chemistry for Food Scientists, 3rd ed.; BeMiller JN, Ed.; AACC International Press: Cambridge, UK. pp. 75-101.

Böttger A, Vothknecht U, Bolle C, Wolf A. 2018. Phenylpropanoids. In Lessons on Caffeine, Cannabis & Co: Plant-Derived Drugs and their Interaction with Human Receptors; Springer International Publishing: Cham, Switzerland. pp. 171-178.

Cai SQ. 2011. Pharmacognostics; People's Medical Publishing House: Beijing, China, 2011.

Chahal KK, Kumar A, Bhardwaj U, Kaur R. 2017. Chemistry and biological activities of *Anethum graveolens* L. essential oil: A review. Journal of Pharmacognosy Phytochemistry 6:295-306.

Chaudhary A, Arjun, Devi S. 2020. An Overview of *Selinum vaginatum* - A Medicinal Plant Species: Broad Features, Phytochemical Constituents, and Pharmacological Action. Asian Pacific Journal of Health Science. doi: 10.21276/apjhs.2022.9.2.50.

Cui CY, Xiao L, Yang YT, Li Q. 2020. Research progress in chemical constituents and pharmacological activities of *Carotae fructus*. Liaoning Chemical Industries 49:651-654.

Deng YX, Lu SF. 2017. Biosynthesis and regulation of phenylpropanoids in plants. Critical Review in Plant Science 36:257-290.

Emiru B, Aynekulu E, Mekuria W, Endale D. 2011.Management, use and ecology of medicinal plants in the degraded dry lands of Tigray, Northern Ethiopia. Journal of Horticulture and Forestry 3(2):32-41.

Farooq A, Amjad MS, Ahmad K, Altaf M, Umair M, Abbasi AM. 2019. Ethnomedicinal knowledge of the rural communities of Dhirkot, Azad Jammu and Kashmir, Pakistan. Journal of Ethnobiology and Ethnomedicine 15(1):1-30.

Fraternale, D.; Flamini, G.; Ricci, D. 2014. Essential oil composition and antimicrobial activity of *Angelica archangelica* L. (Apiaceae) roots. Journal of Medicinal Foods 17:1043-1047.

Gairola S, Sharma J, Bedi YS. 2014. A cross-cultural analysis of Jammu, Kashmir and Ladakh (India) medicinal plant use. Journal of Ethnopharmacology 155(2):925-986.

Gao BX, Lan ZQ, Deng JJ, Wu TT, Man XK, Lu XM. 2015. HPLC fingerprint of *Heracleum candicans* roots. Chinese Journal of Experimental Traditional Medical Formulae 21:61-63.

Gras A, Hidalgo O, D'Ambrosio U, Parada M, Garnatje T, Vallès J. 2021. The Role of Botanical Families in Medicinal Ethnobotany: A Phylogenetic Perspective. Plants 10(1):163.

Haq SM, Waheed M, Khoja AA, Amjad MS, Bussmann RW, Ali K, Jones DA. 2023c. Measuring forest health at stand level: A multi-indicator evaluation for use in adaptive management and policy. Ecological Indicators 150:110225.

Haq, S.M., Waheed, M., Khoja, A.A., Amjad, M.S., Bussmann, R.W. and Ali, K., 2023.A cross-cultural study of high-altitude botanical resources among diverse ethnic groups in Kashmir Himalaya, India. Journal of Ethnobiology and Ethnomedicine 19(1):12.

Haq SM, Khoja AA, Lone FA, Waheed M, Bussmann RW, Casini R, Mahmoud EA, Elansary HO. 2023a. Keeping Healthy in Your Skin—Plants and Fungi Used by Indigenous Himalayan Communities to Treat Dermatological Ailments. Plants 12(7):1575.

Haq SM, Khoja AA, Lone FA, Waheed M, Bussmann RW, Mahmoud EA, Elansary HO. 2023b. Floristic composition, life history traits and phytogeographic distribution of forest vegetation in the Western Himalaya. Frontiers in Forests and Global Change 6:1169085.

Haq SM, Khoja AA, Waheed M, Pieroni A, Siddiqui MH, Bussmann RW. 2024. Plant cultural indicators of forest resources from the Himalayan high mountains: implications for improving agricultural resilience, subsistence, and orest restoration. Journal of Ethnobiology and Ethnomedicine.20(1):44.

Haq SM, Khoja AA, Waheed M, Siddiqui MH, Alamri S, Alfagham AT, Al-Humaid LA, Bussmann RW. 2024a. Food ethnobotany of forest resource in the high-altitude Himalaya Mountains: Enhancing the food sovereignty of ethnic groups. Forest Policy and Economics 164:103247.

Haq SM, Malik AH, Khuroo AA, Rashid I. 2019.Floristic composition and biological spectrum of Keran-a remote valley of northwestern Himalaya. Acta Ecologica Sinica 39(5):372-379.

Haq SM, Malik AH, Khuroo AA, Rashid I. 2020. Contribution to the flora of Keran Valley. In book: Ethnobotany and Biodiversity Conservation Publisher: Indus Book Services Prvt. Ltd. New Delhi.39-59.

Haq SM, Singh B. 2020. Ethnobotany as a Science of Preserving Traditional Knowledge: Traditional Uses of Wild Medicinal Plants from District Reasi, J&K (Northwestern Himalaya), India. In Botanical Leads for Drug Discovery, Springer, Singapore. pp. 277-293.

Irshad, M.; Shahid, M.; Aziz, S.; Ghous, T. 2011.Antioxidant, antimicrobial and phytotoxic activities of essential oil of *Angelica glauca*. Asian Journal of Chemistry 23:1947.

Joshi RK, Mathela CS. 2013. Volatile oil composition and antioxidant activity of leaf of *Chaerophyllum villosum* Wall. ex DC from Uttrakhand, India. Recent Research in Science and Technology 5(1):25-28.

Kasole R, Martin HD, Kimiywe J. 2019. Traditional medicine and its role in the management of diabetes mellitus:"patients' and herbalists' perspectives". Evidence-Based Complementary and Alternative Medicine 2019.

Kaur J, Kaur R, Nagpal AK. 2020. Traditional use of ethnomedicinal plants among people of Kapurthala District, Punjab, India. Pharmacognosy Magazine 16(68):69.

Kaya A, Demirci B, Dinc M, Dogu S. 2018. A monotypic species from Turkey: characterization of the essential oil of *Berula erecta* (Apiaceae). Natural Volatiles and Essential Oils 5(1):7-10.

Khan H. 2016. Anti-inflammatory potential of alkaloids as a promising therapeutic modality. Letters Drug Design Discovery 14:240-249.

Khare CP. 2008. Indian Medicinal Plants: An Illustrated Dictionary; Springer Science & Business Media: Berlin, Germany, 2008.

Khoja AA, Andrabi SAH, Mir RA. 2022. Traditional medicine in the treatment of gastrointestinal diseases in northern part of Kashmir Himalayas. Ethnobotany Research and Applications 23:1-17.

Khoja AA, Andrabi SAH, Mir RA, Bussmann RW. 2022a. Ethnobiological uses of plant species among three ethnic communities in the administrative (Kupwara) of Jammu and Kashmir-India: A cross-cultural Analysis. Ethnobotany Research and Applications 24:1-22.

Khoja AA, Andrabi SAH, Mir RA. 2023. An ethnobotanical study on across different ethnic groups from high-altitude areas of the North-western Himalayas. Asian Journal of Ethnobiology 6(1):48-59.

Khoja AA, Waheed M, Haq SM, Bussmann RW. 2024. The role of plants in traditional medicine and current therapy: A case study from North part of Kashmir Himalaya. Ethnobotany Research and Applications 27:1-22.

Kim MR, Lee JY, Lee HH, Aryal DK, Kim YG, Kim SK, Woo ER, Kang KW. 2006. Anti oxidative effects of quercetin glycosides isolated from the flower buds of *Tussilago farfara* L. Food and Chemical Toxicology. 44:1299-1307.

Kukula-Koch WA, Widelski J. 2017. Chapter 9—Alkaloids. In Pharmacognosy; Badal S, Delgoda R, Eds.; Academic Press: Boston, MA, USA. pp. 163-198.

Li B, Zhang WH, Gong HD. 2022. Research on forage plant resources of Umbelliferae in Gansu. Journal Mudanjiang Normal University 2:57-61

Liu Y, Liu M, Liu MY. 2002. Resource plants of Apiaceae (Umbelliferae) in China. Natural Resources 4:76-78.

Lu ZB, SUn YS, Wang JH, Li SH, Huang HM. 2011.HPLC determination of saikosaponins a, c, and d in different parts of *Bupleurum falcatum*. Chinese Journal of Pharmaceutical Analysis 31:225-227.

Ma XC, Chen SP, Wang JH, Li J, Xie YL. 2011. Planting density oa affects dry material accumulation and saikosaponin contents of *Bupleurum falcatum* L. Journal of Shandong Agricultural University (Natural Sciences) 42:65-69.

Malik ZH, Malik NZ. 2014. Phenological patterns among the vegetation of Ganga Chotti and Bedori Hills in a moist temperate to alpine forests. International Journal of Biodiversity and Conservation 6(6):444-451.

Mandal S, Mandal M. 2015. Coriander (*Coriandrum sativum* L.) essential oil: Chemistry and biological activity. Asian Pacific Journal of Tropical Biomedicine 5:421-428.

Miya MS, Timilsina S, Chhetri A. 2020.Ethnomedicinal uses of plants by major ethnic groups of Hilly Districts in Nepal: A review. Journal of Medicinal Botany 4:24-37.

Monigatti M, Bussmann RW, Weckerle CS. 2013. Medicinal plant use in two Andean communities located at different altitudes in the Bolívar Province, Peru. Journal of Ethnopharmacology 145(2):450-464.

Naeini S, Delazar D, Asghariyan P, Asnaashari S. 2017. Phytochemical analysis of essential oil of *Anthriscus nemorosa* and evaluation of antioxidant and anti-malarial activity. Research Journal of Pharmacognosy 4:42.

Ojha SN, Tiwari D, Anand A, Sundriyal RC. 2020. Ethnomedicinal knowledge of a marginal hill community of Central Himalaya: diversity, usage pattern, and conservation concerns. Journal of Ethnobiology and Ethnomedicine 16(1):1-21.

Palchetti, M.V., Zamudio, F., Zeballos, S., Davies, A., Barboza, G.E. and Giorgis, M.A., 2023. Large-scale patterns of useful native plants based on a systematic review of ethnobotanical studies in Argentina. Perspectives in Ecology and Conservation 21(2): 93-100.

Pan SL. 2006. Bupleurum Species: Scientific Evaluation and Clinical Applications; Taylor & Francis Group: London, UK.

Pang M, Cui XM. 2022. Extraction of *Carum carvi* L. essential oil by supercritical carbon dioxide and its composition analysis. Food and Machinery 38:175-179.

Pardo-de-Santayana M, Quave CL, Söukland R, Pieroni A. 2015.Medical ethnobotany and ethnopharmacology of Europe. In Heinrich M, Jäger AK.(eds.), Ethnopharmacology. John Wiley & Sons: Chichester, UK. 343-355.

Pavela R, Žabka M, Bednár J, Tˇríska J, Vrchotová N. 2016. New knowledge for yield, composition and insecticidal activity of essential oils obtained from the aerial parts or seeds of fennel (*Foeniculum vulgare* Mill.). Industrial Crops and Products 83:275-282.

Perviz S, Khan H, Pervaiz A. 2016. Plant alkaloids as an emerging therapeutic alternative for the treatment of depression. Frontiers in Pharmacology 7:28.

Phillips O, Gentry AH. 1993. The useful plants of Tambopata, Peru: I. Statistical hypotheses tests with a new quantitative technique. Economic Botany 47:15-32.

Razavi SM. 2012. Chemical and allelopathic analyses of essential oils of *Prangos pabularia* Lindl. from Iran, Natural Product Research 26:2148-2151.

Redouan FZ, Benítez G, Picone RM, Crisafulli A, Yebouk C, Bouhbal M, Driss AB, Kadiri M, Molero-Mesa J, Merzouki A. 2020. Traditional medicinal knowledge of Apiaceae at Talassemtane National Park (Northern Morocco). South African Journal of Botany 131:118-130.

Sajad S, Haq SM, Yaqoob U, Calixto ES, Hassan M. 2021.Tree composition and standing biomass in forests of the northern part of Kashmir Himalaya Vegetos 1-10.

Saleem F, Sarkar D, Ankolekar C, Shetty K. 2017. Phenolic bioactives and associated antioxidant and anti-hyperglycemic functions of select species of Apiaceae family targeting for type 2 diabetes relevant nutraceuitcals. Industrial Crops Products 107:518-525.

Sardari K, Delazar A, Ghanbari H, Asnaashari S, Asgharian P. 2024. Phytochemical Evaluation of Aerial Parts of *Eryngium billardieri* growing in Iran. Chemical Methodologies 8(1):47-57.

Sayed-Ahmad B, Talou T, Saad Z, Hijazi A, Mera O. 2017. The Apiaceae: Ethnomedicinal family as source for industrial uses. Industrial Crops and Products 109:661-671

Shelef LA. 2003. Herbs of the Umbelliferae. In Encyclopedia of Food Sciences and Nutrition, 2nd ed.; Caballero, B., Ed.; Academic Press: Oxford, UK, 2003; pp. 3090-3098.

Singh A, Lal M, Samant SS. 2009. Diversity, indigenous uses and conservation prioritization of medicinal plants in Lahaul valley, proposed Cold Desert Biosphere Reserve, India. International Journal of Biodiversity, Science and Management 5(3):132-154.

Sørensen TAA. 1948. Method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Kongelige Danske Videnskabernes selskabs skrifter 5:1-34.

Thakur S, Devi A, Tashi N, Dutt HC. 2021. Plants for Novel Drug Molecules: Ethnobotany to Ethnopharmacology. New Delhi publishing agency. 275-286.

Thawkar MM, Pimpalshende DPM, Kosalge DSB, Jeurkar MM. 2023. Phytochemistry pharmacology and multifarious activity on *Bunium persicum* seed: A comprehensive Review 10(1):499-507.

Thiviya P, Gamage A, Piumali D, Merah O, Madhujith T. 2021. Apiaceae as an Important Source of Antioxidants and Their Applications. Cosmetics 8:111.

Uniyal SK, Singh KN, Jamwal P, Lal B. 2006.Traditional use of medicinal plants among the tribal communities of Chhota Bhangal, Western Himalaya. Journal of Ethnobiology and Ethnomedicine 2:1-8.

Wang DD, Liu HB, Song HL, Yang WX, Jia XG, Tian SG. 2012. Determination of ferulic acid content in roots and leaves of *Ferula fukanensis* K. M. Shen. by HPLC. Journal of Xinjiang Medical University 31:1139-1142.

Wei J, Gao YZ, Zhou J, Liu ZW. 2019. Collection and sorting of medicinal plants in Chinese Apiaceae (Umbelliferae). China Journal of Chinese Materia Medica 44:5329-5335.

Wen Q, Wang XY. 2018. Determination the content of ferulic acid in *Pleurospermum* Hoffm. by HPLC. Chinese Journal of Ethnomedicine and Ethnopharmacy 27:49-51.

Xing YC, Li N, Xue J. 2012. Progress on chemical constituents of *Ferula* genus. Journal of Shenyang Pharmaceutical University 29:730-741.

Xu YF, Chen YH, Yang SP. 2013. Review of chemical constituents and pharmacological effects of Hydrocotyle genus. Fujian Science & Technology of Tropical Crops 38:59-61.

Yang XW. 2018. Bioactive Material Basis of Medicinal Plants in Genus *Ferula*. Modern Chinese Medicine 20:123-144.

Yonekura-Sakakibara K, Saito K. 2009. Functional genomics for plant natural product biosynthesis. Natural Products Reports 26:1466.

Yuan CQ. 1999. Ethnobotanical research on Umbelliferous plants in China. Chinese Journal of Ethnomedicine and Ethnopharmacy 4:221-224.

Zhao ZL, Yan YP. 2020. Pharmaceutical Botany, 2nd ed.; Scientific & Technical Publishers: Shanghai, China.

Zheng Y, Bai L, Zhou Y, Tong R, Zeng M, Li X, Shi J. 2019. Polysaccharides from Chinese herbal medicine for anti-diabetes recent advances. International Journal of Biological Macromolecules 12:1240-1253.