Ethnobotanical assessment of medicinal plants used in alpine regions of Uttarakhand, west Himalaya

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Research

Abstract

Background: Himalaya, the youngest mountain biodiversity hotspot, embraces a variety of high-value medicinal flora used by the indigenous population to treat various health related ailments. However, this indigenous knowledge is gradually being lost owing to generation gaps and dependency on modern medicine. Thus, documentation of indigenous knowledge and evaluation of the use of plants assume greater significance to preserve the socio-economic and cultural heritage of mountain communities.

Methods: The study was conducted during the months of July-October in 2019-2022 in different alpine regions of Uttarakhand and ethnopharmacological data was collected through questionnaire-based interviews and discussions with local people. The Use Value (UV) and Fidelity Level (FL) for each documented species was calculated along with informant consensus factor (ICF) to estimate the relative importance of species. Rapid Threat Assessment (RTA) was conducted using 10 criteria to identify the priority medicinal plants.

Results: A total of 77 plant species in 69 genera and 30 families were documented to have variety of roles in treating 44 different kinds of ailments by the locals. The highest species were used for dermatological (cuts and wounds, boils, blisters) and gastrointestinal (stomachache, indigestion, dysentery, diarrhea) problems. Roots/rhizomes and leaves were most utilized in making herbal formulations, and method of administration of 37 species was oral, 29 species was topical and 11 species were taken both orally and topically. *Aconitum heterophyllum, Nardostachys jatamansi* and *Picrorhiza kurroa* and were the most valuable species in terms of use value (>0.90) and frequency of citation (>0.50). The ICF values for all ailment categories ranged from 0.73 to 0.94, indicating a high level of informant agreement, with highest for urogenital and gastrointestinal disorders. RTA scores for *N. jatamansi* (31) and *P. kurroa* (32) identified them to be highly threatened medicinal plants in the region. Some other vulnerable medicinal plants include *A. heterophyllum*, *Angelica glauca*, *Malaxis muscifera*, *Podophyllum hexandrum* and *Rheum australe*.

Conclusions: The study provides comprehensive information about the traditional knowledge of herbal medicine as well as identified priority species at high-risk of extinction, which will pave way towards initiating conservation, sustainable harvesting and enhancing cultivation practices of medicinal plants in Himalaya.

Keywords: Ethnomedicine, medicinal plants, alpine regions, traditional knowledge, threat assessment, Himalaya

Background

Humans have long relied on nature for their basic needs like sustenance, shelter, clothing, transportation, fertilizers, flavors, aromas and medications (Cragg & Newman 2005). Among the various components of nature, plants have established the foundation of traditional medicinal systems that have provided humanity with cures against multifarious ailments since antiquity (as depicted in Egyptian papyrus, Unani manuscripts, Chinese writings, etc.), and still continue to do so. Over 60% of world's populace, 80% in developing countries, depend on plants directly or indirectly for medicinal & therapeutic purposes (Shrestha & Dhillion 2003). In many rural and high-altitude mountain ecosystems traditional medicine is still recognized as the primary healthcare system because of its affordability, effectiveness, minimal side effects and cultural preferences (Krishnaiah *et al.* 2011). Many rural populations have an abundance of traditional knowledge on the therapeutic properties of plants that has been passed down from generation to generation, ensuring its survival. These indigenous communities have acquired this diverse knowledge by trial and error, thus contributing to the evolution of traditional herbal therapies (Negi 2010). The Indian Himalayan Region (IHR) boasts rich biodiversity, including a plethora of medicinal flora deeply intertwined with traditional healing practices. A total of 1748 plant taxa from the region have been documented to have various medicinal properties used for treating multifarious health problems. However, due to the rapid exposure to urbanization and access to modern conveniences in the recent decades there has been a gradual loss in the extent and distribution of ethnomedicinal knowledge in many local communities (Kala *et al.* 2004, Maikhuri *et al.* 1998). This has led to discussions among ethnobotanists, conservationists and scientists for detailed documentation of the traditional practices involving medicinal plants to keep it alive and make it available for future. Additionally, as the trade of medicinal plants is one of the vital sources of livelihoods of the communities their improper/illegal collection and bulk extraction (Ali *et al.* 2021, Khan *et al.* 2013) have become major threat to their populations. Several medicinal plants have been listed in the various threat categories by IUCN with their population status decreasing continuously at local as well as global level. Thus, making medicinal flora as well as traditional knowledge further vulnerable to a great transition and giving urgency to document and conserve the traditional knowledge of phytotherapies practiced by local people. Conservation efforts, coupled with scientific research, are essential to safeguarding these plants and ethnomedicinal wisdom.

This present study is an attempt to document indigenous knowledge of local medicinal practitioners and other erudite people and develop sound strategies for medicinal plant cultivation to sustain the traditional healthcare system. We hypothesized that the inhabitants of the study area retain considerable indigenous knowledge of medicinal plants, and used three research questions: 1) how many alpine plant species are used for treating various health ailments by the local communities residing in study areas? 2) what is the present status of traditional ethnomedicinal practices among local population and which plants are regarded as highly valued medicinally? 3) how did the medicinal plant knowledge differ from existing regional ethnomedicinal studies? 4) identify threatened and high-value medicinal plants in the region (THMPs) based on their local traditional use, demand, etc. through standard rapid-threat assessment.

Materials and Methods

Study area

The study was conducted in high-altitude (>3000 m) alpine regions of Uttarakhand (28°43' N 31°27' N and 77°34' to 81°02' E), west Himalaya. The changing topography, micro and macro-climatic conditions in the region lead to wide range of geological formations and climate regimes (Sekar *et al.* 2023). The Great Himalayan belt characterized by rugged topography, optimum rainfall and glacial features like lateral and medial moraines (Murti 2001, Negi 2002) represents the monsoonal regime, while arid mountainous tract positioned in the rain shadow region of great Himalayan belt represents the non-monsoonal regime exhibiting scanty and erratic rainfall. As a result of these broad geo-morphological formations and climate regimes the region consists of unique combinations of mountain ecosystems inhabiting representative floral and faunal diversity. For the documentation of medicinal plants four valleys were selected, which represented (Figure 1). Two of the selected valleys, *i.e.*, Lata (Chamoli district) and Pindari (Bageshwar district), are situated in the alpine buffer zone of Nanda Devi Biosphere Reserve (NDBR), a World Heritage Site in Uttarakhand. Also, Chaudans and Byans valleys situated in Pithoragarh district are a part of the Kailash Sacred Landscape Conservation and Development Initiative (KSLCD), ICIMOD. The region experiences mean temperatures ranging from 1.30 to 6.37°C and precipitation ranging from 84.2 mm to 160.3 mm and remain completely snowbound for around six months. These valleys are inhabited by '*Bhotiyas*', an ethnic community of Indo-Mongoloid origin (Maikhuri *et al.* 2017, Nautiyal *et al.* 2001). Food crops, medicinal plant products, livestock and trading are some major sources of income of the community. The community has a wealth of ethnobotanical knowledge on the use and protection of natural resources.

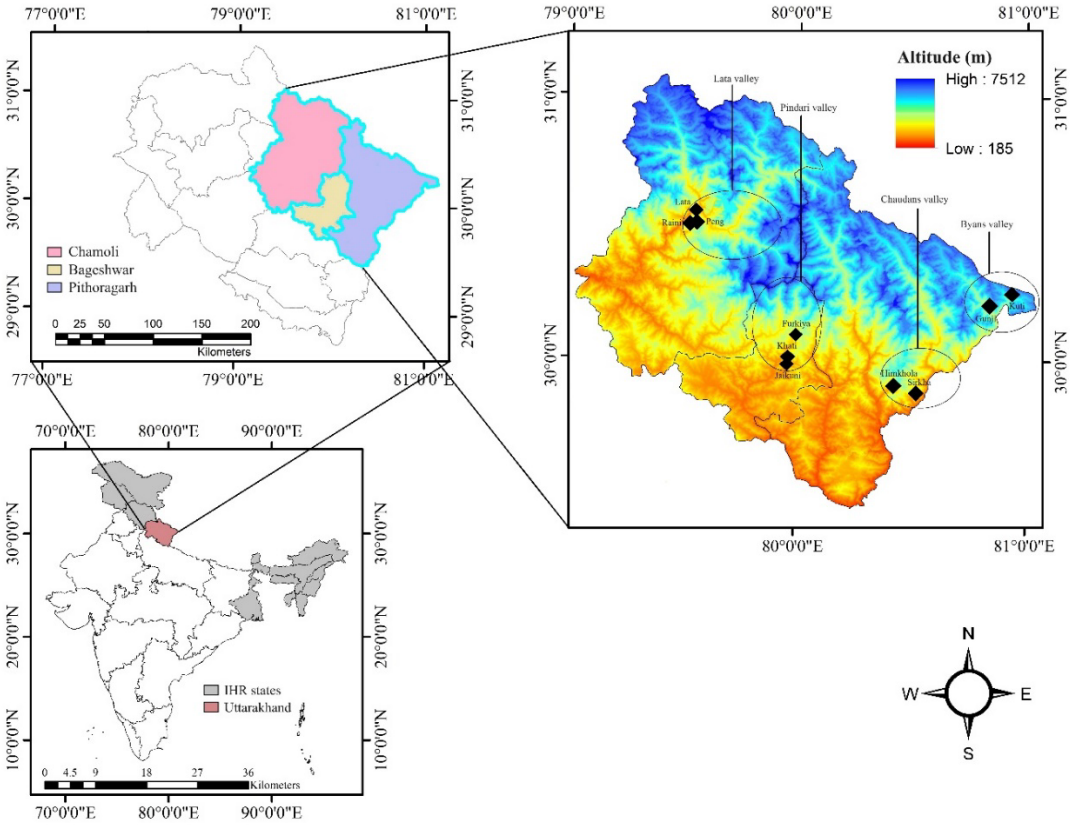

Figure 1. Study area map showing selected valleys in Uttarakhand, west Himalaya.

Methods

Intensive survey trips were conducted from May to October 2019 to 2022 covering an altitude range from 3200m to 4500m in the representative valleys. During the survey trips, the plant specimens were collected using random sampling (Jain & Rao 1977). The collected specimens were housed in the herbarium of G.B. Pant National Institute of Himalayan Environment, Kosi- Katarmal, Almora (Acronym: GBP). The collected specimens were identified by using local and regional floras as well as relevant literature (Deva & Naithani 1986, Gaur 1999, Naithani 1984, Osmaston 1927, Pusalkar & Singh 2012, Srivastava & Shukla 2015) and earlier herbarium records (i.e. Botanical Survey of India, Dehradun; Forest Research Institute, Dehradun, etc.). For nomenclature, the online source of Plants of the World Online (powo.science.kew.org, Royal Botanic Gardens Kew, 2023) based on Angiosperm Phylogeny Group classification, APG IV (Chase *et al.* 2016). Along with this, the local name of the taxa used by local communities in Uttarakhand is also provided after the scientific name of the taxa.

Ethnomedicinal data was collected through Participatory Rural Appraisal (PRA), a method which is based on the voluntary participation of local rural community in data collected through interviews and meetings (Chambers 1994). In this study, the indigenous people (mainly guides, shepherds, porters, *vaidyas*) of the villages located in the valleys were interviewed regarding the various uses of collected plant specimen. In addition, before the interview's, verbal prior informed consent was obtained from all respondents. A total of 80 (50 men and 30 women) participants were interviewed by using a semi-structured (Martin 2004) and an open-ended questionnaire for gathering information regarding the usage of plants. Further, the informants and *Vaidyas* (Medicine practitioners) were also accompanied in the field for correct identification of plants, apart from house-hold interviews. The information further crossed with elderly people/*Vaidyas* repeatedly to confirm the utilization patterns. For surveys and data collection, the adult age ranges (≥25 years old) of both genders were considered (Table S1). The present study considered consent from at least three informants regarding the medicinal uses of plants and consent from less than three informants were omitted. Originally, we showed them fresh specimens and detailed photographs that were collected/captured for further species taxonomy authentication.

Quantitative analysis

The data collected through interviews was analyzed using two quantitative indices as below: 1) Use value (*UV*): A quantitative measure for the relative importance of species for indigenous medicinal use by local communities was obtained by calculating the use-value (Phillips *et al.* 1994), using formula: $UV = \Sigma U/n$, where *U* is the number of use reports cited by each informant for a given species and *n* refers to the total number of informants. Use values are high when there are many use-reports for a plant, implying that the plant is important, and approach zero (0) when there are few reports related to its use. 2) Informant Consensus Factor (*ICF*): This parameter test homogeneity of knowledge about the medicinal plants, it has been calculated in accordance (Heinrich *et al.* 1998). Based on the information gathered through interviews, little modifications have been made in the categories of ailments. *ICF* = n_{ur} - n_t/n_{ur-1}, where n_{ur} is number of use reports, n_t is number of taxa used. Low *ICF* values (near 0), indicates that plants are chosen randomly or there is no exchange of information about their use among informants, and approach one (1) when there is a well-defined selection criterion in the community and/or information is exchanged between informants (Bhatia *et al.* 2014, 2018). 3) Fidelity Level (FL): This index is used to calculate the percentage of informants claiming the use of a particular species to treat the same illness/disease: $\mathrm{FL}\ (\%) = \frac{\mathrm{Ip}}{\mathrm{Iu}} \times 100$, where Ip is a number of informants used to indicate the species for the same illness/disease, Iu refers to a total number of informants claiming the same plant for other medicinal uses (Friedman *et al.* 1986). Percentage similarity of medicinal usage of study species over previous studies was calculated using the *Jaccard similarity coefficient* (González-Tejero et al., 2008).

$$\mathrm{JI}|\mathrm{A}, \mathrm{B}| = \frac{|\mathrm{A} \cap \mathrm{B}|}{|\mathrm{A} \cup \mathrm{B}|}$$

where A and Y denote two sets of variables, ∩ denote intersection, ∪ denotes union and | denotes cardinality.

Rapid Threat Assessment

For threat assessment of the documented plant species utilised by the local communities in the study area, the rapid vulnerability assessment method (Cunningham 1997) was adapted, with modifications as per our field conditions and available datasets. The method has also been employed successfully in Nepal Himalaya (Shrestha & Shrestha 2012) and in Indian Himalaya (Kumar *et al.* 2021, Mehta *et al.* 2020, Pandey *et al.* 2019). Here, we used a total of ten threat criteria to assess each species (*i.e.*, habitat, use value, number of use reports, plant parts used, extraction trend, threat status, etc.) as given in Table S2, and each criterion was assigned scores in increasing order of threat level. Criteria 1 (species habitat) was evaluated using visual observations made during the field study as well as relevant literature, and four categories were scored. Habitats such as rocky and gravel slopes are extremely fragile; species in these habitats are considered vulnerable to even minor human disturbance, and hence scored 4 (high threat). Grassland, meadow, and pastureland species, on the other hand, were deemed the least vulnerable (1) due to their extensive ecological range. For criteria 2 (life forms), long-lived perennials were considered the most vulnerable because the environmental conditions of the alpine region do not support such life forms, as proper fructification/seed-set takes a long time, so even minor destruction in their habitat can affect the density and diversity of these species. Annuals were thought to be less vulnerable because to their short life cycle, high population density, and relative adaptability. Based on the information collected from local inhabitants, the criteria 3 to 7 were assessed. Species among which whole plant or root stock is utilised for medicinal purposes were considered more vulnerable as opposed to those in which considered as most vulnerable, while species having leaf as an important part of the preparation of medicine were ranked least vulnerable. Criteria 8 (threat status) and 9 (population trend) was based on IUCN red list of threatened plants, Red Data Books (Nayar & Sastry 1987, 1988, 1990), Conservation Assessment and Management Plan (CAMP), and other available literature. Nativity (criteria 10) of the documented plant species was determined with the help of regional flora (Hooker 1885) and online databases (Plants of World Online, tropicos, e-floras). A complete checklist was created, and the values of each species' linked categories were added together to calculate the final score. Based on the final results, species were classified into four threat categories. Species having scores of ≥30, 23-29, 16-22, and ≤15 were classified as threat categories I, II, III, and IV, respectively (category I being the most threatened and category IV the least).

Results

On the basis of ethnobotanical survey, 77 alpine plants belonging to 69 genera and 30 families were utilised by the local community of the valleys for various medicinal purposes as presented in Table 1, arranged family-wise along with their local/vernacular names. Of the recorded species, herbaceous growth form was dominant with 69 species, while only 8 shrubs were reported having medicinal uses. The most frequently cited family was Asteraceae (12 species), followed by

Polygonaceae (7 species), Ranunculaceae (6 species) and Lamiaceae (5 species), while 13 families were represented by one species each.

Plant parts used, modes of preparations and administration

Different medical/herbal formulations used by the local people involved different plant parts of species such as seed, flower, leaves etc. While for many species multiple parts were used, as per the documentation, overall roots/rhizome were used in maximum herbal preparations (28 species; ~36%), followed by leaves (21 species; ~27 %) and flowers (11 species; ~14%). Moreover, whole plant was used in 14 species (~18%) and only aerial part was used in 10 species (~13%) (Figure 2). In present work, a total of six preparation modes of herbal formulation were reported: paste (31 reports), powder (22 reports), decoction (20 reports), infusion (11 reports), juice (7 reports) and raw (2 reports) (Table 1). The most common formulation ingredient or solvent was water, while milk, salt, honey, oil/ghee were also used. Roots/rhizomes were mostly used in the form of ground powder, while paste formulation was more common in leaves and flowers (Figure 2). The method of administration documented in the study revealed that 37 species (48%) were taken orally, 29 species (38%) were applied externally, while 11 species (14%) were used both internally (orally) as well as externally (Table 1). Majority of the paste formulations were used for external applications, while oral administration was commonly in the form of powder, decoction and infusions (Figure 2).

Disease categories

The documented medicinal plants were used to treat nearly 44 different types of health ailments by the local community such as cuts & wounds (21 spp.), fever (16 spp.), stomach-ache (12 spp.), cough (12 spp.), etc. All the reported ailments were grouped into 12 broad categories (Figure 3) and these categories were evaluated for total number of plant taxa used, number of citations and their informant consensus factor (ICF). In terms of the plant species used, the highest number was observed for dermatological (29 species), followed by gastrointestinal (24 species), respiratory (18 species) and unclassified general

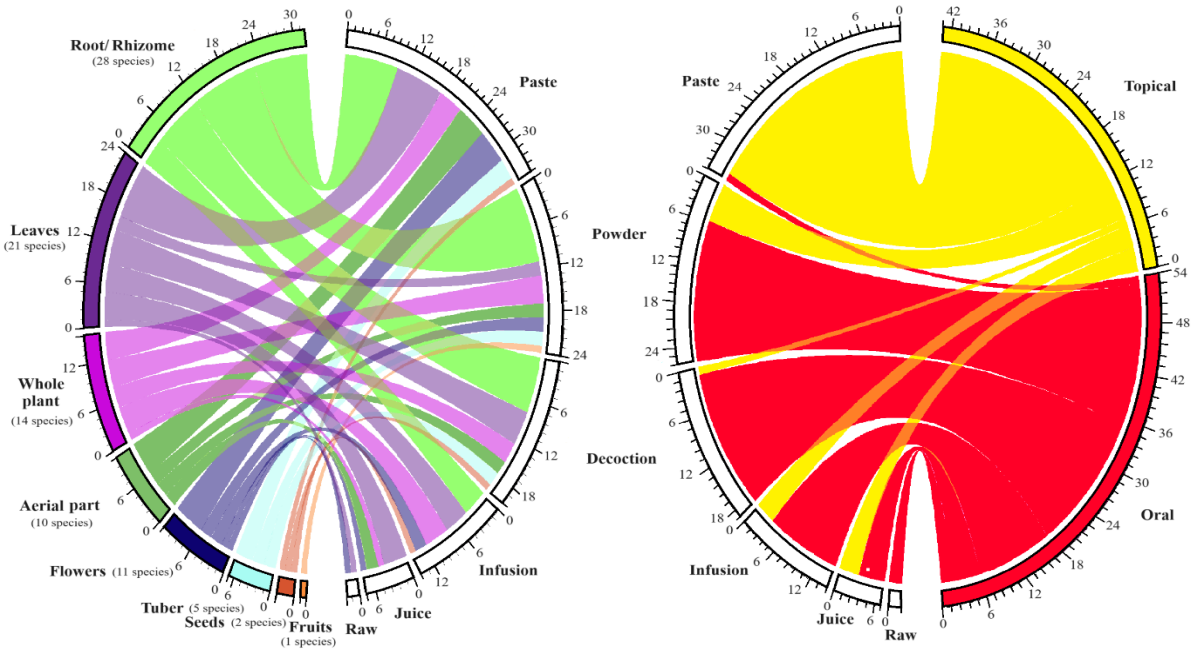

Figure 2. Plant parts used in the treatment of diseases in the study area

ailments (18 species) such as fever, weakness, headache (Figure 3a). The category of dermatological ailments has the highest citations (20.3%), followed by gastrointestinal (19.2%), respiratory diseases (14.7%). General ailments (13.7%). The lowest most conspicuous difference was concerned with neurological (1 species & 1.1% citations), odontal (1 & 0.6%) and ophthalmic (1 & 0.9%) problems. Other noticeable disease categories were skeleton-muscular (10 species & 9.2% citations), hepato-pancreatic (10 & 7.3%), urogenital (7 & 8.4%) and cardiovascular (4 & 2.9%) (Figure 3). The quantitatively analysed consensus of informants on use of medicinal plants for different categories of ailments ranged from 0.73 to 0.94 (Figure 4). The highest ICF value for urogenital and gastrointestinal ailments revealed that informants have the same opinion for their treatment (ICF=0.95), followed by cardiovascular (ICF=0.94). However, informant's opinions vary the most for the treatment of eye problems.

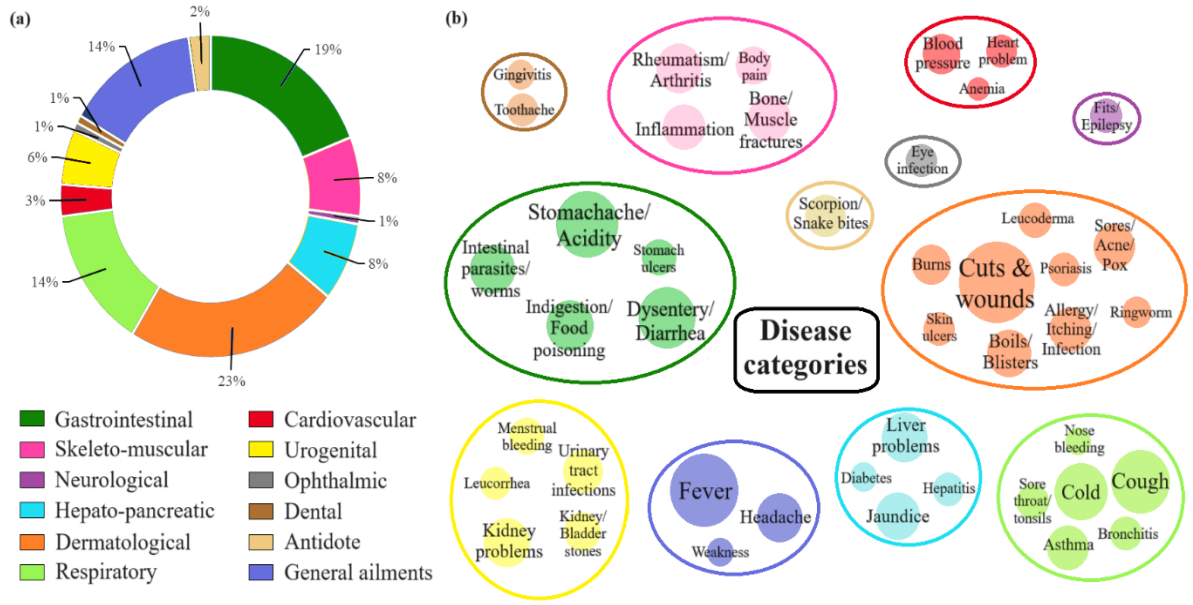

Figure 3. Cluster diagram showing specific uses reported in the present study under the indigenous usage category. Oval width indicates the number of use reports for each ailment, (wide width = more species); each color indicates a different category of indigenous uses.

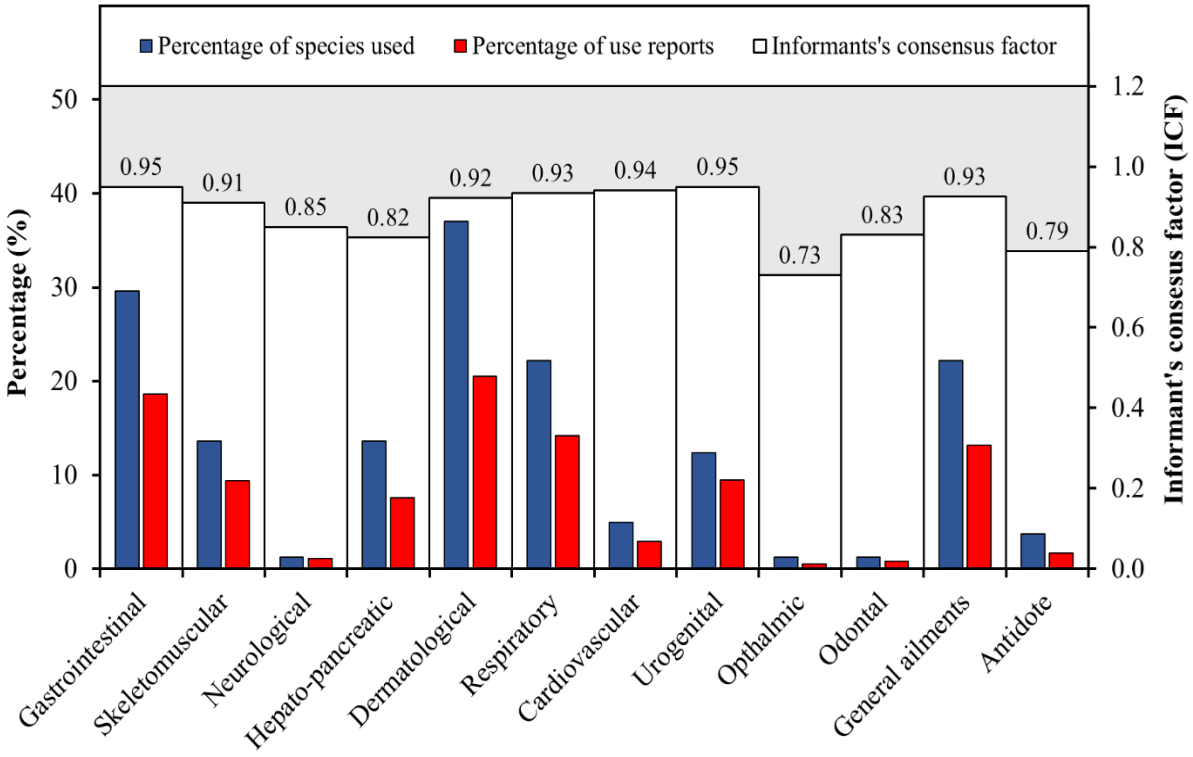

Figure 4. Consensus of agreement on traditional medicinal uses of alpine herbs among informants.

Relative importance of plants

The relative frequency of citation (RFC) was calculated to depict the local eminence of each species with reference to informants who cited these plant species as of medicinal purposes. RFC values, here, ranged from 0.08 to 0.60 (Table 1). Plant species such as *Aconitum heterophyllum* (0.60), *Picrorhiza kurroa* (0.60), and *Podophyllum hexandrum* (0.52), with comparatively higher values of RFC were established as predominantly used and commonly known for their therapeutic properties. Of the documented medicinal plants, several were used for treating more than one ailment by the local

communities (Table 1). Based on the number of use reports documented of each plant, *N. jatamansi* was the most important species (UV=0.96) used for 6 different types of ailments related to gastro-intestinal, neurological, hepato-pancreatic, dermatological and cardiovascular. Also, *P. kurroa* (UV=0.93) also used to treat 6 types of ailments related to gastric, skeleton-muscular, hepatic and respiration related problems, while *A. heterophyllum* (UV=0.92) was used in 5 ailments related to gastro-intestinal and general problems such as fever, headache and body weakness. Some other species having high use values were *Swertia chirayita* (0.76), *Origanum vulgare* (0.76) and *Dactylorhiza hatagirea* (0.73).

The fidelity level of plant species for treating specific diseases in the study area varied between 14% to 100%. We found 17 plants having 100% FL: *Achillea millefolium* (diarrhoea), *Anemonastrum polyanthes* (joint pains); *Arnebia benthmii* (hairfall); *Cotoneaster microphyllus* (menstrual bleeding), *Delphinium denudatum* (intestinal parasites); *Impatiens sulcata* (acne & pimples); *Juniperus communis* (Urinary tract infections); *Oxyria digyna* (dysentery); *Primula dentuculata* (cough); *Rhododendron anthopogon*, *Thalictrum foliosum* (stomach-ache); *Polygonatum verticillatum*, *Bistorta affinis* (fever); *Geranium wallichianum*, *Ranunculus hirtellus, Rumex nepalensis*, *Saussurea gossypiphora* (cuts & wounds). We have recognised plants having FL 80% or above as more important. Hence, with respect to the major ailment categories, 12 species had FL more than 80% for dermatological ailments, followed by 9 species for gastrointestinal, 7 for respiratory, 6 for urogenital, 5 for skeleton-muscular, 4 for general ailments, 2 for hepatopancreatic, 2 for cardiovascular, and 1 each for ophthalmic and odontal and 2 for treating insect or scorpion/snake bites (Figure 5).

Ethnomedicinal uses reported in the present study were compared to previous literature from the study region as well as adjacent areas of Uttarakhand Himalayas. Jaccard similarity coefficient (JI) was calculated between the present study and 33 published studies (R1 to R33), to find out similarity of medicinal usage of studied species with previous literature as well as find out new therapeutic use reports of plants. The similarity coefficient ranged from 0.001 to 0.458, with high JI with Bhat et al. 2013 (0.43), Kala 2006 (0.49), Rana and Samant, 2011 (0.47), Kumar et al. 2020 (0.51) (Figure 6). On the other hand, Pala et al. 2010, Kumar et al. 2015 and Uniyal et al. 2002 showed the lowest values, *i.e.*, below 0.05.

Rapid threat assessment

As per the RTA score system opted in the present study, two species, *N. jatamansi* and *P. kurruoa* were categorised as the most vulnerable (Category I) with an aggregate score of 31 and 32, respectively (Figure 7a). In category II, 15 species were identified with an aggregate score between 23 to 29, such as *Aconitum heterophyllum* (29), *Malaxis muscifera* (27), *Rheum australe* (27), *Angelica glauca* (26), *Podophyllum hexandrum* (26), *Origanum vulgare* (26), *Aconitum violaceum* (26), etc (Figure 7a). Among these seventeen highly vulnerable species, twelve are recognised as threatened (CR, EN, VU) at global level, while one (*Rheum moocroftiana*) is near threatened (NT), one (*Origanum vulgare*) is least concerned (LC) and three are not evaluated due to data deficiency. Rest of the species categorised in Category III (36 species) and Category IV (28 species) were identified as less vulnerable. *Geranium pratense* and *Sibbaldia parviflora* were the least vulnerable species with an aggregate score of 10 each, followed by *Arenaria serpyfollia*, *Oxyria digyna* and *Primula denticulata* (12 score).

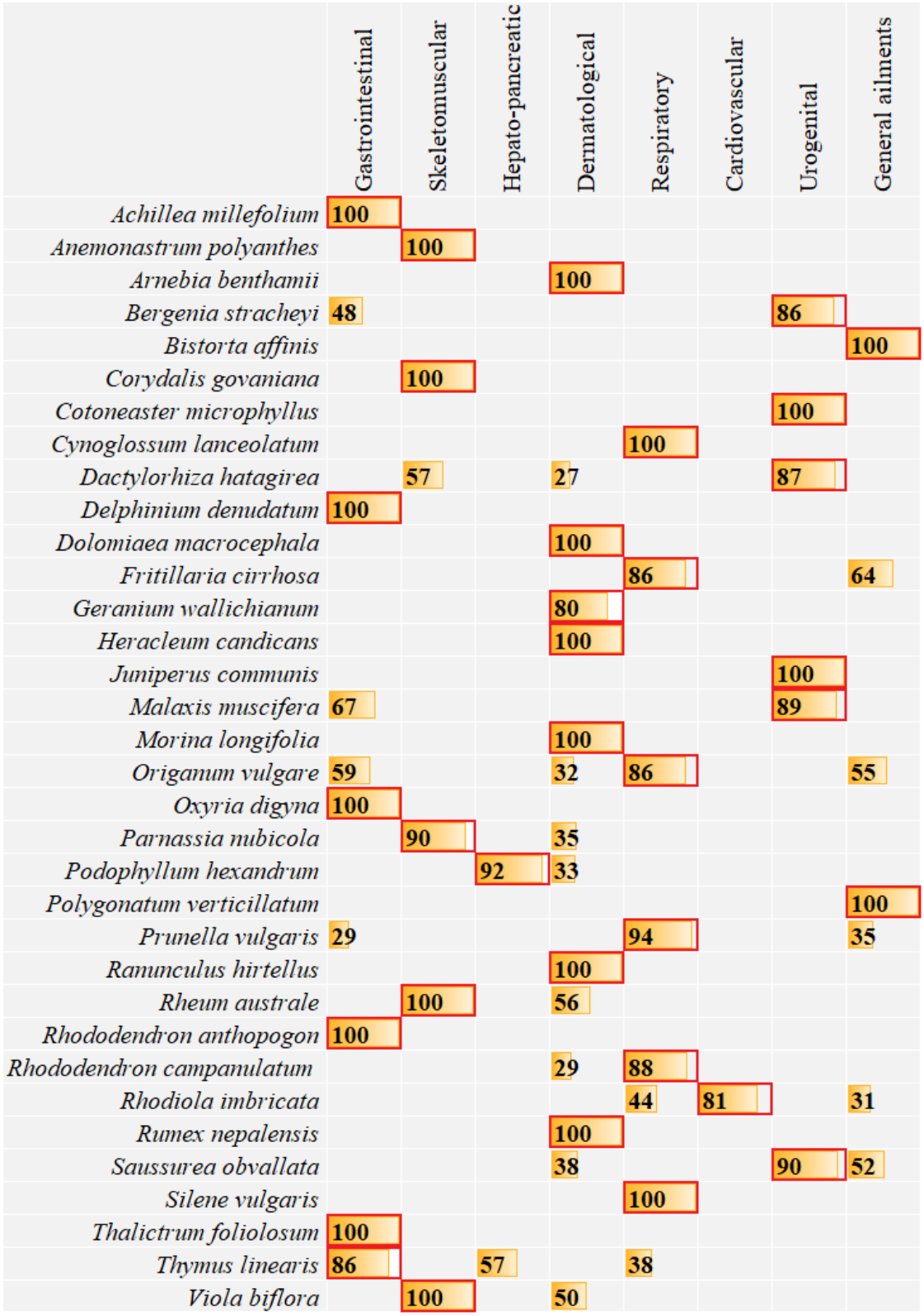

Figure 5. Plant species having Fidelity level (FL) of more than 80% (red square) in each of the disease category in Uttarakhand Himalaya.

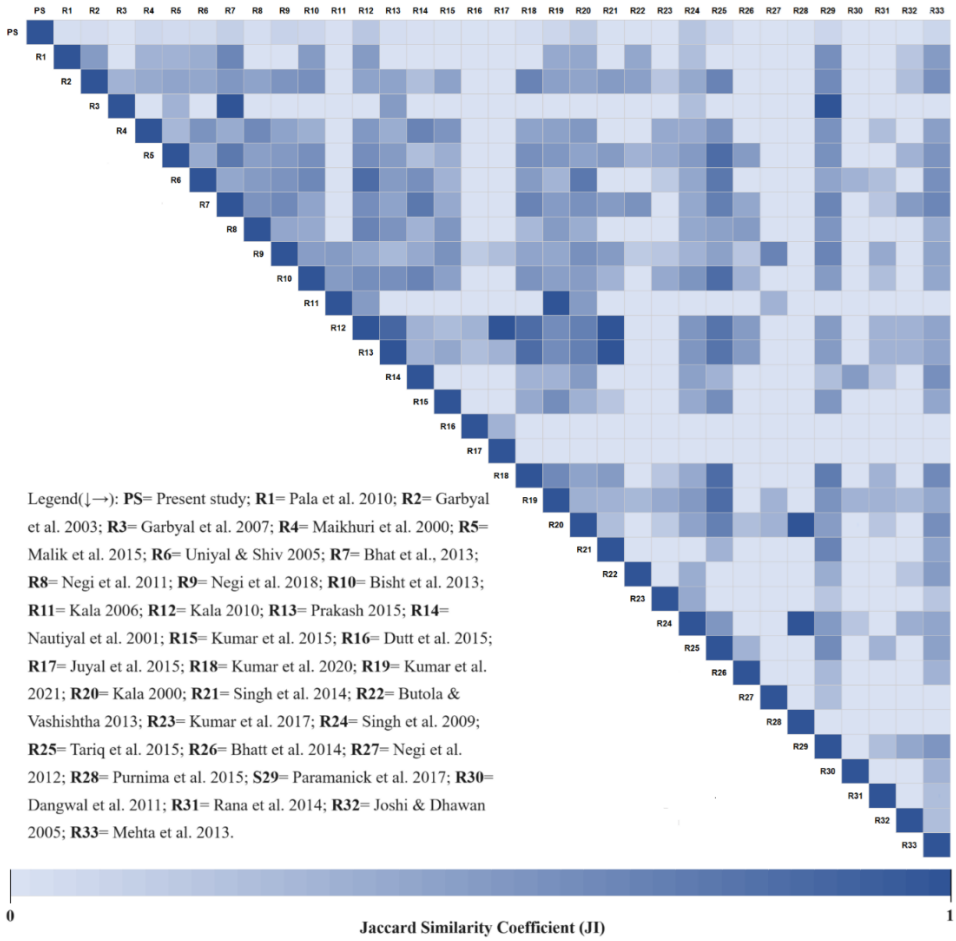

Figure 6. Jaccard similarity coefficient (JI) between specific medicinal values of study species reported in the present study and specific medicinal values of the same species across previously published literature.; JI=close to 1 denotes high similarity, 0 denotes low similarity and invisible grids do not reflect similarity

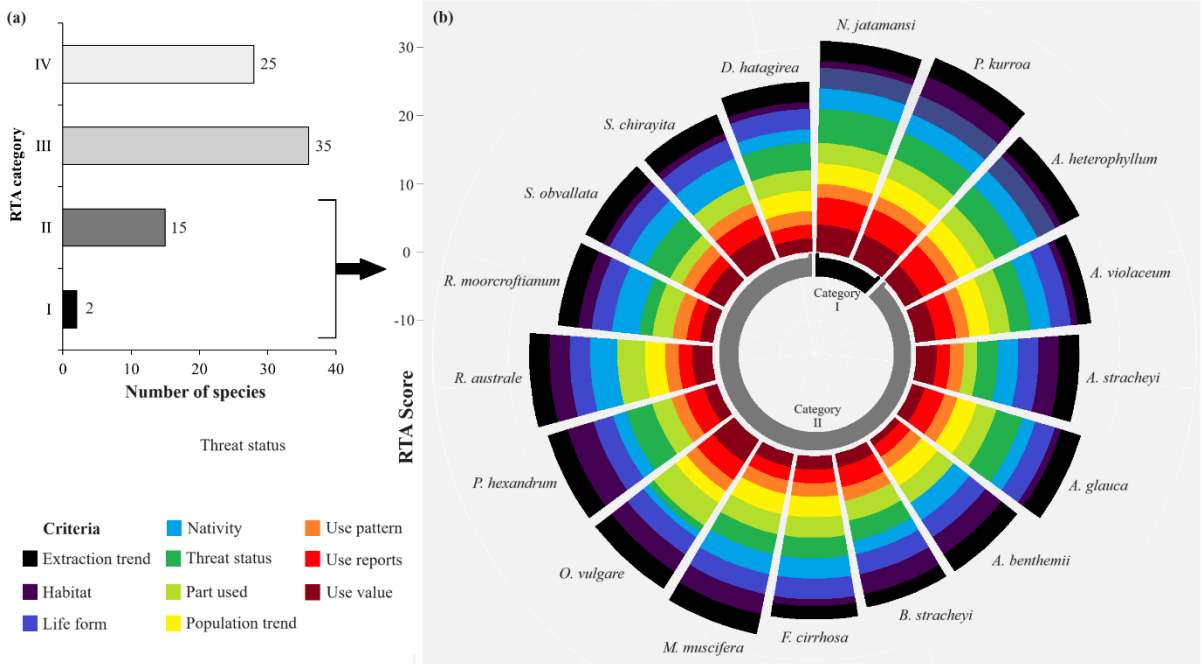

Figure 7. Rapid Threat Assessment (RTA) analysis of the documented medicinal plants. (a) Number of species in each RTA category; (b) RTA score of high value threatened and medicinal plants (THMPs), *i.e.*, Category I and Category II.

Table 1. Indigenous knowledge of medicinal plant species used for different ailments with their altitude range, vernacular names, habit, use value (UV) & relative frequency of citation (RFC).

Name	Common name	Altitudinal range	Part used	Intake	Method	UV	RFC
Amaryllidaceae							
Allium stracheyi Baker	Jambu, Faran, Jwari dhun, Dhungar	3000-4000	Shoot	Oral	Dried parts are ground into powder, then fried with *ghee* and consumed to cure stomached-ache	0.46	0.26
			Leaves	Topical	Clean cloth is dipped into leaf decoction and applied on wounds		
				Oral	Decoction of green leaves is drunk to cure indigestion and jaundice		
Allium wallichii Kunth	Jangali lasun, Gobka, Lhadum	2300-4300	Bulb	Oral	Fresh or stored bulbs are boiled and fried in ghee, then eaten to cure dysentery	0.16	0.14
Apiaceae							
Angelica glauca Edgew.	Gandrayani, Chhipi, Chaura	3000-4000	Roots	Oral	Powdered roots are consumed with "*gudd*" (jaggery) to cure fever and cold	0.55	0.42
Bupleurum falcatum L.	Singu, Jangli jeera, Kalizevar	2600-4250	Roots	Oral	Decoction is taken to treat chronic hepatitis and fever	0.26	0.17
Heracleum candicans Wall. ex DC.	Patrala, Radara, Gojihwa, Rasal	2500-4500	Shoots	Topical	Paste is applied on skin affected by psoriasis and leukoderma	0.34	0.20
Hymenidium brunonis (DC.) Lindl.	Laser, Gokul Dhup, Hiyaan	3100-4500	Whole plant	Topical	Powdered shoot is mixed with butter and massaged over entire body to relieve fever and headache	0.19	0.11
			Leaves	Topical	Powder of dried leaved is mixed with mustard oil and applied in case of small pox		
Asparagaceae							
Polygonatum verticillatum (L.) All.	Khakan, Meda, Khinraula	3000-4500	Rhizome	Oral	A decoction is prepared and consumed with/without sugar to cure fever	0.35	0.33
Asteraceae							
Achillea millefolium L.	Ramban, Bhutkeshi	3500-4100	Whole plant	Oral	A decoction in warm milk is taken in diarrhoea	0.35	0.24
Anaphalis contorta (D.Don) Hook.f.	Pati, Neefa	3000-4500	Leaves	Topical	Paste of fresh leaves is applied on cuts, wounds and boils	0.29	0.18
Artemisia roxburghiana Besser	Kunju	3600-4200	Whole plant	Topical	Freshly prepared paste is applied on skin allergies	0.14	0.12
Aster flaccidus Bunge	Lugmig chunwa, Seertik	3000-5400	Whole plant	Oral	Dried plant is powdered and a teaspoon is consumed in cold	0.13	0.11
Dolomiaea macrocephala DC. ex Royle	Jangli dhup, Guggal	3000-4600	Leaves, Flowers	Topical	Paste of fresh leaves and flowers is applied on sores, cuts and wounds as antiseptic	0.35	0.24

Hippolytia longifolia (Rech.f.) C.Shih	Dhoop, Khampa	3300-4400	Flowers, Leaves	Oral	Juice is consumed with water to treat intestinal worms	0.14	0.12
Jacobaea analoga (DC.) Veldkamp	Parpat, Sangebala	3000-4300	Flowers	Topical	Flowers are crushed and applied on wounds as antiseptic	0.16	0.14
Leontopodium himalayanum DC.	Sampakasa	3700-4500	Whole plant	Oral	An infusion of whole plant is taken to relieve headache and weakness	0.16	0.08
Saussurea gossypiphora D.Don	Kasturi kamal, Gaiphool, Guggibaan	4000-5600	Flowers	Topical	Freshly prepared paste of flowers is applied on cuts and wounds	0.20	0.18
Saussurea obvallata (DC.) Sch.Bip.	Brahma kamal	3700-5200	Flowers	Topical	Extract of flower/buds is applied 2-3 times a day on boils, bruises, cuts and wounds.	0.50	0.26
				Oral	Flower is cooked with *taga misri* and taken against urinary tract infections		
			Seed	Topical	Seed oil is applied on the head twice a day as a remedy for headache		
Senecio graciliflorus DC.	Zerjum	2000-4100	Whole plant	Topical	Fresh paste is used as an antidote to insect bite and ringworm	0.17	0.11
Taraxacum officinale F.H.Wigg.	Kan fulya, Dudhi, Beera phool, Paranbala	3000-4200	Roots	Oral	Decoction of roots is taken to treat kidney and liver disorders	0.50	0.42
Balsaminaceae							
Impatiens sulcata Wall.	Chaul, Halva	2500-4000	Flower	Topical	Paste of flower buds is applied on acne and pimples	0.20	0.18
Berberidaceae							
Podophyllum hexandrum Royle	Ban kakri, Burkhalo, Cheecharpu, Khora	3000-4200	Roots	Oral	Decoction of roots is consumed to cure liver problems	0.70	0.52
				Topical	Root paste is applied on ulcers, cuts and septic wounds		
Boraginaceae							
Arnebia benthamii (Wall. ex G.Don) I.M.Johnst.	Ratanjot, Balchadi, Laaljari	3100-4600	Roots	Topical	Fresh or dried roots are soaked in hot hair oil for 2-3 days and then the oil is applied on hair as a remedy to treat hairfall	0.32	0.30
Cynoglossum lanceolatum Forssk.	Laksmana, Lichkuru	3000-3800	Whole plant	Oral	Plant infusion is consumed to treat cough and cold	0.31	0.20
Caprifoliaceae							
Lonicera obovata Royle ex Hook.f. & Thomson	Phut	3000-3400	Leaves	Oral	Freshly prepared decoction in water is consumed to treat GIT worms	0.10	0.08

Morina longifolia Wall. ex DC.	Viskanar, Kandij, Sibsha, Bhishkandra	3000-4000	Roots	Topical	Dried powder or fresh paste is applied on cuts, wounds, burns and boil	0.34	0.23
Nardostachys jatamansi (D.Don) DC.	Jatamansi, Mashi	3000-4100	Roots	Oral	Root extract is given to treat fits and epilepsy; and teaspoon of root powder with *ghee* is taken to cure high blood pressure	0.96	0.57
				Topical	An extract of roots is applied to teat burns		
			Leaves	Oral	Fresh or dried leaves are crushed to make extract and consumed twice a day to treat jaundice and stomach-ache		
Valeriana hardwickei Wall.	Shamaiwa, Tagger, Asarun, Chhar, Nakhniani	2500-4200	Root	Topical	Paste is applied on insect & scorpion sting	0.14	0.12
Caryophyllaceae							
Acanthophyllum cerastioides (D.Don) Madhani & Zarre	Mendok	2600-4700	Shoot	Topical	Plant paste is applied on boils, cuts and wounds	0.19	0.11
Silene vulgaris (Moench) Garcke	Gandoli, Khushu	3000-3700	Leaves	Oral	Fresh young leaves are used as pot herb and consumed in case of bronchitis and asthma	0.37	0.23
Celastraceae							
Parnassia nubicola Wall. ex Royle	Nirbisi, Futka, Phutkya	3200-4400	Tubers	Topical	A fine paste of fresh mature tubers is applied on affected parts of skin to heal cuts, wounds, boils, muscle fractures and swellings	0.43	0.24
Rhodiola imbricata Edgew.	Chundol	3500-5500	Root	Oral	Fine powder with milk is consumed to treat cough, fever, headache and anaemia	0.22	0.18
Cupressaceae							
Juniperus communis L.	Bhitaru, Dhup, Bethathri	2200-3600	Fruit	Oral	Berry powder is consumed to stimulate urination	0.28	0.26
Ephedraceae							
Ephedra intermedia Schrenk & C.A.Mey.	Somalata, Khaut	3000-4800	Shoot	Oral	A teaspoon powder of dried aerial parts is given for asthma twice in a day	0.13	0.11
Ericaceae							
Cassiope fastigiata (Wall.) D.Don	Salu, Phallu, Nilli buti	3500-5300	Shoot	Topical	Paste of branches made in water is applied on fire burns	0.16	0.14
Rhododendron anthopogon D.Don	Kouti, Tar jhippan, Talis patra, Kodiya	3500-5600	Flower	Oral	Chewed raw to treat stomach-ache	0.25	0.23
Rhododendron campanulatum D.Don	Chimmul, Awom, Simru, Shergal	3200-4400	Leaves	Topical	Fresh leaves are mixed with mustard oil to form a paste and applied on wounds and cuts	0.44	0.20

			Leaves	Oral	Dried leaves are ground into powder and consumed with boiled/lukewarm water to cure cold and cough		
Euphorbiaceae							
Euphorbia stracheyi Boiss.	Sangmen	3500-4300	Shoot	Topical	Plant paste is applied on boils, wounds and rheumatic pain	0.22	0.11
Fabaceae							
Oxytropis microphylla (Pall.) DC.	Tag-sha nagpo	3200-3600	Flower	Topical	Powder of flowers is used to treat animal bite twice in a day	0.11	0.09
Parochetus communis Buch.-Ham. ex D.Don	Fuljari, Chemgeephul, Badaame jhaar	3000-3400	Leaves	Topical	Juice of pounded leaves is used to treat eye problems	0.11	0.09
Gentianaceae							
Gentiana stipitata Edgew.	Chirotu	3400-4900	Shoot	Oral	Juice of young shoots is used to cure fever	0.11	0.09
Swertia chirayita (Roxb.) H.Karst.	Charaita	3200-3800	Shoot	Oral	Fresh juice of young shoots is consumed in case of fever, high blood pressure and diabetes	0.76	0.46
			Roots	Oral	Root powder or extract is given in fever, cough, cold and asthma		
Swertia purpurascens (D.Don) C.B.Clarke	Kalo Chiraito	3000-4300	Whole plant	Oral	Dried plant is made into powder and consumed to cure irregular bowel movement and stomach burn	0.31	0.17
Geraniaceae							
Geranium pratense L.	Likatur, Kashayamool	2500-4300	Leaves	Oral	Decoction of leaves is consumed in case of diarrhoea	0.19	0.17
Geranium wallichianum D.Don ex Sweet	Chowhri, Sucha phulli, Likatur	2600-4800	Roots	Topical	Powder of dried roots is applied on wounds	0.34	0.32
Lamiaceae							
Elsholtzia eriostachya (Benth.) Benth.	Bhotepaati	3000-4200	Whole plant	Oral	Decoction of whole plant is used to remove intestinal parasites	0.10	0.08
Lamium album L.	Tilka, Banbuti	2500-3700	Roots	Topical	Paste is applied on cuts and wounds	0.13	0.11
Origanum vulgare L.	Jangli/Ban Tulsi, Sathra, Mirzanjosh, Maruwa	2500-3600	Whole plant	Oral	Powder of dried plant is taken with warm water or milk cure cold, fever, headache and stomach-ache	0.76	0.27
			Leaves	Topical	Fresh paste of leaves is used as an ointment in boils, ulcers, cuts and wounds		
Prunella vulgaris L.	Kalbyuth	3000-3500	Leaves	Oral	Leaves consumed in the form of tea for treating fever, diarrhoea and sore throat	0.34	0.20
Thymus linearis Benth.		2500-4600	Whole plant	Oral	Plant is used to make tea and/or juice to cure stomach & liver complaints	0.53	0.26

	Jangli/Ban ajwain, Balama, Kochi masha		Seed	Oral	Seed extract in water is given to cure cough, indigestion and stomach pain		
Liliaceae							
Fritillaria cirrhosa D.Don	Kakoli, Chichaor, Dharru ghanti	3200-4600	Bulb	Oral	Powdered bulbs are taken orally to relieve fever; and decoction is taken in treatment of asthma and tuberculosis	0.56	0.27
			Root	Oral	Extract of roots in water is given twice a day to cure fever and cough		
Orchidaceae							
Dactylorhiza hatagirea (D.Don) Soó	Hathajari, Hathpanja, Salampanja	2800-4300	Tuber	Topical	A paste obtained from fresh mature tuber is applied externally to cure fractures, wounds and cuts	0.73	0.39
			Root	Oral	Root powder is consumed with milk to cure leucorrhoea		
Malaxis muscifera (Lindl.) Kuntze	Jeevak, Rishbhak, Ridhhi	3800-4000	Root	Oral	Extract of roots in water is given to cure stomach ulcers and kidney complaints	0.40	0.21
Orobanchaceae							
Euphrasia himalayica Wettst.	Kangchuk	2900-4400	Whole plant	Oral	Finely selected plants are cooked and consumed against cold, cough and sore throat	0.22	0.09
Pedicularis punctata Decne.	Saur	3000-4500	Flower	Oral	Dried flowers are powdered and consumed with water to treat blood pressure and fever	0.20	0.12
Papaveraceae							
Corydalis govaniana Wall.	Halsu, Bhoojati, Togsil	3100-4800	Roots	Oral	Root extract is administered orally to relieve muscular pains	0.28	0.24
				Topical	Extract of mature roots is applied on swelling and inflammations thrice a day		
Meconopsis aculeata Royle	Kania, Neela posta, Vanita, Veerbhuti	3200-5600	Roots	Topical	A paste of the root is used to cure infected wounds and treat inflammation	0.44	0.23
			Flower	Oral	Extract of flowers is given twice a day to cure fever		
Plantaginaceae							
Picrorhiza kurroa Royle ex Benth.	Kutki, Kardi, Karoi, Anjani	3300-4600	Roots	Oral	A decoction of root is consumed for treating jaundice and stomach-ache	0.93	0.60
				Topical	Fresh as well as dry roots/rhizomes are ground with water to prepare a paste and applied to cure joint pains		
			Leaves	Oral	Decoction of leaves is consumed in cough		
Polygonaceae							
Bistorta affinis (D.Don) Greene	Chunru, Kapad, Kukdi	3000-5300	Roots	Topical	Root paste is applied on forehead to bring down body temperature in treating high fever	0.25	0.23

Bistorta vacciniifolia (Wall. ex Meisn.) Greene	Pulunge jhaar	3600-4900	Roots	Oral	Decoction of roots in water is consumed to treat tuberculosis	0.13	0.11
Koenigia polystachya (Wall. ex Meisn.) T.M.Schust. & Reveal	Amahaldhu	2500-3800	Shoot	Oral	Decoction of fresh shoot is consumed to treat acidity and indigestion	0.20	0.11
Oxyria digyna (L.) Hill	Surjilap, Chyakulti	2600-5300	Leaves	Oral	Leaves are cooked and eaten in the treatment of dysentery	0.26	0.24
Rheum australe D.Don	Dolu, Padamchaal, Archoo, Chhircha	3000-4400	Root	Topical	A paste made from mature roots is mixed with water and used to treat boils, wounds and cuts	0.58	0.32
			Whole plant	Topical	Poultice is made on a cotton cloth from freshly crushed plant and heated to apply on swellings, developed as a result of fractured bones		
Rheum moorcroftianum Royle	Lajua, Tanturi, Archa, Raiwand, Tukshu	3500-5300	Rhizome	Oral	Rhizome powder with water is taken orally to relieve cough, cold, indigestion & constipation	0.37	0.18
Rumex nepalensis Spreng.	Pahadi palak, Khunkuya, Bhilmora	3000-4300	Leaves	Topical	Paste made from fresh mature leaves is applied on cuts to stop bleeding	0.29	0.27
Primulaceae							
Primula denticulata Sm.	Kutra, Jayan	3000-4500	Flower	Oral	Paste of freshly plucked flowers is mixed with honey and consumed to cure cough	0.20	0.18
Ranunculaceae							
Aconitum heterophyllum Wall. ex Royle	Atees, Ativikha, Boa, Patish	3000-4000	Tubers	Topical	A paste is made from mature tubers and applied to cure headache	0.92	0.60
			Tubers	Oral	Decoction of tuber or powder is consumed with milk to cure fever, diarrhoea and indigestion		
Aconitum violaceum Jacquem. ex Stapf	Vish, Vsastanabh, Kadwi	3300-4700	Roots	Oral	Roots are dried, ground into fine powder and boiled with water to consume for treating stomach-ache, fever, cough and as liver tonic.	0.62	0.32
Anemonastrum polyanthes (D.Don) Holub	Ratni, Gul-laalaa	3200-4700	Leaves	Topical	A paste of fresh leaves is applied to cure joint pains	0.28	0.26
Delphinium denudatum Wall. ex Hook.f. & Thomson	Jadwar, Nirbishi	3000-3500	Leaves	Oral	Leaf powder is taken orally along with warm milk to treat intestinal parasites	0.28	0.26
Ranunculus hirtellus Royle	Piryali, Simariya, Goodi	3000-4300	Shoot	Topical	Paste applied externally on cuts and wounds	0.23	0.21
Thalictrum foliolosum DC.	Makada jhar, Mamiri, Barmot	3000-3600	Roots	Oral	Dried roots are powdered and mixed with *Thymus linearis* in equal proportion and consumed regularly to cure stomach pain and gastric troubles	0.25	0.23

Rosaceae							
Cotoneaster microphyllus Wall. ex Lindl.	Khareto, Rogthali, Bhedro	3000-3600	Leaves	Oral	Tea prepared from leaves is used in case of excessive bleeding during menstruation	0.22	0.20
Geum elatum Wall. ex G.Don	Gwali	3500-5400	Roots	Oral	Decoction of roots is used for treatment of jaundice and diarrhoea	0.20	0.12
Potentilla atrosanguinea G.Lodd.	Tasheg, Ratiphul	3000-5200	Roots	Topical	Paste of roots is applied on affected area to treat toothache and gingivitis	0.29	0.17
Sibbaldia parviflora Willd.	Loma	3400-4500	Leaves	Topical	Leaf juice is mixed with mustard oil and applied on joint pains	0.11	0.09
Saxifragaceae							
Bergenia stracheyi (Hook.f. & Thomson) Engl.	Silphori, Pashanbheda, Ghee-pati, Silpayi	3000-4500	Leaves	Oral	Infusion of dried leaves is consumed to treat stomach-ache	0.59	0.37
			Rhizome	Oral	Rhizome powder mixed with honey is given to person suffering from stone problems		
Violaceae							
Viola biflora L.	Dundibirali, Banpansa	3200-5000	Whole plant	Topical	Paste fresh plants is applied on wounds, sores and fractured bone	0.41	0.24

Discussion

Traditional practices of medicinal plants in Uttarakhand

The rural communities residing in the Indian Himalayan Region, particularly in the remote high-altitude villages, continue to employ medicinal plants for treatment of various ailments (Malik *et al.* 2015, Negi *et al.* 2018). While this reliance is mostly associated with lack of accessibility to modern healthcare facilities and poverty, such traditional societies tend to be more self-sufficient having better nutritional security and are motivated by sustainable natural resource management. Their local culture is further strengthened by their close linkages to the natural environment that sustains them and prioritize holistic well-being, considering physical, mental and spiritual aspects of heath (Anthwal *et al.* 2010). These herbal remedies and natural treatments, integral to traditional medicine, provide effective relief with minimal side effects. The geographic seclusion of these valley communities has fostered the development of distinct indigenous knowledge systems, including ethnobotanical knowledge of therapeutic plants. However, traditional wealth is gradually fading even from the remote communities majorly due to migration of the younger generations to urban societies and adopting modern practices. There is also a significant lack of interest among them to learn traditional therapeutic practices as it is considered less effective compared to allopathic medicines in the modern world. Hence, the range of information retained in unwritten form by tribal folk is gradually diminishing, and the oral tradition of passing down knowledge from generation to generation is declining, and that retained have become fragmented (Kala 2005, Malik *et al.* 2015). In our study, of the total plant taxa documented from the studied valleys, 196 have been documented as having traditional medicinal uses in various literatures (Bhat *et al.* 2013, Butola & Vashistha 2013, Dangwal *et al.* 2011, Garbyal *et al.* 2005, 2007, Kala 2006, Kumar *et al.* 2020, Maikhuri *et al.* 2000, Mehta *et al.* 2013, Nautiyal *et al.* 2001, Negi *et al.* 2018, 2019, Prakash 2015, Uniyal *et al.* 2002), among indigenous communities in the studies regions of Uttarakhand Himalayas. The decline in traditional knowledge of underutilised medicinal plants and the process of creating herbal formulations among the younger generation is consistent with previous research (Nijar 2013). Given the serious threat of total loss of such a rich heritage of information restricted to only the older generations, there is an urgent need for government attention and progressive exposure.

The preference for roots/rhizomes and leaves to prepare traditional remedies can be attributed to the presence of higher concentrations of bioactive compounds (Uprety *et al.* 2010), as these are the storage units of plants. In the study, several plants were used in more than one way, owing to the difference in healthcare practices in the studied villages. In the majority of cases, a paste of plant parts was used made by crushing fresh material with the help of mortar and pestle and applied externally/plastered on skin or affected area to ease irritations, muscular pain, fractured bones, etc. Powder form was also widely used both externally and internally after drying and crushing plant material. Most of the decoctions and infusions were made as water being the main solvent, as also reported in earlier studies (Kala 2005, Malik *et al.* 2015, Negi 2010). While there were multiple ways in which plants were utilised, the usage was more prominent for general problems such as cuts and wounds, fever, stomach-ache, indigestion, cough and cold, while more specific ailments were treated by one or two species only. While only one species is used by the locals to treat neurological disorders such as fits and epileptic attacks, but maximum informants were having the same opinion. The average ICF value for different categories of ailments was 0.84, indicating that the locals do share ethnobotanical knowledge among themselves. Among the documented species in present study, *A. heterophyllum*, *P. kurroa*, *N. jatamansi* and *P. hexandrum*, *S. chirayita*, *O. vulgare* and *D. hatagirea* were having highest use value (>0.70) and frequency of citations (>0.50), thus exhibiting their importance among local communities. While, there have been wide variety of published literature assessing the phytochemistry of these species (Bhardwaj *et al.* 2021, Kamraj Singh *et al.* 2015, Khan *et al.* 2017, Kumar & Dhillon 2018, Mathew *et al.* 2021, Packirisamy *et al.* 2023), it can be encouraged to pursue tissue culture and micropropagation for large scale cultivation of such valuable species. Apart from these, *Rheum australe*, *S. obvallata*, *B. stracheyi*, *D. macrocephala*, *F. cirrhosa*, *T. linearis*, etc. were also identified as medicinally important and widely utilised species by the locals. Furthermore, detailed assessment of other under-utilised or lesser-known species having therapeutic properties should be undertaken, especially those having high fidelity level, such as *A. millefolium*, *A. polyanthes*, *B. affinis*, *C. govaniana*, *C. microphyllus*, *I. sulcata*, *P. nubicola*, *O. digyna*, *T. foliosum*, *V. biflora*, etc. This may provide leads for novel drug discovery paving way towards strengthening the healthcare and pharmaceutical sector.

Threatened assessment of medicinal plants

The criteria for identifying priority medicinal plant species are reliable and useful in regional contexts. The species falling under threat category I and II were identified as threatened and high value medicinal plants (THMPs), exclusively found in alpine habitats with a distribution range of 3200-5300 m. Owing to their habitat, these are highly sensitive to any disturbance (natural or anthropogenic) in their ecosystem. In category I, we have *N. jatamansi* and *P. kurroa* as the most threatened species having multiple uses (Ballabh *et al.* 2008, Kayani *et al.* 2015, Kumar *et al.* 2017, Uniyal *et al.* 2006, Uprety *et al.* 2010), not only in Uttarakhand, but across the Himalayas. The diverse socio-economic uses, extraction trends and high trade

demand are the major threat factors for both species. As per previous literatures, both *Kutki* and *Jatamansi* face significant threats due to their diverse socio-economic uses, extraction trends, and high trade demand, with an approximate annual collection of 40,000-50,000 kg and 10,000-20,000 kg, respectively (Pandey *et al.* 2019). Similar assessments in other alpine regions have also identified them as highly threatened (Kumar *et al.* 2021, Shrestha & Dhillion 2003). At global level, both species are recognized under major threat categories, with *N. jatamansi* being classified as CR (population reduction of >90% over the last 10 years or three generations) and *P. kurroa* as EN (population reduction of >70% over the last 10 years or three generations) (IUCN, 2023). The distribution of these species is mostly restricted to the Himalayan region in specific areas, due to which their density is low at global level (Pusalkar & Singh 2012). The species under category II have also been documented as medicinal in different regions of Himalayas (Ahmad & Habib 2014, Bano *et al.* 2014, Dutt *et al.* 2015, Kala 2000, Khan *et al.* 2013, Kumar & Singhal 2013, Kumar *et al.* 2017, Rahman *et al.* 2016). Apart from the diverse uses and extraction trends, plant part used, type of habitat and distribution are the major threat factors for determining threat status. Most of these plants are extracted for their belowground part or taken out as a whole without leaving any remains, which stops further regeneration. Moreover, species such as *A. stracheyi*, *B. stracheyi*, *M. muscifera*, *P. hexandrum*, *R. australe*, etc. inhabiting stony and gravel slopes types of fragile habitat were more vulnerable to any disturbance. Trading of many of these species have been documented in previous literatures, *i.e.*, *D. hatagirea* 100-200 kg/yr, *A. stracheyi* 500-600 kg/yr, *P. hexandrum* 143-186 kg/yr (Pandey *et al.* 2019). As per the IUCN threat assessment, *A. glauca*, *S. obvallata*, *P. hexandrum*, *D. hatagirea* and *A. heterophyllum* are also identified as endangered species at global level, while *A. stracheyi*, *F. cirrhosa*, *A. violaceum* and *B. stracheyi* are categorised as vulnerable (VU, population reduction of >50% over last 10 years or three generations). Moreover, *R. moorcroftianum* is also identified to be near threatened, *i.e.*, close to qualifying for threatened category in the near future. However, *A. bentamii* and *R. australe* are considered as data deficient and *S. chirayita* has not been evaluated, hence can be made a focus for global assessment by ecologists. Only *O. vulgare* is categorised in Least Concern by IUCN, which indicates it largely suffers from unscientific harvesting for local consumption only.

Rest of these species were identified as least threatened species in the studied regions. Among these species, *D. denudatum*, *P. verticillatum* and *S. gossipyphora* are categorised as threatened and *R. anthopogon*, *R. campanulatum* are near threatened in IUCN. Thus, local consumption and trade demand in the region do not cause major threat to these species, but habitat degradation and natural calamities at global scale may be responsible. Underutilization and lesser-known benefits of these species especially in the region are major reason for their low vulnerability. However, similar studies have identified *D. macrocephala*, *J. communis*, *R. anthopogon* and *T. linearis* as threatened high-value medicinal plants in Johar valley due to unsustainable harvesting, habitat degradation, grazing and trampling (Pandey *et al.* 2019). In view of this, it can be encouraged for the utilisation of the less vulnerable species in the region in place of those categorised in I and II, and exploration of the phytochemical constituents of these species.

Conclusion

With renewed interest in herbal remedies, the demand for medical plant-based healthcare is expected to rise in the near future. Documenting and preserving medicinal plants as well as the traditional pharmacological knowledge are crucial to prevent the loss of our biodiversity and cultural heritage. To conserve medicinal plants, it's important to include local residents in sustainable collection and cultivation in their native habitats, taking into account their ecological relevance and demographic situation. Unsustainable harvesting, overexploitation, and habitat destruction have all been cited as significant concerns to medicinal plant sustainability. Thus, official institutions might provide incentives and measures to encourage medicinal plant production and conservation in distant locations, as well as undertake capacity development activities and demonstrations to raise local awareness of the rising fragility of high-altitude biodiversity. Given the availability of resources, people's desire to participate in conservation projects, and the government and other organisations' prioritisation of the medicinal plants industry, it has the potential for sustainability. Sustainable harvesting, effective domestication methods, community participatory management, and the provision of information, education, and awareness campaigns to the community are all critical tactics for maximising the advantages of medicinal plants. The 17 priority species identified here are highly valued on national and international markets, therefore, it is important to consider these species to implement policy and to guide management authorities of the Uttarakhand for proper management and use of medicinal plants to benefit local people in their traditional healthcare delivery systems and income generation activities. The study provides valuable firsthand insights into the THMPs of underexplored and climate change-sensitive areas like cold deserts.

Declarations

List of abbreviations: NDBR: Nanda Devi Biosphere Reserve; KSLCD: Kailash Sacred Landscape Conservation and Development Initiative (KSLCD); PRA: Participatory Rural Appraisal; UV: Use Value; ICF: Informant's Consensus Factor; FL: Fidelity Level; RTA: Rapid Threat Assessment

Ethics approval and consent to participate: In order to conduct the research on traditional knowledge, a number of ethical and legal guidelines were followed.

Consent for publication: Not Applicable

Availability of data and materials: All data generated or analysed during this study are included in this published article [and its supplementary information files].

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Author's contributions: NT & PB involved in data collection, engaged in discussions, reviewed the previous literature, and made herbarium. PB & KCS involved in species identification. NT analyzed the data and prepared the manuscript draft. DA & KCS supervised the whole study, proof read and finalized the manuscript.

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Supplementary files

Table S1. Details of the total number of respondents

Village name	Respondents		
	Male	Female	Total
Lata	15	9	24
Raini	14	6	20
Peng	10	5	15
Khati	17	11	28
Jaikuni	14	5	19
Furkiya	12	7	19
Himkhola	15	7	22
Sirkha	10	4	14
		Total	**161**

Table S2. Rapid Threat Assessment (RTA) criteria for medicinal plants documented from the study area.

Criteria	Category	Score
Habitat	Gravel/soil, boulder/stony/rocky slopes	4
	Moist, marshy, shady, glacial moraine land	3
	Riverine, shrubberies, riverbeds	2
	Grassland/alpine pasture/open/alpine slopes	1
Life form	Perennial	3
	Biennial	2
	Annual	1
Part used	Whole plant	4
	Underground portions (root/rhizome/tuber)	3
	Bark, stems, fruits, bulbs, seeds	2
	Leaves, resin, latex	1
Use value	More than 6	4
	4-5	3
	2-3	2
	1	1
Use reports	>50	4
	36-50	3
	20-35	2
	<20	1
Extraction trend	Commercial + self use	3
	Commercial	2
	Self use	1
Use group	Local people+local exchange+ trade	4
	Local people+ trade	3
	Local people+ local exchange	2
	Local people	1
Threat status	CR	5
	EN	4
	VU	3
	NT	2
	LC	1
	DD/UNKN	0
Population trend	Decreasing	2
	Stable	1
	Increasing	0
Nativity	Native to west Himalaya	4
	Native to Himalaya	3

	Native to Himalaya & surrounding countries	2
	Cosmopolitan	1