# Ethnopharmacology and phenology of high-altitude medicinal plants in Kashmir, Northern Himalaya

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## Research

## Abstract

*Background:* Traditional knowledge plays an important role in the conservation of floral diversity and is often used for the treatment of numerous diseases in local medicinal systems. Diverse cultural groups in the Himalayan regions have their own local indigenous healthcare systems, with medicinal plant applications that differ depending on geography and ecology. Therefore, it is important to understand plant ecological behavior for prioritizing conservation efforts and comprehending the impact of climate change on plant phenological traits.

*Methods:* Ethnopharmacological data was collected through interviews and group discussions using semi-structured and close-ended questionnaires from different ethnic groups i.e., Gujjar, Bakarwal, and Kashmiri. The data was subjected to hierarchical cluster analysis and ordination techniques (Principal Component Analysis) using multivariate software.

*Results:* The present investigation documented a total of 32 plant species belonging to 31 genera in 23 families. Across the 23 families, the distribution of species was unequal, half of the species belonged to just 6 families (Asteraceae, Berberidaceae, Lamiaceae, Ranunculaceae, Solanaceae and Amaranthaceae) while the remaining half belonged to 17 families. Amongst the parts of plants, roots were the most utilized plant part with 25% of usage followed by whole plant (22%). Gastro-intestinal disorders were treated with most species (18%), followed by pulmonary infections (13%). A heat map showed two distinctly separated clusters based on the degree of intensity of flowering timing of the flora and month. Based on the conservation assessment, out 19% of all species observed fell in the Critically Endangered category of IUCN, followed by 6% in the Vulnerable category.

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*Conclusions:* This study provides the ethnopharmacological and ecological scope of the plants of the Kashmir in the northern Himalaya. There is need to develop strategies to conserve and sustainably harvest these plants in order to maintain their long-term benefits in the medicinal field.

*Key words:* Flowering time; Disease cured; Conservation; Kashmir

## Background

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 (Zhu 2016). 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 (Liu *et al.* 2016).

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). Therefore, ethnobotanical research is dominated by the collecting of plant uses connected to health, primarily medical and food uses, but other uses are also relevant. Based on the importance of folk local knowledge to safeguard and enhance health, a number of medications have been produced based on their ethnobotanical background, including the antiviral oseltamivir and the antimalarial artemisinin, to name just two well-known and recent examples (Tringali *et al.* 2012; Tu *et al.* 2016). Ethnopharmacology, is one of the discipline's key foundations (Pardo-de-Santayana *et al.* 2013; Hassan *et al.* 2021).

Medicinal plants are often incorporated into new commercial interests because of the expansion of highways and population growth. Many medicinal plant species are under severe harvesting pressure and require immediate conservation measures to avoid extinction (Chen *et al.* 2016). The disappearance of many taxa could result in the loss of associated traditional knowledge (Lamsal *et al.* 2017). Therefore, it is highly important to understand the ecological behavior of these medicinal plants, e.g., their flowering phenology, to understand their reproductive success (Liu *et al.* 2021). It is important to understand reproductive behavior of plants to prioritize the conservation efforts as well as comprehend the effect of climate change on plant's reproductive traits (Tandon *et al.* 2020).

This study focused on a comprehensive assessment of the useful flora of the Kashmir Himalaya to achieve the following objectives: (i) to have an in-depth understanding of the ethnopharmacology of high-altitude medicinal plants (2) elucidate major diseases cured and the mode of remedy preparation by indigenous communities, and (3) to study phenological spectra and conservation status of documented medicinal plants. By answering these questions, we aim to provide fundamental information about the ethno-medicinal use of species that exist in the area, which might serve as a benchmark for their protection. Observing the phenological patterns of plants, we provide important information for understanding how species are adapted to specific climatic regime in the region.

## Material and Methods

### Study area

The district Kupwara lies in the Northern part of the Kashmir valley (India), between 34°45 Nand 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 Dar et al. (2012), 153 (8%) angiosperm taxa found in Kashmir are endemic exclusively to this region. The district Kupwara has a total geographical area of 2379 $km^2$ 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.* 2020), 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, four villages (Chowkibal, Marsari, keran, Budnamal) which lie in the frontier area were selected (Fig. 1). The "Keran" region is located on the banks of the sacred river Kishan Ganga. This River forms the actual line of control between Keran and Pakistan administrated Kashmir (POK) (https://kupwara.nic.in/places-of-interest/).

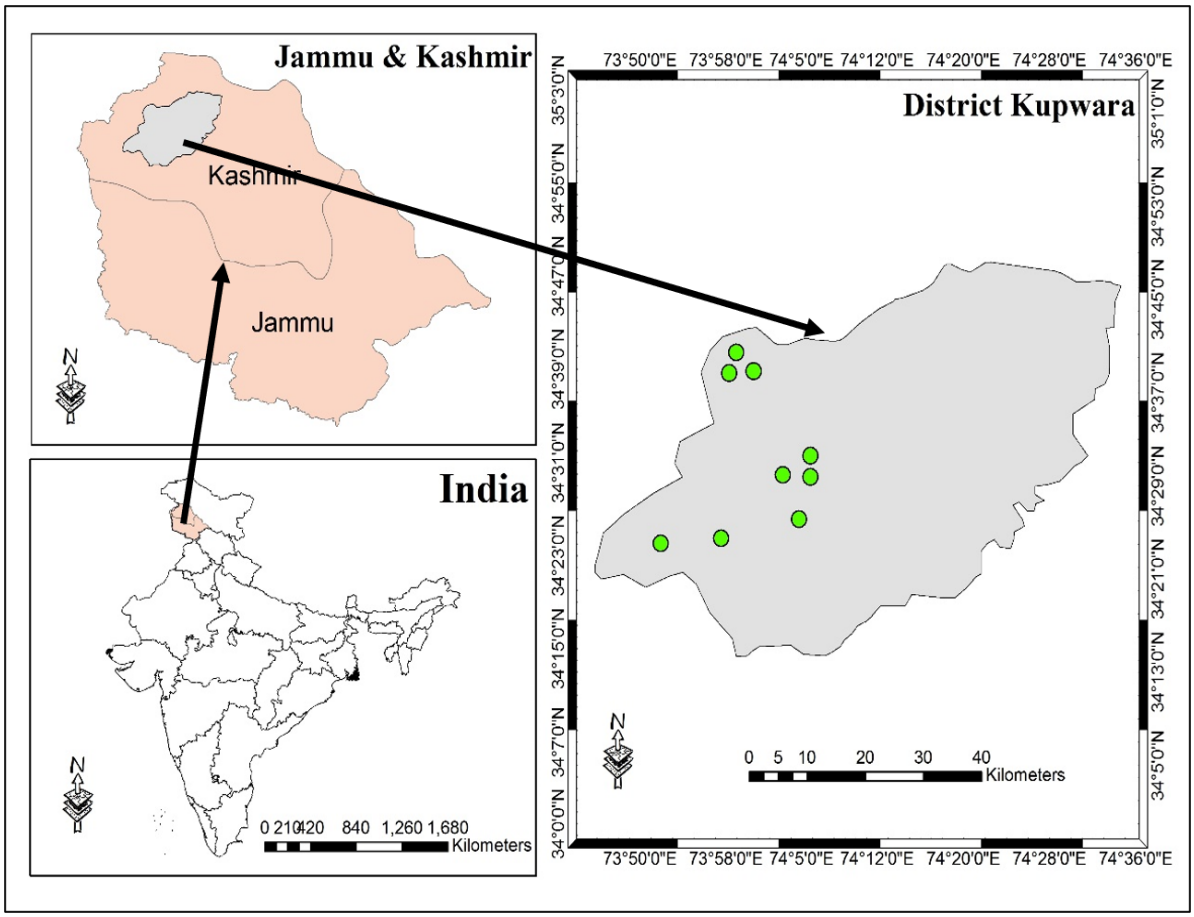


Figure 1. Map of the Jammu and Kashmir, India and points showing surveyed village in District Kupwara.

**Ethnobotanical data collection**

The study was carried out in 2019-20. Field surveys were conducted frequently in different seasons following standard protocols (Haq *et al.* 2020a). The ethnopharmacological data was collected through face-to-face semi-structured interviews and discussions, after obtaining prior informed consent form the participants (Asif *et al.* 2021). Since the selected villages are mainly inhabited by Gujjar, and Pahari ethnic groups, with some Kashmiri people, we employed a translator to improve data collection. The information collected was also crosschecked with the available literature (Gaiorola et al., 2014; Haq *et al.* 2019a). 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 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.* 2021), and voucher specimens were collected.

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 (Asif et al. 2021; Haq et al. 2019a). Nomenclature and botanical families of all the specimens were further authenticated using The Plant List (www.plantsoftheworldonline.org/).

**Data analysis**

Cluster analyses of ecological variables and plant compositions were carried out with heatmap and clustering analysis (Haq *et al.* 2021). The heatmap 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). Principal Component Analysis (PCA) was used to find hypothetical variables (components) that accounted for as much of the variance in our multidimensional data as possible using PAST software ver.3.14. (https://www.techworld.com/download/office-business/past-314-3330821/linkid=163338).

## Results and Discussion

### Demography of Respondents

A total of 109 respondents (89 men, 20 women) were interviewed. The uneven ratio of men and women was because women are restricted mainly to their homes and do not have access to distant areas (Haq *et al.* 2020b; Asif *et al.* 2021). Data was from three ethnic groups [Gujjar (49.54%), Pahari (40.36%) and Kashmiri (10.09%)] among which shepherds accounted for 28.44%, herbalists 23.85%, shopkeepers 16.51%, daily laborers 17.43% and housewives 13.76%. The most important knowledge holders were old people (50.45%) followed by middle aged (25.52%) and young (22.01%). Most respondents were illiterate (71.55%), whereas 13.76% of the participants had primary education, 11.92% secondary level and only 2.75% higher education. 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 Respondents in the study area.

| Demographic features | Number of people | Percentage (%) |
|---|---|---|
| *Administrative Region* | | |
| Kupwara | 109 | |
| *Villages* | | |
| Chowkibal | 32 | 29.35 |
| Marsari | 38 | 34.86 |
| Keran | 21 | 19.26 |
| Budnamal | 18 | 16.51 |
| *Education* | | |
| Illiterate | 78 | 71.55 |
| Primary education | 15 | 13.76 |
| Secondary education | 13 | 11.92 |
| Higher education | 3 | 2.75 |
| *Age range* | | |
| Young (18-26 Years) | 24 | 22.01 |
| Middle (27-55 Years) | 30 | 25.52 |
| Old (56-75+ Years) | 55 | 50.45 |
| *Profession* | | |
| Shepherds | 31 | 28.44 |
| Herbalists | 26 | 23.85 |
| Shopkeepers | 18 | 16.51 |
| Daily laborers | 19 | 17.43 |
| Housewives | 15 | 13.76 |
| **Ethnic Groups & Language* | | |
| Gujjar | 54 | 49.54 |
| Pahari | 44 | 40.36 |
| Kashmiri | 11 | 10.09 |
| Forest Type | Himalayan dry-temperate to subalpine forest type | |
| *Religion* | | |
| Islam | | |
| *Gender* | | |
| Male | 89 | 81.65 |
| Female | 20 | 18.34 |

### Plant diversity and distribution patterns

The present investigation documented 32 plant species belonging to 31 genera in 23 families. The usage of plant species and mode of use are presented in Table 2. Although this number of species might seem low, especially in relation to the high biodiversity of the area, the species richness of useful plants documented was comparable to studies published by other investigators from diverse areas of the Himalaya. For example, Shaheen *et al.* (2014) reported the usage of 36 species from tribal communities of Kashmir Himalayas. Jabeen *et al.* (2015) documented

a total of 49 ethnobotanically important plants of district Ghizer, Gilgit- Baltistan. Bhatia et al. (2014) reported a total of 166 species of flowering plants belonging to 63 families and 145 genera used to cure 78 ailments. Mahmood *et al.* (2011) reported traditional uses of 38 plants from district Bhimber Azad Kashmir, Pakistan. The results were similar to earlier findings (Haq *et al.* 2019; Umair *et al.* 2019; Haq *et al.* 2021a), however, the number of plant species in our study was lower than Haq *et al.* (2020a) who reported the traditional use of 57 plant species from Kashmir Himalaya, India. Gairola et al. (2014) reported a total of 948 plant taxa (923 angiosperms, 12 gymnosperms and 13 pteridophytes) belonging to 129 families, 509 genera, 937 species and 11 varieties to have a traditional medicinal use by indigenous communities of Western Himalayan region in his review.

Across the 23 families, the distribution of species was unequal (Fig. 2). Half of the species belonged to just 6 families (Asteraceae, Berberidaceae, Lamiaceae, Ranunculaceae, Solanaceae and Amaranthaceae) while the remaining half belonged to 17 families. Many families (18) were monotypic (Table 2). The predominance of families was also comparable with investigations carried out in other parts of the Himalayan region where various studies described Asteraceae as the dominant family (Altaf *et al.* 2021; Asif *et al.* 2021; Nafeesa *et al.* 2021; Singh *et al.* 2017). Owing to widespread ecological amplitude, the members of the family Asteraceae acclimatize easily and adapt to arid dry habitats rapidly (Haq *et al.* 2021). Pala *et al.* (2019) reported Lamiaceae as the leading family from the Eastern Himalaya, which is in line with our results.

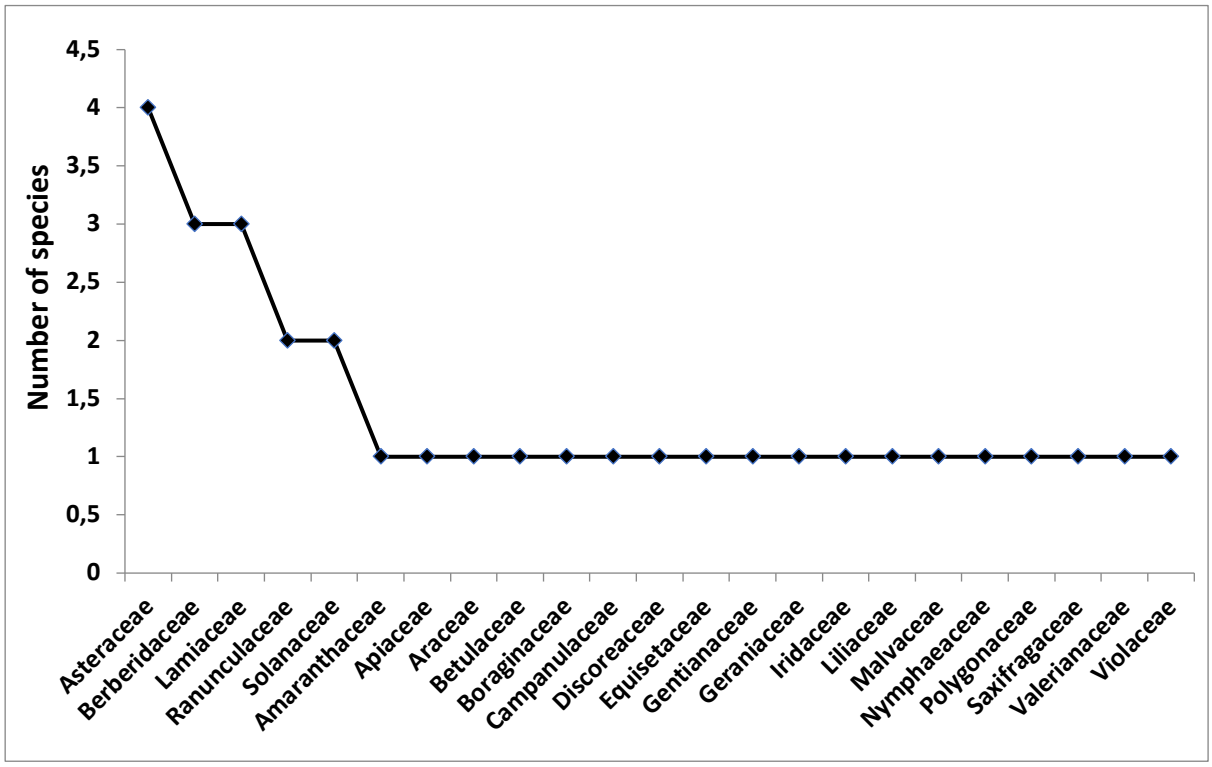


Figure 2. Number of species contributed by different families in the study area.

**Plant part used**

Different parts of plants were documented for indigenous usage with a significant difference ($\chi^2$=70.587, df=9, p<0.001) between their uses. Amongst the parts of plants, roots were most utilized with 25% of usage, followed by whole plant (22%), rhizomes (15%), leaves (13%), flowers (10%), fruits, seeds and bark (5%) each (Fig. 3). Roots are often the most favored part of plants used as they often comprise a higher concentration of bioactive constituents (Uprety *et al.* 2010; Yousuf *et al.* 2020; Hassan *et al.* 2021). 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 (Ghimire *et al.* 2008). In addition to roots, leaves are commonly used for food and medicines due to the high content of bioactive constituents (Jan *et al.* 2017).

Table 2. List of medicinal plant with family, part used, preparations, ailment cured, conservation status and flowering timing.

| **Botanical name** | **Family** | **Vernacular name** | **Parts used** | **Preparations** | **Ailment cured** | **Conservation status** | **Flowering period** |
|---|---|---|---|---|---|---|---|
| *Aconitum heterophyllum* Wall. | Ranunculaceae | Patris | Roots | Extracts of roots are mixed with milk/warm water and taken at the bedtime daily for 1 week. | Large and small intestine infection, abdominal pain, diarrhea. | Endangered | July -Sept |
| *Ajuga bracteosa* Wallich ex. Benth | Lamiaceae | Janeadam | Whole herb | The whole herb is boiled in 2 lit of water forming solution which is taken empty stomach for 2 weeks. | Intestinal infection, loss of appetite. | Least Concern | April-Sept |
| *Anaphalis griffithii* Hook. f. | Asteraceae | Daderi-Dawa | Whole plant | The herb is dried and crushed into powder mixed with oil to make paste. The paste is applied on effected parts externally. | Wounds, skin cracks | Least Concern | July-Sept |
| *Anemone obtusiloba* D. Don | Ranunculaceae | Rattanjog | Rhizome | The dried rhizome is grinded and boiled in water, extract obtained is sieved and mixed with wheat made traditional dish (Nishasta) and is taken orally for 3 weeks. | Joint inflammation, bone fracture | Least Concern | May-Aug |
| *Arisaema jacquemontii* Blume | Araceae | Hapetcheor | Rhizome | Dried rhizome is powdered and mixed with edible oil forming a paste which is applied on the affected areas. | Pimples, blisters | Least Concern | May-Sept |
| *Arnebia benthamii* (Wall. ex G. Don.) Johnst | Boraginaceae | Kah-zaban Gao-Zaban | Whole plant | The whole plant is crushed and boiled in water. The obtained decoction is taken for more than a week. | Tongue infection, urolithiasis liver problems | Critically Endangered | May-July |
| *Artemisia absinthium* L. | Asttab eraceae | Teethwen | Leaves Flowers | The leaves and flowers are boiled in water and the obtained decoction is taken orally for a month. | Diabetes mellitus, Anthelminthic, obesity, fatty liver. | Least Concern | June-Sept |
| *Atropa acuminata* Royle ex Lindl. | Solanaceae | Brand | Roots Stem Leaves | The root, stem and leaves are dried, powdered and mixed with ghee/butter, forming the paste, which is applied on affected areas. | Type 1 hypersensitivity, cough, rheumatic pain | Endangered | May-Sept |
| *Berberis aristata* DC. | Berberidaceae | Dandleder | Bark of roots | The bark of the root is dried and crushed to make powder; the powder is taken orally with warm water. | Spinal pain, weakness, jaundice | Least Concern | July-Sept |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Berberis lyceum* Royle | Berberidaceae | Kawdach | Root<br>Fruit | ®Roots are boiled in water and the same water is used for washing affected area.<br>*Berries are taken as raw. | ®Bone fracture,<br>*Stomach-ache | Least Concern | July-Sept |
| *Bergenia ciliata* (Haw.) Sternb. | Saxifragaceae | Pulfort | Roots | The root is dried & crushed to make powder. The powder is mixed with traditional dish (Nishasta) and is eaten daily for 2 weeks. | Wounds,<br>acidity, cough, fever, chest infection | Vulnerable | June-Sept |
| *Betula utilis* D. Don | Betulaceae | Burza | Bark | Raw bark is used. | Leprosy | Endangered | June-Aug |
| *Chenopodium album* L. | Amaranthaceae | Buthwa | Whole plant | *Raw shoots and ®roots are used. | *Constipation<br>*Piles<br>®Jaundice,<br>®Urinary problems. | Least Concern | June-Oct |
| *Codonopsis rotundifolia* Benth. | Campanulaceae | Tunda-jaide | Whole plant | Extract of herb is used for the treatment of pulmonary infections. | Pulmonary infection | Least Concern | Jun-Sept |
| *Datura stramonium* L. | Solanaceae | Datur<br>Datura | Seeds | *Seeds are burned to produce smoke which is given to affected teeth.<br>®Seeds are powdered and mixed with egg Albumin/mustard oil to form a paste which is used on affected area. | *Toothache,<br>®Rheumatism. | Least Concern | June-Sept |
| *Dioscorea deltoidea* Wall. ex Griseb | Discoreaceae | Kraeth | Leaves | Decoction is made from the leaves, taken orally for three days. | Urinary tract infections | Critically Endangered | May-Aug |
| *Equisetum arvense* L. | Equisetaceae | Gandumgud | Whole plant | Whole plant is dried powdered and taken with water, meanwhile powder is used as such for tooth decay. | Stomach pain, GERD, | Least Concern | - |
| *Foeniculum vulgare* Mill. | Apiaceae | Badiyan Saunf | Seeds | Seeds are dried powdered and mixed with warm water and taken orally for 10-20 days.1 spoon of dry seeds are chewed directly after meals. | Acidity, bloating irritable bowel syndrome, blood purifier | Least Concern | May-Sept |
| *Fritillaria roylei* Hook. | Liliaceae | Sheethkar | Roots | The roots are crushed and mixed with warm water and taken orally. | Abdominal pain<br>Stomach-ache | Critically Endangered | June-Sept |
| *Gentiana kurroo* Royle | Gentianaceae | Nilkanth | Rhizome | The rhizome is crushed, mixed with water and taken orally. | Kidney and urinary tract infection. | Critically Endangered | June-Sept |
| *Geranium wallichianum* D. Don. | Geraniaceae | Rathenjoth | Roots | Tea is obtained from the roots. | Hepatitis, premature delivery, toothache | Least Concern | June-Oct |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Iris hookeriana* Foster | Iridaceae | Mazermund | Root stock | The roots are dried, crushed to make powder, the powder is mixed with ghee/butter to make paste which is taken orally. | Swelling in throat, expectorant | Least Concern | May-Sept |
| *Malva sylvestris* L. | Malvaceae | Gurisochal | Whole plant | The root is made into powder and taken orally with water. | Diarrhea, Dysentery | Least Concern | May-Sept |
| *Mentha longifolia* L. | Lamiaceae | Jangle pudina | Flowers Leaves | A decoction is made from the flower and leaves, two spoons of powder are mixed with a glass of water or curd and is taken orally. | Stomach-ache | Least Concern | May-July |
| *Nymphaea mexicana* Zucc. | Nymphaeaceae | Bum posh | Flowers Rhizome | *Rhizome is dried powder, mixed with oil to form a paste.<br>®Flowers are made into decoction which is taken orally for 3 days. | *Hair loss<br>*Boils,<br>®Fever | Least Concern | June-Aug |
| *Origanum vulgare* L. | Lamiaceae | Baber | Seeds | Seeds are mixed with water and is taken empty stomach early morning. | Stomach acidity, Urinary tract infection, Menstruation issues. | Least Concern | June-Sept |
| *Rheum webbianum* Royle | Polygonaceae | Pamb-chalan | Roots Leaves | *Warm poultice prepared from the roots and applied externally.<br>®Leaves are boiled in water and applied externally. | *Hair loss<br>®Boils | Vulnerable | June-Aug |
| *Saussurea costus* Falc. | Asteraceae | Kuth | Roots | *Roots are dried and powdered and taken orally with warm water or cooked vegetables & with ghee.<br>®Juice is obtained from the fresh roots which are taken orally. | *Cough,<br>*Toothache,<br>®Joint swelling | Critically Endangered | July-Sept |
| *Sinopodophyllum hexandrum* (Royle) T.S. Ying | Berberidaceae | Wanwagun Kakri | Rhizome Fruit | Ripened fruit is consumed. | Tumor | Critically Endangered | April-June |
| *Taraxacum officinale* Weber ex Wiggers | Asteraceae | Madan hand | Whole plant | Decoction is made from the whole plant which is taken orally for a month. | Blood purifier, Jaundice | Least Concern | April-July |
| *Valeriana jatamansi* Jones | Valerianaceae | Budjeeth | Roots | Roots are dried powdered, mixed with cooked pulses or warm water and taken orally. | Abdominal pain, Stomach-ache, Heart diseases | Endangered | June-Sept |
| *Viola odorata* L. | Violaceae | Nun posh | Flowers | Flowers are made into decoction which is taken orally for a week. | Lung infection | Least Concern | May-Aug |

Our results are similar to the ethnobotanical surveys completed in diverse regions of the Himalaya (Singh *et al.* 2009). This fact was supported PCA analyses which showed three distinct groups based on the variations in the preference levels of plant part usage (Fig. 4). Roots, whole plant, rhizomes, and leaves were distinctly separated from each other, while other parts formed separate groups (Fig. 5). Similar classifications were found in previous studies. For example, Asif *et al.* (2021) reported five groups of wild plants from tribal communities in tehsil "Karnah" (Jammu and Kashmir) India. Haq & Singh (2020) classified the wild plants of district Reasi into four plant usage groups. Similarly, multivariate analysis was used by Haq *et al.* (2020a, b), for quantitative ethnobiological approaches in their studies.

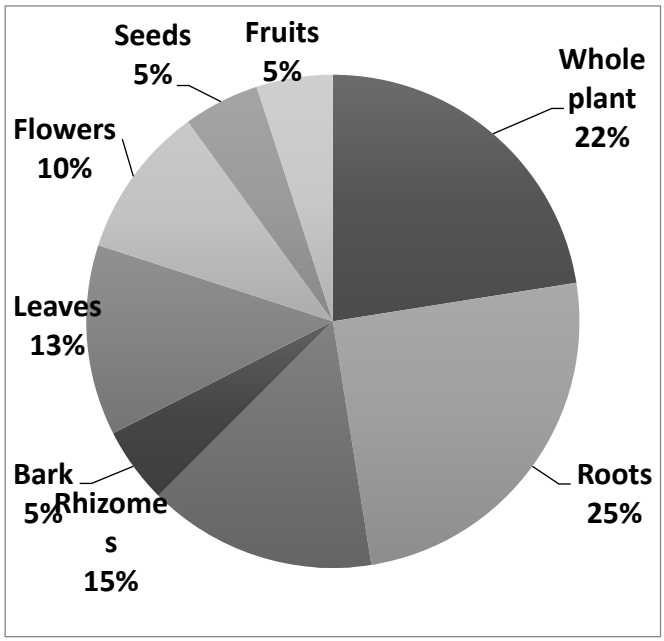


Figure 3. Percentage of different plant parts used in the study area.

**Disease cured**

Plants are a potent and rich source of different phytochemicals (Avato & Argentieri 2015). Gastro-intestinal disorders were treated with most species (18%), followed by pulmonary infections (13%), dermatological problems (11%), hepatic problems (9%), arthritis (9%) and urological problems (7%) (Fig. 5). 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.

In the present study, decoction (25%) was the most common form of remedy preparation followed by powder (18%), paste (17%), raw (8%), and juice (7%) (Fig. 6). Decoctions are commonly prepared as the local population believes that they have higher efficacy than any other form, and at the same time it is believed that the water from the mountains used for the decoction does also have healing potential, leading to a synergetic effect. Other researchers also reported the maximum usage of decoctions (Naveed *et al.* 2013; Okoli *et al.* 2007).

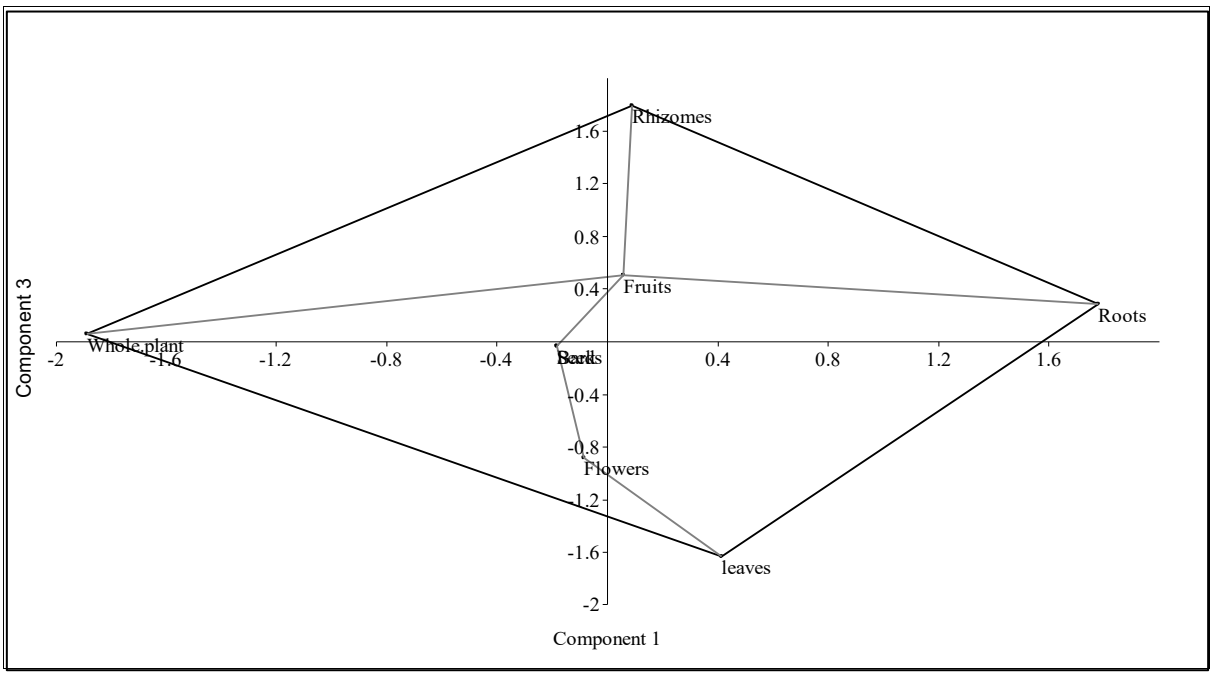


Figure 4. Principal Component Analyses (PCA) biplot of different part(s) usage in the study area.

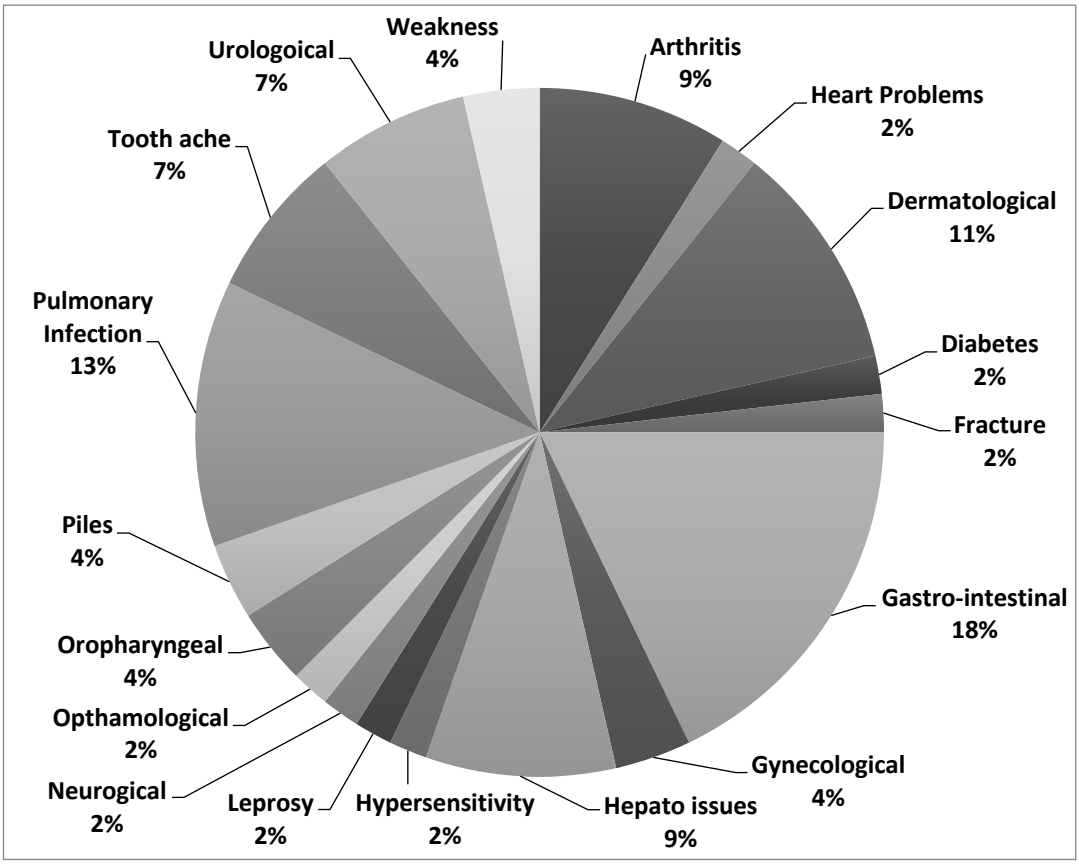


Figure 5. Percentage of plants used to treatment of various disorders in the study area.

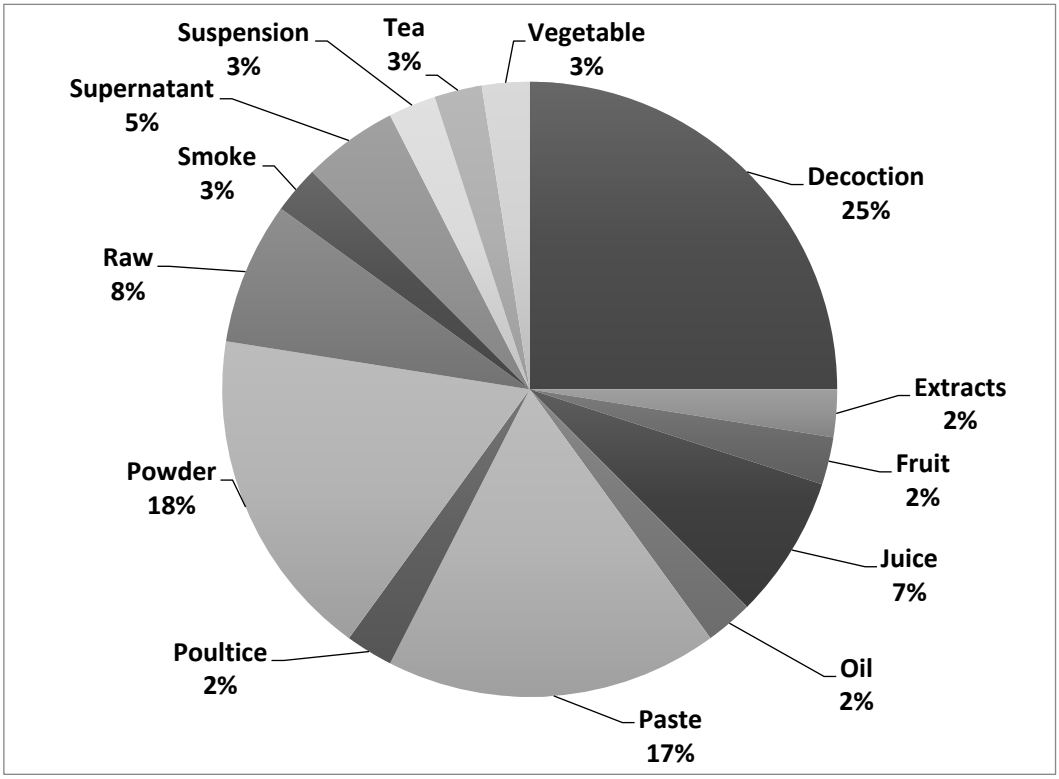


Figure 6. Percentage of plants used to treatment of various forms in the study area.

***Phenological spectrum***

The phenological spectrum of a flora depicts the flowering period of each species. In the present study, the flora showed two major flowering periods from July to September in which about 62% of plant species (e.g., *Anemone obtusiloba, Arnebia benthamii, Aconitum heterophyllum, Dioscorea deltoidea, Foeniculum vulgare, Saussurea lappa,* and *Gentiana kurroo*) were observed in flowering stage, while a second flowering period occured in which 38% plant species (e.g., *Arisaema jacquemontii, Atropa acuminata, Ajuga bracteosa, Berberis lyceum, Mentha longifolia, Datura stramonium, Malva sylvestris*, *Viola odorata,* and *Taraxacum officinale*) were observed in full bloom (Table 2). These findings are in line with those of Malik & Malik, (2014) and 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 (Fig. 7). The dendrogram showed two distinctly separated clusters based on the degree of intensity of flowering of the vascular flora, in which May and June formed one cluster and rest of months formed second cluster.

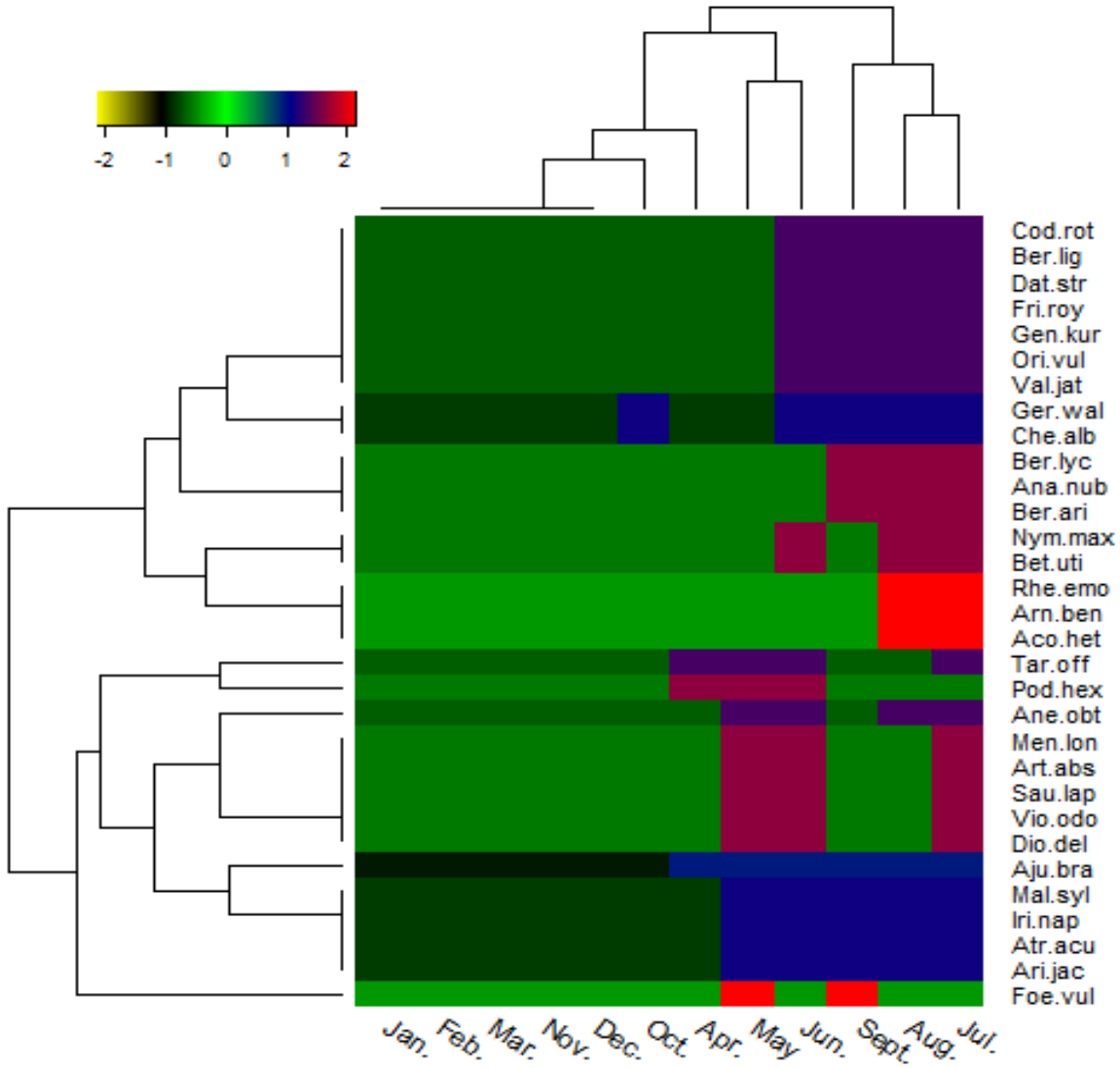


Fig. 7. Heat map showing clustering dendrogram based on phenological response in different months.

**Conservation Status**

Based on the conservation assessment, out of 32 species observed, six (18%) fell in the Critically Endangered category of IUCN, four (12%) were Endangered, two (6%) were Vulnerable, and 20 (62%) fell in the Least Concern category (Fig. 8; Table 2). Many important medicinal plants such as *Aconitum heterophyllum*, *Bergenia ciliata, Trillium govanianum, Rheum webbianum,* and *Arnebia benthami* are facing threats because of exhaustive utilization of their underground parts on a large scale. It was found during our study that medicinal plant species

were under enormous harvesting pressure and needed immediate conservation (Mushtaq *et al.* 2016; Haq *et al.* 2020c). Previously local people used these plants mostly for their consumption, but now there is large-scale exploitation carried out by pharmaceutical companies (Gerlitz *et al.* 2014).

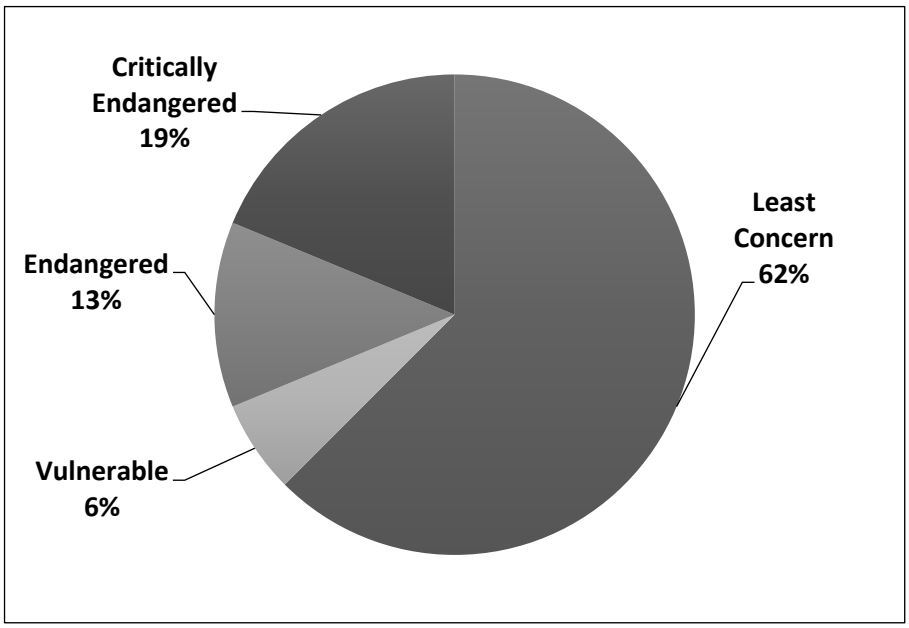


Fig. 8. Percentage of plant in different IUCN conservation status.

## Conclusion

The present study is the first one of its kind for the documentation of the ethnopharmacological and ecological aspect of high-altitude medicinal plants in Kashmir Himalaya. The local communities have developed several strategies to establish a traditional health-care system. In the present study a total of 32 plant species belonging to 23 families were documented for their medicinal uses. The result showed that roots (25%) were the most frequently used part. The first major flowering period in which about 62% of plant species were observed in flowering stage lasted from July to September. In the rest of the year a total of 38% plant species were observed in full bloom. The current research will aid in a better understanding of traditional medicines, their relationship to the region's ecological and socioeconomic values, biodiversity protection, and plant resource management techniques for long-term use.

## Declarations

**Ethics approval and consent to participate:** All the participants provided prior informed consent before the interviews.

**Availability of data and materials:** Data is available from the first author.

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

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**Author contributions**: SMH conceived the research idea. AYM collected data. SMH analyzed and interpreted the data and results. SMH, UY, MUH, FB, SBZ and RBU wrote and revised the manuscript. All authors read and approved the final manuscript.

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## Literature cited

Altaf A, Haq SM, Shabnum N, Jan, HA. 2021. Comparative assessment of Phyto diversity in Tangmarg Forest division in Kashmir Himalaya, India. Acta Ecologica Sinica. doi: 10.1016/j.chnaes.2021.04.009

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.

Bhatia H, Sharma YP, Manhas RK, Kumar K. 2014. Ethnomedicinal plants used by the villagers of district Udhampur, J&K, India. Journal of Ethnopharmacology 151(2):1005-1018.

Chen SL, Yu H, Luo HM, Wu Q, Li CF, Steinmetz A. 2016. Conservation and sustainable use of medicinal plants: problems, progress, and prospects. Chinese medicine 11(1):1-10.

de Rochebrune AT. 1879. Recherchesd'ethnographiebotanique sur la flore des sépulturespéruviennesd'Ancon. Actes de la Société linnéenne de Bordeaux 3:343-358.

dan Prospek M, dar G, khuroo A. 2013. Floristic diversity in the Kashmir Himalaya: progress, problems and prospects. Sains Malaysiana 42(10):1377-1386.

Ghimire SK, Gimenez O, Pradel R, McKey D, Aumeeruddy-Thomas Y. 2008. Demographic variation and population viability in a threatened Himalayan medicinal and aromatic herb Nardostachys grandiflora: matrix modelling of harvesting effects in two contrasting habitats. Journal of applied Ecology 45(1):41-51. doi: 10.1111/j.1365-2664.2007.01375.x

Gras A, Garnatje T, Bonet M, Carrió E, Mayans M, Parada M, Rigat M, Vallès J. 2016. Beyond food and medicine, but necessary for life, too. Other folk plant uses in several territories of Catalonia and the Balearic Islands. Journal of Ethnobiology and Ethnomedicine 12(1):1-53.

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. doi: 10.3390/plants10010163

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.

Haq SM, Calixto ES, Singh B. 2020. Investigation of the traditional knowledge of economically important plants in proper Neelum Valley, District Bandipora, Jammu & Kashmir, North-Western Himalaya, India. -In Singh B and Sharma YP (eds), Plants of Novel drug molecules Ethnobotany to ethnopharmacology. New India Publishing Agency. 287-302.

Haq SM, Calixto ES, Yaqoob U, Ahmed R, Mahmoud AH, Bussmann RW, Mohammed OB, Ahmad K, Abbasi AM. 2020a. Traditional Usage of Wild Fauna among the Local Inhabitants of Ladakh, Trans-Himalayan Region. Animals 10(12):2317.

Haq SM, Hamid M, Lone FA, Singh B. 2021. Himalayan Hotspot with Alien Weeds: A Case Study of Biological Spectrum, Phenology, and Diversity of Weedy Plants of High-Altitude Mountains in District Kupwara of J&K Himalaya, India. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 91(1):139-152.

Haq SM, Khuroo AA, Malik AH, Rashid I, Ahmad R, Hamid M, Dar GH. 2020. Forest ecosystems of Jammu and Kashmir State. In Biodiversity of the Himalaya: Jammu and Kashmir State Springer, Singapore. pp. 191-208.

Haq SM, Malik AH, Khuroo AA, Rashid I. 2020c. 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, Malik ZA, Rahman IU. 2019. Quantification and characterization of vegetation and functional trait diversity of the riparian zones in protected forest of Kashmir Himalaya, India. Nordic Journal of Botany 37(11).

Haq SM, Shah AA, Yaqoob U, Hassan M. 2021a. Floristic Quality Assessment Index of the Dagwan Stream in Dachigam National Park of Kashmir Himalaya. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 1-8.

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.

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

Hassan M, Haq SM, Rasool A, Fatima S, Ashraf A, Zulfajri M, Hanafiah MM. 2021. Ethnobotanical Properties and Traditional Uses of Medicinal Plant *Abutilon theophrasti* Medik. Medicinal and Aromatic Plants: Healthcare and Industrial Applications.271.

Hassan M, Haq SM, Yaqoob U, Qazi HA. 2021. *Abutilon theophrasti* from Kashmiri Himalayas: A Life Savior for Livestock. International Research Journal of Plant Science 12(3):1-9.

Jabeen N, Ajaib M, Siddiqui MF, Ulfat M, Khan B. 2015. A Survey of ethnobotanically important plants of District Ghizer, Gilgit- Baltistan. FUUAST Journal of Biology 5(1):153-160

Jan HA, Wali S, Ahmad L, Jan S, Ahmad N, Ullah N. 2017. Ethnomedicinal survey of medicinal plants of Chinglai valley, Buner district, Pakistan. European Journal of Integrated Medicine 13:64-74. doi:10.1016/j.eujim.2017.06.0 07.

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

Lamsal P, Kumar L, Atreya K, Pant KP. 2017. Vulnerability and impacts of climate change on forest and freshwater wetland ecosystems in Nepal: A review. Ambio 46(8):915-930.

Liu F, Gao C, Chen M, Tang G, Sun Y, Li K. 2021. The impacts of flowering phenology on the reproductive success of the narrow endemic *Nouelia insignis* Franch. (Asteraceae). Ecology and Evolution. doi: 10.1002/ece3.7747

Mahmood A, Mahmood A, Shaheen H, Qureshi RA, Sangi Y, Gilani SA. 2011. Ethno medicinal survey of plants from district Bhimber Azad Jammu and Kashmir, Pakistan. Journal of Medicinal Plants Research 5(11):2348-2360.

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.

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.

Nafeesa Z, Haq SM, Bashir F, Gaus G, Mazher M, Anjum M, Rasool A, Rashid N. 2021. Observations on the floristic, life-form, leaf-size spectra and habitat diversity of vegetation in the Bhimber hills of Kashmir Himalayas. Acta Ecologica Sinica 41(3):228-234.

Naveed A, Abdur R, Waheed M, Bergmeier E. 2013. Diversity and use of ethno-medicinal plants in the region of Swat, North Pakistan. Journal of Ethnobiology and Ethnomedicine 9(25).

Okoli RI, Aigbe O, Ohaju-Obodo JO, Mensah JK. 2007. Medicinal herbs used for managing some common ailments among Esan people of Edo State, Nigeria. Pakistan Journal of Nutrition 6(5):490-496.

Pala NA, Sarkar BC, Shukla G, Chettri N, Deb S, Bhat JA, Chakravarty S. 2019. Floristic composition and utilization of ethnomedicinal plant species in home gardens of the Eastern Himalaya. Journal of Ethnobiology and Ethnomedicine 15:14.

Pardo-de-Santayana M, Macía MJ. 2015. The benefits of traditional knowledge. Nature 518(7540):487-488.

Pardo-de-Santayana M, Pieroni A, Puri RK. 2013. Ethnobotany in the New Europe: People, Health and Wild Plant Resources. Environmental Anthropology and Ethnobiology; Berghahn Books: New York, NY, USA; Oxford, UK, Volume 14.

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.

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.

Shaheen H, Islam M, Ullah Z. 2014. Indigenous ethnobotanical remedies practiced to cure feminine diseases in tribal communities of Kashmir Himalayas. International Journal of Phytomedicine 6(1):103.

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. doi: 10.1080/17451590903230249.

Singh A, Nautiyal MC, Kunwar RM, Bussmann RW. 2017. Ethnomedicinal plants used by local inhabitants of Jakholi block, Rudraprayag district, western Himalaya, India. Journal of Ethnobioloy and Ethnobiomedicine 13(1):1-29.

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 Videnskabernesselskabsskrifter 5:1-34.

Tandon R, Koul M, Shivanna KR. 2020. Reproductive Ecology of Flowering Plants: An Introduction. In Reproductive Ecology of Flowering Plants: Patterns and Processes Springer, Singapore. 1-24.

Tringali C. 2012. Bioactive Compounds from Natural Sources: Natural Products as Lead Compounds in Drug Discovery, 2nd ed.; CRC Press: Boca Raton, FL, USA.

Tu Y. 2016. Artemisinin—A gift from traditional Chinese medicine to the World (Nobel lecture). Angewandte Chemie International Edition 55:10210-10226.

Umair M, Altaf M, Bussmann RW, Abbasi AM. 2019. Ethnomedicinal uses of the local flora in Chenab riverine area, Punjab province Pakistan. Journal of Ethnobiology and Ethnomedicine 15(1):1-31. doi:10.1186/s13002-019-0285-4.

Uprety Y, Asselin H, Boon EK, Yadav S, Shrestha KK. 2010. Indigenous use and bio-efficacy of medicinal plants in the Rasuwa District, Central Nepal. Journal of Ethnobiology and. Ethnomedicine 6(1):1-10. doi: 10.1186/1746-4269-6-3.

Yousuf S, Haq SM, Rasool A, Zulfajri M, Hanafiah MM, Nafees H, Tasneem S, MahboobM. 2020. Evaluation of antidepressant activity of methanolic and hydroalcoholic extracts of Acorus calamus L. rhizome through tail suspension test and forced swimming test of mice. Journal of Traditional Chinese Medical Sciences 7(3):301-307.

Zhang X, Tarpley D, Sullivan JT. 2007. Diverse responses of vegetation phenology to a warming climate. Geophysical Research Letters 34(19).