



Ethnomedicinal exploration in remote Himalayan villages along the Bhagirathi River in Uttarkashi, Uttarakhand (India)

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Abstract

This study investigates the ethnomedicinal plants and traditional medical practices in three remote villages along the Bhagirathi River in Uttarkashi, Uttarakhand. Data were collected from 17 respondents, predominantly older individuals with minimal formal education, regarding 22 ethnomedicinal plant species. The Apiaceae, Ranunculaceae, Rosaceae, and Taxaceae families are the most represented, with herbaceous plants being the dominant life form and roots identified as the most frequently utilized plant part. Decoction emerged as the primary method of plant-based medicine preparation. A high Informant Consensus Factor (ICF) is recorded for the treatment of stone problems, with frequently cited plant *Bergenia ciliata*. Key species such as *Aconitum heterophyllum*, *Bergenia ciliata*, *Asparagus racemosus*, *Berberis lycium*, and *Dactylorhiza hatagirea* exhibited the highest relative frequency of citation (RFC) and fidelity level (FL), indicating their significance in local healthcare practices. Additionally, *Malus domestica* demonstrated the highest use value (UV) due to its frequent availability in the region. Notably, this study provides the first documentation of the use of *Thalictrum foliolosum* for genito-urinary ailments, thereby expanding its known ethnomedicinal applications. However, several medicinal species, including *Aconitum heterophyllum*, *Angelica glauca*, and *Dactylorhiza hatagirea*, are classified as endangered, while *Nardostachys jatamansi* is critically endangered due to overharvesting driven by high market demand. The findings underscore the importance of documenting traditional knowledge and the potential of these plants for future pharmaceutical applications, while also emphasizing the need for conservation efforts to protect these valuable species in their natural habitats.

Keywords Bhagirathi River · Ethnomedicinal plants · Himalaya · Threat · Traditional knowledge

Introduction

The Himalayan region is renowned for its rich floral diversity, owing to its unique geography, wide range of altitudes, and varying climatic conditions. This diversity

supports many plant species with significant medicinal, ecological, and cultural importance. The area serves as a reservoir for rare and endemic species, making it a key hotspot for conservation and ethnobotanical studies. Among the various rivers originating from the Himalayas, the Bhagirathi River, which begins at the Gomukh (30° 36' N; 79° 40' E; 3800 m), Gangotri glacier in Uttarkashi district, Uttarakhand, is notable for supporting natural vegetation and the livelihoods of nearby communities. Several villages are still isolated in the Himalayan region among them some villages located along the Bhagirathi River, depend on natural resources and the river itself for their livelihood and healthcare systems. These communities rely on the area's vegetation assemblages, which create crucial habitats for ecosystems and medicinal plants. Many commercially important medicinal plants grow naturally here, offering a lifeline to local people. Indigenous medicines derived from these plants provide considerable economic

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benefits (Malla et al. 2015). The World Health Organization (WHO) reports that about 25% of modern medicines are developed from plant sources traditionally used for healing, and research into these plants has led to the discovery of 75% of herbal drugs (Singh et al. 2019a). The ancient medical system is believed to developed in the Bhagirathi Valley during the Vedic era (Singh and Rana 2016; Kumar 2017a, b; Georgiadis 2020; Sati 2021; Kumar and Sati 2023). The medicinal plants of the region are integral to the healthcare practices of indigenous communities, whose traditional knowledge and environmental awareness play a crucial role in treating ailments. However, despite their therapeutic value, many of these plants are increasingly under threat due to overharvesting driven by their high market demand. Moreover, traditional knowledge about these medicinal plants is gradually eroding among Himalayan Indigenous communities. Younger generations are becoming less engaged, influenced by modern education and shifting lifestyles. As a result, this valuable knowledge is now largely confined to elders and traditional healers (Bisht and Adhikari 2018; Bhatt et al. 2024). The ethnobotanical studies offer opportunities to document unstudied medicinal plants for pharmaceutical development and to create conservation strategies (Singh et al. 2019b). Given these challenges, this study aims to document the ethnomedicinal knowledge of remote villages around the Bhagirathi River in the Himalayas. The

research focuses on the socio-ecological aspects of plant-derived medicines used to treat various human ailments and highlights the local inhabitants' continued reliance on ethnomedicinal plants for healthcare.

Materials and methods

Study area

The present study focused on three remote villages in the Uttarkashi district of Uttarakhand, situated along the Bhagirathi River in the Bhagirathi Valley: Bagori (30°04' N, 78°45' E, 2584 m), Sangrali (30°44' N, 78°26' E, 1742 m), and Purali (31°01' N, 78°42' E, 2648 m) (Fig. 1). These villages, located in the western Himalayan region, experience a year-round cool and chilly climate due to their high altitudes, with snow-covered elevations persisting annually. The residents rely heavily on the surrounding forests for their livelihoods, making them dependent on local natural resources. The villages were chosen based on their proximity to the Bhagirathi River, enabling the study of areas directly influenced by the river's ecosystem. Due to their remote location in the Himalayan range, these villages face extreme weather conditions, which significantly shape their environment and daily lives.

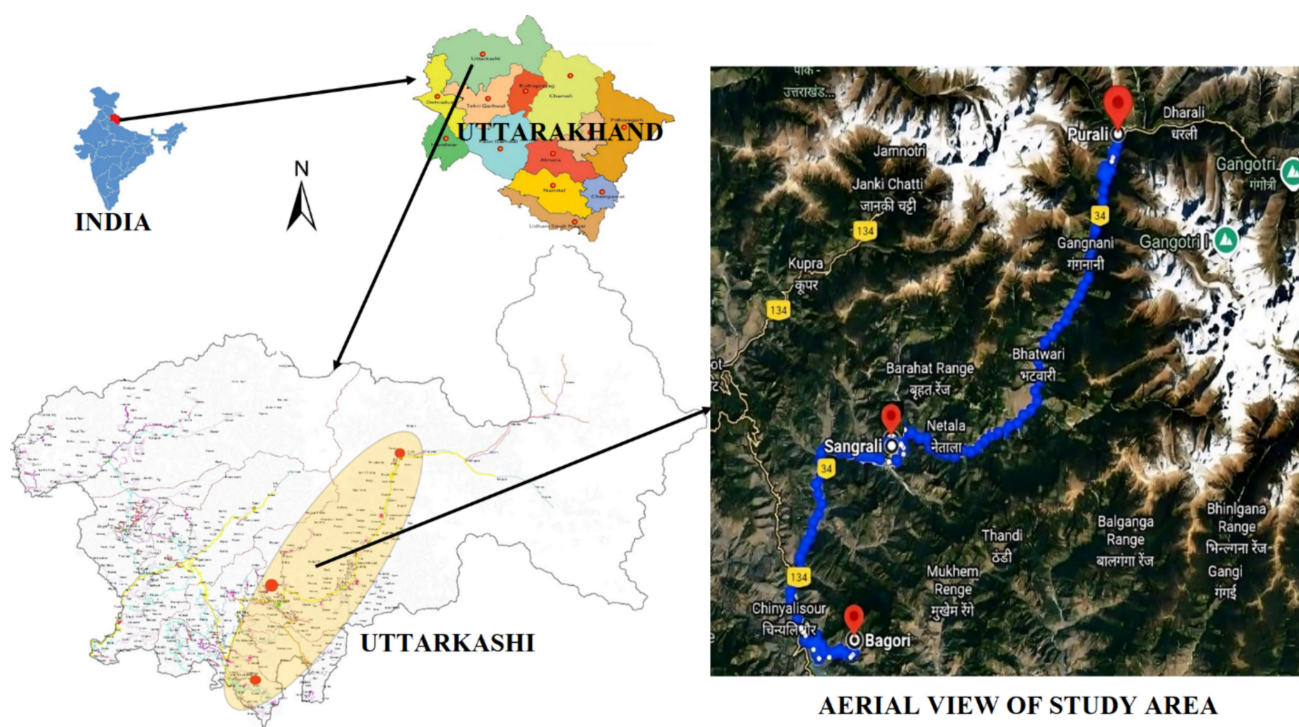


Fig. 1 A map of the study area showing various study sites. (Red marks denote the studies villages)

Data collection

Before initiating the fieldwork, a comprehensive literature review was conducted on the Bhagirathi River and its surrounding regions to understand the local ecological and ethnobotanical context. A field survey was carried out in the selected villages in May 2023, using a validated questionnaire to gather information from local informants. The questionnaire collected demographic data alongside information about medicinal plants, including local names, parts used, methods of administration, and diseases treated. Detailed field data were documented for the reported plants, such as plant habits, habitat, size, and the color of flowers and fruits. Plant identification was conducted using local names, cross-referencing with previous literature, and matching available photographs. Updated botanical nomenclature was verified using reliable databases like Plants of the World Online (POWO) and World Flora Online (WFO). Not all plants were physically collected; some were identified based on local names and their photographic evidence (Fig. 2). The identification process involved cross-referencing these names with existing literature and reliable online databases, such as the Global Biodiversity Information Facility (GBIF) and other online floras. Based on the questionnaire and information gathered from the respondents, the reported disease conditions were grouped into a total of 9 key ailments categories (Table 1).

Quantitative analysis

The data were entered into an Excel sheet and quantitatively it was analyzed using various quantitative indices such as relative frequency of citation (RFC), use value (UV), informant consensus factor (ICF), relative importance level (RIL), corrected fidelity level (CFL), and fidelity level (FL). Apart from these the similarity indices such as Jaccard's similarity index (JI%) and Sorensen's similarity index (QS%) have been analyzed.

Relative frequency of citation (RFC)

RFC represents the relative importance of plant species and depends on the number of informants that report the use of the species. It has been calculated to assess the consensus amongst the informants on the reported taxa. RFC indicates the local importance of plant species which is calculated by using the given formula (Rehman et al. 2017; Balkrishna et al. 2024):

$$RFC = \frac{FC}{N}$$

where 'FC' is the number of informants who reported the use of plant species, and 'N' is the total number of participating informants.

Use value (UV)

The UV is an index that indicates the relative importance of locally known plant taxa, depending on the number of uses recorded for each species. It was calculated by the following formula (Phillips et al. 1994):

$$UV = \frac{U}{n}$$

where 'U' represents the number of use reports for a plant species, and 'n' is the total number of informants who inquired about that plant.

Informant consensus factor (ICF)

ICF expresses the consensus of informants related to the use of plant taxa in treating different use categories (Ahmad et al. 2018; Uzun and Koca 2020; Balkrishna et al. 2024). High ICF values indicate that there is a consensus among informants about plants used for a particular disease group (Uzun and Koca 2020). ICF was calculated using the given formula:

$$ICF = \frac{N_{ur} - N_t}{N_{ur} - 1}$$

where 'N_{ur}' is the number of use reports for a specific ailment category and 'N_t' is the number of taxa used in that particular category. ICF is generally used to indicate the consensus of knowledge on the medicinal plant used for a particular ailment.

Fidelity level (FL)

The more often used medicinal plants by the community have higher FL values than the less commonly used ones. The percentage of informants who assert that a certain plant species is used for the same primary purpose is demonstrated by the fidelity level. This is intended to measure the species' significance for a certain objective. The FL value was determined for each of the identified plants as a whole and a specific disease category using the following formula (Friedman et al. 1986; Khan et al. 2014):

$$FL(\%) = \frac{N_p}{N} \times 100$$

where 'N_p' is the number of respondents who reported the utilization of the plant, and 'N' is the total number of participating informants.



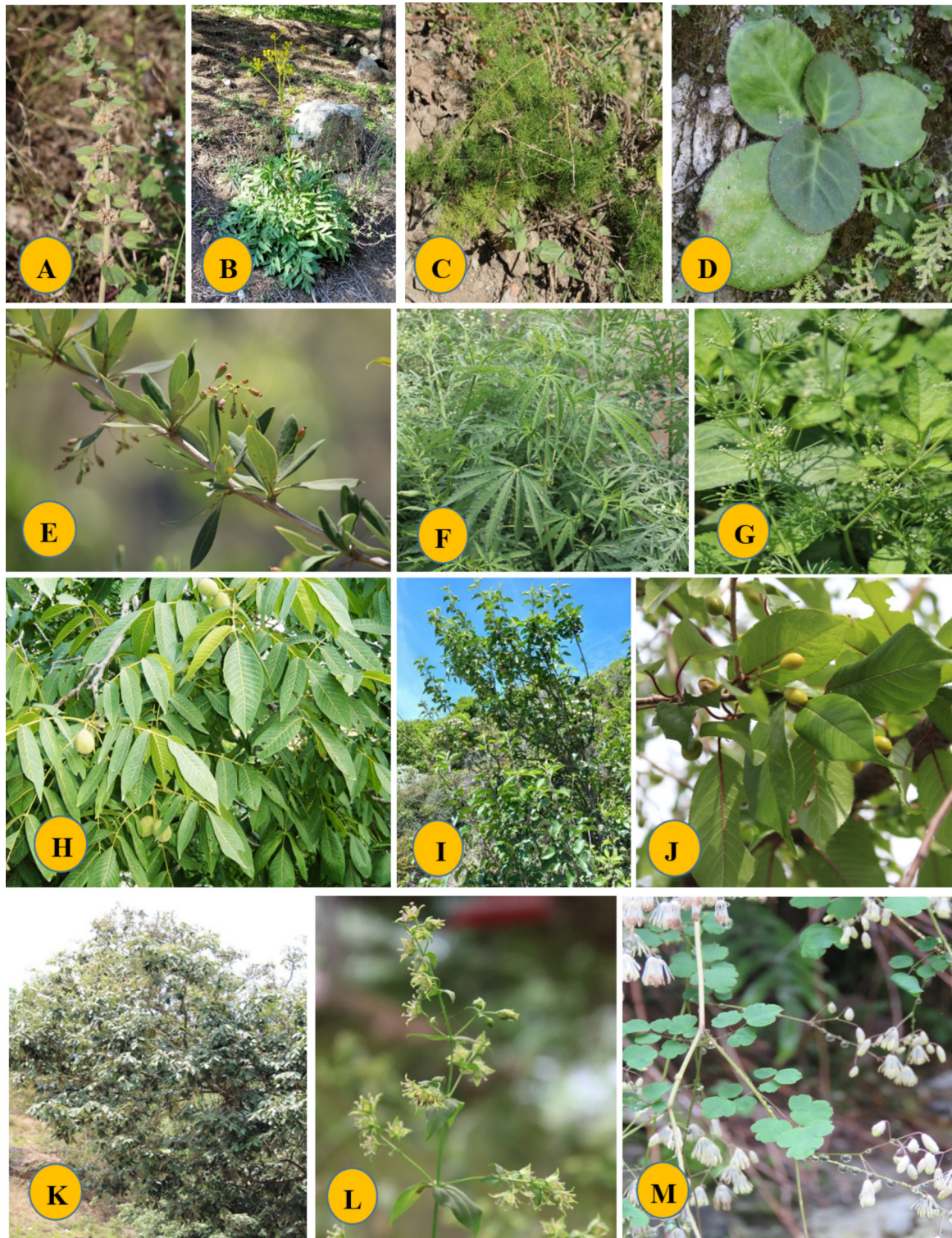


Fig. 2 Ethnomedicinal plants. **A**—*Ajuga integrifolia*, **B**—*Angelica glauca*, **C**—*Asparagus racemosus*, **D**—*Bergenia ciliata*, **E**—*Berberis lycium*, **F**—*Cannabis sativa*, **G**—*Carum carvi*, **H**—*Juglans*

regia, **I**—*Malus domestica*, **J**—*Prunus cerasoides*, **K**—*Quercus leucotrichophora*, **L**—*Swertia chirayita*, **M**—*Thalictrum foliolosum*

Table 1 Ailment use categories along with their disease conditions

Ailment categories	Use categories	Disease conditions
Category 1	Dermatological disorders	Boil, Cut, Wound
Category 2	Fever, Cough, and Cold	Asthma, Cold, Cough, Fever
Category 3	Metabolic disorders	Diabetes, Diarrhea, Dysentery, Jaundice, Stomachache, Uric acid (Hyperuricemia)
Category 4	Skeleto-muscular disorders	Internal injury, Muscular pain
Category 5	Cardiac-neurological disorder	Blood pressure, Epilepsy
Category 6	Bone disorders	Arthritis or Joint pain, Bone disease, Bone fracture, Toothache
Category 7	Stone problem	Stone (calculus)
Category 8	Cancer and ulcer	Cancer, Ulcer
Category 9	Genito-urinary ailments	Sexual disorders, Spermatorrhea, Urinary disease

Relative importance level (RIL)

The RIL presents the level of prominence of each species in a study site. The RIL varies from 0 to 1.0, with “1” being the full importance of a medicinal plant for particular diseases and “0” no ailment cured by a plant species. The RIL value was calculated using the method described by Friedman et al. (1986) with the given formula:

$$RIL = \frac{FC}{FC_t}$$

where ‘FC’ is the number of respondents mentioning a species and FC_t is the total number of respondents of all species.

Corrected fidelity level (CFL)

The CFL of plant species is used as a correction factor to more accurately rank species based on varying FL and RIL values. By integrating these two metrics, the CFL provides a more precise representation of a plant species' significance in the study area. The CFL is calculated by multiplying the FL by the RIL values, ensuring that species with high importance and consistent use are ranked appropriately. The CFL index is obtained using the following formula (Friedman et al. 1986; Umair et al. 2019):

$$CFL = FL \times RIL$$

Similarity indices

Jaccard's Similarity Index (JI%) and Sorensen's Similarity Index (QS%) were assessed to measure the similarities in the utilization of common medicinal plants between the current study and previously published evidence from adjacent locations. The following formula (Kayani et al.

2015; Rahman et al. 2019) is used to determine the JI% by comparing it to previously published research and examining the percentages of mentioned species and their therapeutic uses:

$$JI = C \times \frac{100}{a + b + c}$$

In contrast, Sorensen, a botanist, created and published the QS% in 1948. The following method was used to evaluate the percentages of the stated species and their medicinal applications to compare the results with previously published data (Rahman et al. 2019).

$$QS = \frac{2c}{a + b} \times 100$$

In both the indexes, ‘a’ is the number of species in the cited study, ‘b’ is the number of species in the current study, and ‘c’ is the number of common species in both studies.

Statistical analysis

The demographic and plant-based data were plotted in Excel and subjected to analysis. A correlation analysis was performed to explore the relationships between different variables. The Pearson Correlation Coefficient (r) was used to measure the strength and statistical significance of the linear association between two component variables, providing insight into the degree to which changes in one variable are associated with changes in another. The data obtained from various quantitative indices were systematically arranged and analyzed to examine the relationships between variables. Additionally, the coefficient of determination (r^2) was calculated to quantify the proportion of variability in the dependent variable that could be explained by the independent variable, further allowing for the assessment of species variability and cross-relations between the indices.



Results and discussions

Informant's socio-demographic characteristics

A total of 17 respondents from the study villages were interviewed and grouped into three age categories: Group I (25–40 years), Group II (41–60 years), and Group III (> 60 years). Among the villages, 35.29% of respondents were from Bagori, 23.53% from Sangrali, and 41.18% from Purali (Table 2). In terms of gender distribution, 58.83% were male and 41.18% were female. As per the respondent's occupations, 58.82% of respondents were non-farmers, including constructors, LIC service workers, sheep rearers, and homemakers, while 41.18% were farmers. Educational backgrounds were categorized into five categories: illiterate (zero schooling), basic (1–5 schooling), middle (6–8 schooling), intermediate (11–12 schooling), and higher education (> 12 schooling). The majority of respondents (47.06%) were illiterate, 23.53% had attained higher education, 11.76% had completed middle and intermediate levels, and 5.88% had basic education (Table 2). Throughout the study, a total of 127 plant use reports were recorded, and there were 45 discussions on the documented plants. These plants have reportedly been shown to cure 45 disease conditions (Table 2). The age of the informants statistically exhibited a minor negative association with the diseases mentioned ($y = 0.1248x$, $r^2 = -0.414$) and discussed plants ($y = 0.1114x$, $r^2 = -0.872$).

This study involves interviewing a total of 17 respondents, selected from villages located in remote areas with limited household numbers. According to the 2011 Census

data, these villages are home to only 314 households, with a population of 1679 individuals. Among these households, the number of respondents knowledgeable about ethnomedicinal plants was notably small, primarily due to the decline in traditional practices among the younger generation. Among all the respondents, the number of male informants sharing their knowledge was slightly higher than that of female informants. Similar findings have demonstrated that male informants frequently have a greater influence on therapeutic practices (Mir et al. 2021; Rao et al. 2022; Lal et al. 2023; Ahirwar and Gupta 2024). It has been observed globally that studies with predominantly female participants are rare, although some have recorded female-dominated respondents (Yemele et al. 2014; Mussarat et al. 2014). One possible reason for fewer female participants is that women often face greater challenges in gathering medicinal plants from remote forest areas and are primarily engaged in domestic responsibilities and caregiving.

Plant exploration

Most of the plants used to cure common diseases were known to the responders. Twenty-two plants from 19 families have been identified and their ethnomedicinal applications have been documented (Table 3). Of these families, Apiaceae, Ranunculaceae, Rosaceae, and Taxaceae had two plants each and the remaining 15 families (Amaryllidaceae, Araceae, Asparagaceae, Berberidaceae, Cannabaceae, Caprifoliaceae, Fagaceae, Gentianaceae, Juglandaceae, Lamiaceae, Liliaceae, Melanthiaceae, Orchidaceae, Polygonaceae, Saxifragaceae) each had a single plant (Fig. 3). Three distinct habit categories—herb, shrub, and

Table 2 Socio-demographic characteristics of the respondents (n = 17)

Categories	Variables	Age Groups (Years)			Total	%
		25–40	41–60	> 60		
Villages	Bagori	1	3	2	6	35.29
	Sangrali	0	0	4	4	23.53
	Purali	4	2	1	7	41.18
Gender	Male	1	3	6	10	58.82
	Female	4	3	0	7	41.18
Occupation	Farmer	1	2	4	7	41.18
	Non-Farmer	4	4	2	10	58.82
Education	Illiterate	1	3	4	8	47.06
	Basic	1	0	0	1	5.88
	Middle	1	1	0	2	11.76
	Intermediate	1	1	0	2	11.76
	Higher education	1	1	2	4	23.53
Responses	Plants used report	41	46	40	127	
	Plants discussed	12	17	16	45	
	Diseases cured	14	16	15	45	

Table 3 List of ethnomedicinal plants and their mode of preparation/administration, uses, and quantitative analysis

Botanical name (Family) – Habit	Local name	Preparation/administration methods and uses	*	**	RFC	UV	FL	RIL	CFL	***
<i>Aconitum heterophyllum</i> Wall. ex Royle (Ranunculaceae)—Herb	Atish	The root decoction is useful in stomachache, fever, and diarrhea	20	13	0.76	1.54	76.47	0.59	45.19	EN
<i>Ajuga integrifolia</i> Buch.-Ham. ex D.Don (Lamiaceae) – Herb	Neelkanthi	The root decoction is useful in diabetes	4	4	0.24	1.00	23.53	0.18	4.28	–
<i>Allium humile</i> Kunth (Amaryllidaceae)—Herb	Pangre	The leaves are cooked and taken as a vegetable in stomachache	2	2	0.12	1.00	11.76	0.09	1.07	–
<i>Angelica glauca</i> Edgew (Apiaceae)—Herb	Choru	The root powder or decoction is taken orally in stomachache	4	4	0.24	1.00	23.53	0.18	4.28	EN
<i>Arisaema propinquum</i> Schott (Araceae)—Herb	Faran	The root paste is applied topically in wound or boil healing	2	2	0.12	1.00	11.76	0.09	1.07	–
<i>Asparagus racemosus</i> Willd (Asparagaceae)—Herb	Botareen, Satawar	The root juice is taken orally for sexual disorders, and the powder along with <i>Boerhavia diffusa</i> mixed with cow milk taken twice daily for spermatorrhea	13	9	0.53	1.44	52.94	0.41	21.66	–
<i>Berberis lycium</i> Royle (Berberidaceae) – Shrub	Chotar, Chhakeer	The root extract or decoction taken orally in muscular pain, joint pain, arthritis, and diabetes	9	9	0.53	1.00	52.94	0.41	21.66	LC
<i>Bergenia ciliata</i> (Haw.) Sternb. (Saxifragaceae) – Herb	Pattharchatta, Silphoda	The root decoction is used orally in stones problem	11	11	0.65	1.00	64.71	0.50	32.35	LC
<i>Cannabis sativa</i> L. (Cannabaceae) – Shrub	Bhang	The leaves paste or seed powder is taken orally in fever and jaundice, and leaves paste is applied topically in cuts and boils	7	4	0.24	1.75	23.53	0.18	4.28	–
<i>Carum carvi</i> L. (Apiaceae) – Herb	Jangali Jeera	The seed paste is taken orally in stomachache	2	2	0.12	1.00	11.76	0.09	1.07	LC
<i>Dactylorhiza hatagirea</i> (D.Don) Soó (Orchidaceae)—Herb	Salampanja, Hattha Jadi	The tuber paste is applied locally in wounds, boils	9	9	0.53	1.00	52.94	0.41	21.66	EN
<i>Fritillaria cirrhosa</i> D.Don (Liliaceae)—Herb	Jangali Lahsun	The bulb directly taken or eaten in asthma	2	2	0.12	1.00	11.76	0.09	1.07	VU
<i>Juglans regia</i> L. (Juglandaceae) – Tree	Akhrot	The roots are used regularly as a toothbrush in toothache	2	2	0.12	1.00	11.76	0.09	1.07	LC
<i>Malus domestica</i> (Suckow) Borkh (Rosaceae)—Tree	Seb	The fruits vinegar is useful in curing high blood pressure (hypertension), diabetes, uric acid (hyperuricemia), bone diseases	10	4	0.24	2.50	23.53	0.18	4.28	–
<i>Nardostachys jatamansi</i> (D.Don) DC. (Caprifoliaceae)—Herb	Jatamansi	The root decoction is taken orally in epilepsy	4	4	0.24	1.00	23.53	0.18	4.28	CR
<i>Paris polyphylla</i> Sm. (Melanthiaceae)—Herb	Satuwa	The rhizome decoction is taken orally in stomachache, and the paste applied topically in wounds	4	2	0.12	2.00	11.76	0.09	1.07	VU
<i>Prunus cerasoides</i> Buch.-Ham. ex D.Don (Rosaceae) – Tree	Shekharu	The inner bark is used as plaster during bone fracture	2	2	0.12	1.00	11.76	0.09	1.07	LC
<i>Quercus leucotrichophora</i> A. Camus (Fagaceae) – Tree	Baanj	The bark decoction is taken orally for diarrhea, dysentery, asthma	7	5	0.29	1.40	29.41	0.23	6.68	–
<i>Rheum australe</i> D.Don (Polygonaceae)—Herb	Archa	The root paste is applied topically for internal injury, boils, and wound	8	8	0.47	1.00	47.06	0.36	17.11	DD

Table 3 (continued)

Botanical name (Family) – Habit	Local name	Preparation/administration methods and uses	*	**	RFC	UV	FL	RIL	CFL	***
<i>Swerdia chirayita</i> (Roxb.) H. Karst (Gentianaceae)—Herb	Kadwai	The whole plant decoction is taken orally for fever	5	5	0.29	1.00	29.41	0.23	6.68	–
<i>Taxus wallichiana</i> Zucc. (Taxaceae)—Tree	Bhotiya Chai, Thuner	The Bark decoction or prepared tea along with salt, ghee, and water is useful in cough, cold, cancer, mouth-ulcer	7	4	0.24	1.75	23.53	0.18	4.28	EN
<i>Thalictrum foliolosum</i> DC. (Ranunculaceae)—Herb	Bangla Jadi	The root decoction is taken orally for urinary disease and sexual disorders	4	4	0.24	1.00	23.53	0.18	4.28	EN

*Use Reports, **No. of informants, ***IUCN Status: EN Endangered, CR Critically Endangered, LC Least Concern, VU Vulnerable, DD Data Deficient

tree—were applied to all of the documented plants. The maximum 15 (68.18%) ethnomedicinal plants were found to be herbaceous, followed by trees (5; 22.73%), and shrubs (2; 9.09%) (Fig. 4).

The study areas were dominated by the Apiaceae, Ranunculaceae, Rosaceae, and Taxaceae families because of their wider occurrence, especially in high-altitude zones (Bhatia et al. 2014). The most often used medicinal plants were found to be herbs, which is consistent with the overall trend of herbaceous species domination shown in medicinal plant inventories both in India and throughout the world (Bhatia et al. 2014; Rao et al. 2015). There have been prior reports of similar life-form patterns (Vijayakumar et al. 2015; Umair et al. 2019). The predominance of herbaceous plants is attributed to their widespread availability, their traditional role in the preparation of herbal remedies, and their active participation in digestion and metabolic processes (Lulekal et al. 2013; Balkrishna et al. 2024). The conservation status of the recorded plants was assessed using the International Union for Conservation of Nature (IUCN) Red List Database (<https://www.iucnredlist.org/>). This database indicates that many plants in the Himalayan region are endangered (EN) or critically endangered (CR). Among these, *Aconitum heterophyllum* (EN), *Angelica glauca* (EN), *Dactylorhiza hatagirea* (EN), *Taxus wallichiana* (EN), and *Nardostachys jatamansi* (CR) were recorded in this study (Table 3). These IUCN-categorized species are of significant ethnobotanical and economic importance, underscoring the urgent need for targeted conservation and management strategies to ensure their protection.

Ethnomedicinal plant parts and their modes of administration

Each plant part has medicinal properties that make the plant's medicinal significance. A maximum of 11 plants were recognized based on their root value followed by bark values (3 plants). The leaves and seed-valued plants showed two plants each while the bulb, fruits, rhizome, tuber, and whole plants valued were recognized by a single plant each (Fig. 5). All the identified plants have a different administration mode. A maximum of 11 plants were administered as a decoction; the remaining plants are administered as follows: 6 plants in paste form, 3 in powder form, 2 in raw or direct form, and 1 each for cooked, juice, toothbrushing, vinegar, and water extract form (Fig. 6).

The most commonly used plant parts for herbal preparation in the study areas were roots, a finding consistent with previous studies in the Himalayan region (Uniyal and Shiva 2005; Balodi et al. 2018; Nand and Naithani 2018). The collection of roots, rhizomes, bulbs, bark, and stems poses serious threats to the survival and regeneration patterns of mother plants (Zerabruk and Yirga 2012). Unsustainable

Fig. 3 Number of plants and their prominent families

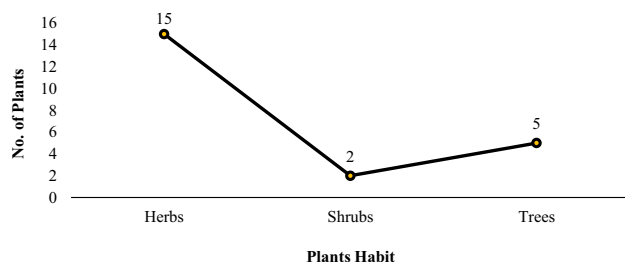
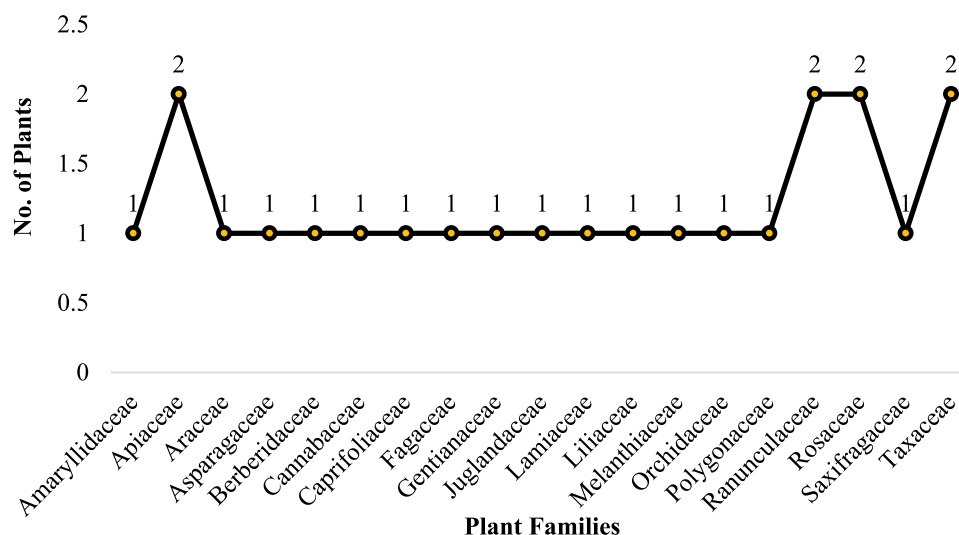


Fig. 4 Number of ethnomedicinal plants with their habits

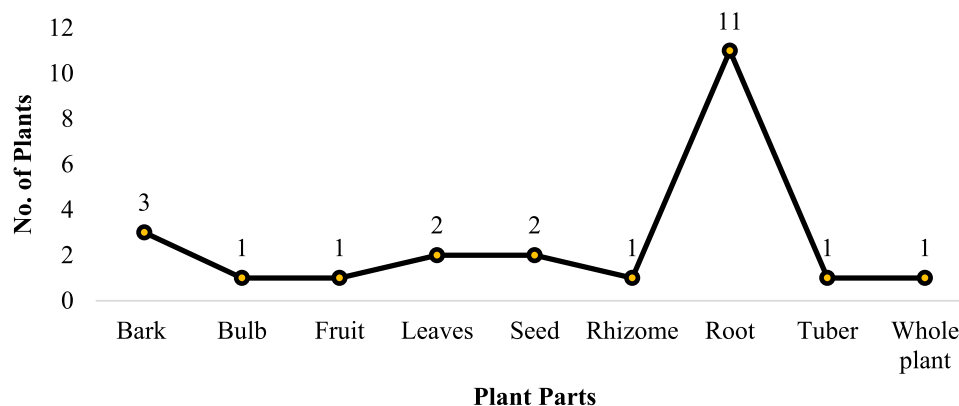
harvesting practices can further endanger these plants, pushing species towards extinction (Balodi et al. 2018). In the study, decoction was the most frequently used administration method. Decoctions are a common form of herbal preparation in traditional healthcare systems due to their simplicity in combining herbs with a solvent of choice (Rokaya et al. 2010; Umair et al. 2019). The use of decoctions and pastes for treating various ailments is widespread across diverse cultures in India, with similar modes of administration

reported in various ethnomedicinal studies (Rehman et al. 2017; Kumar et al. 2019; Ouhaddou et al. 2020; Rahman et al. 2024). The heating process involved in decoction preparation accelerates biological and metabolic processes, enhancing the availability of active compounds (Zhang et al. 2005; Chen et al. 2008).

Ailment categories and their quantitative analysis

A variety of plants were used in various sites throughout the study areas to treat the various disease conditions that were categorized into nine use categories (Table 1). Among the different ailments categories, 17 respondents discussed a maximum of 10 plants in Category 3, followed by Category 2 (16 respondents, 6 plants). 10 respondents discussed 5 plants in Category 1; 7 respondents discussed 2 plants in Category 4; 6 respondents discussed 2 plants in Category 5; 8 respondents discussed 3 plants in Category 6; 11 respondents discussed 1 plant in Category 7; 4 respondents discussed 1 plant in Category 8; 4 respondents discussed 2 plants in Category 9 (Table 4).

Fig. 5 Different used ethnomedicinal plant parts concerning the number of plants



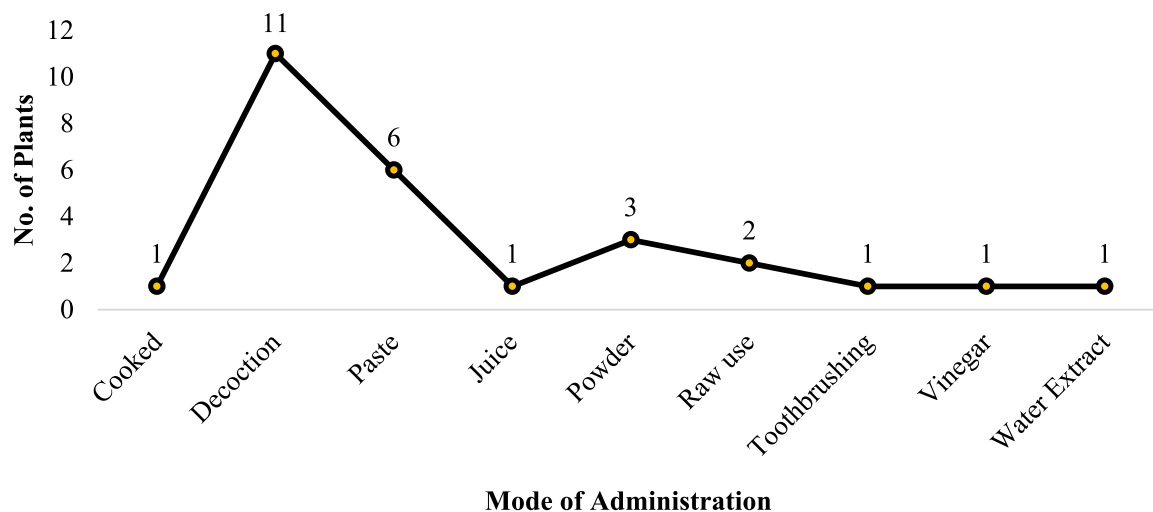


Fig. 6 Number of ethnomedicinal plants and their mode of administration

ICF is a potential method for determining the frequency of therapeutic plants for different ailment categories. The current study examined a total of 9 ailment categories, with ICF values ranging from 0.73 to 1. The highest ICF value of 1 was reported for Category 7 and 8 followed by Category 5 (0.86), and Category 4 (0.83) (Table 4). For each Category, the FL value was measured and it ranged between 23.53 and 100. The maximum of 100 FL value was recorded for Category 3 followed by Category 2 (94.12), Category 7 (64.71), and Category 1 (58.82). Categories 8 and 9 were recorded for a least of 23.53 FL values (Table 4). The summary statistics for these variables are summarized in Table 8.

The results demonstrate a strong consensus on the medicinal uses of plants, as indicated by high Informant Consensus Factor (ICF) values across all categories. High ICF values suggest a strong agreement among informants regarding the use of certain taxa for treating specific ailment categories (Sharma et al. 2012). A high ICF value implies

that a significant percentage of informants use certain plant species to treat a wide range of diseases, whereas a low ICF value indicates the use of plants for a narrower range of ailments (Gazzaneo et al. 2005; Rehman et al. 2017). Categories 7 and 8 exhibited the highest ICF values, likely due to the prevalence of stone and ulcer-related health issues in the study areas. Informants frequently discussed plants associated with these conditions, such as *Bergenia ciliata* for Category 7 and *Taxus wallichiana* for Category 8. These plants are widely used, with similar applications reported locally (Uniyal and Shiva 2005; Singh et al. 2019b) and throughout the greater Himalayan region for a variety of ailments (Sher et al. 2016). The Fidelity Level (FL) values were particularly high for Category 3 (metabolic disorders) and Category 2 (fever, cough, and cold), reflecting the high prevalence of these conditions and their effective treatment in the study area (Rahaman and Karmakar 2015; Rao et al. 2015).

Plant's quantitative analysis

Relative frequency of citation (RFC)

The RFC describes the most frequent ethnomedicinal plants and their local significance concerning informants. A higher RFC score implies that plant species are more prevalent among the informants. In this study, the RFC ranges from 0.12 to 0.76. The plant with the highest RFC was *Aconitum heterophyllum* (0.76) followed by *Bergenia ciliata* (0.65), *Asparagus racemosus*, *Berberis lycium*, and *Dactylorhiza hatagirea* each had 0.53 RFC value (Table 3). As these plants are more common and frequently used by the inhabitants, their RFC is high. The plant *Aconitum heterophyllum* had the highest RFC value because it is an important herb found in high altitudes and used to cure common ailments

Table 4 ICF and FL values of different ailments categories

Ailment categories	No. of plants	Used reports	No. of informants	ICF	FL
Category 1	5	17	10	0.75	58.82
Category 2	6	24	16	0.78	94.12
Category 3	10	34	17	0.73	100.00
Category 4	2	7	7	0.83	41.18
Category 5	2	8	6	0.86	35.29
Category 6	3	10	8	0.78	47.06
Category 7	1	11	11	1.00	64.71
Category 8	1	5	4	1.00	23.53
Category 9	2	5	4	0.75	23.53

such as stomachache, fever, and diarrhea which are more prevalent in the study areas. This plant was discussed by a total of 13 respondents in a total of 20 use reports (Table 3).

The RFC values, ranging from 0 to 1, reflect the knowledge and use of plant species among informants, with higher values indicating more frequent and widespread usage (Medeiros et al. 2011). In this study, species with the highest RFC values included *Aconitum heterophyllum*, *Bergenia ciliata*, *Asparagus racemosus*, *Berberis lyceum*, and *Dactylorhiza hatagirea*, each used for distinct medicinal purposes. *Aconitum heterophyllum*, an endangered species found at high altitudes, is primarily used to treat stomachache, fever, and diarrhea, in line with previous studies that also documented its use for vomiting and cough (Gürdal and Kültür 2013; Singh 2008; Ojha et al. 2020). *Bergenia ciliata* was mainly employed for kidney stone treatment, while other studies have reported its use for fever, digestive issues, and urinary infections (Gaur 1999; Malik et al. 2015). *Asparagus racemosus* was cited for treating sexual disorders and spermatorrhea, though earlier research highlights its broader applications for headaches, hysteria, and liver disorders (Bisht et al. 2012; Singh and Attri 2014). *Berberis lyceum* was used for muscular pain, joint pain, and arthritis, while *Dactylorhiza hatagirea* was favored for wound healing and treating boils, with prior studies extending its use to burns and bleeding control (Malik et al. 2015; Bisht et al. 2012). These species are culturally important due to their long-standing use and bioactive properties (Singh et al. 2017). Still, their high RFC values suggest overexploitation, particularly for endangered or critically endangered species. The urgent need for conservation efforts is underscored by their inclusion in IUCN threat categories, with some species at serious risk of extinction.

Use value (UV)

The UV is used for quantitative data analysis that confirms the relative importance of ethnomedicinal plants to the population. The higher UV indicates more use reports for a plant species which is significant among informants whereas, the lower UV indicates fewer use reports. In the current study the UV value range from 1 to 2.5. The plant with the highest UV is *Malus domestica* (2.5 UV) followed by *Paris polyphylla* (2 UV), *Cannabis sativa*, and *Taxus wallichiana* each had 1.75 UV (Table 3). The high use of these plant species indicates the common occurrence and importance among respondents as they frequently use these plants in herbal therapies for various ailments. The UV simply indicates the local importance of plant species against different ailments.

The highest UV in this study was recorded for *Malus domestica*, with 4 informants reporting 10 use reports. This species is highly cultivated in the study area for trade, making it a commonly used plant in various forms. Interestingly,

this study uniquely identifies *Malus domestica* as having the highest UV, which contrasts with other studies that do not emphasize its widespread use. A possible explanation for this is the plant's prevalence in nearly every household within the region. *Paris polyphylla* ranked second in UV, being frequently found in high altitudes and widely used for treating stomachaches and wound healing. *Cannabis sativa* and *Taxus wallichiana* were tied for third place in UV, reflecting their common occurrence and significant use in herbal therapies for various ailments. Although plants with lower UV values, as shown in Table 3, were less frequently reported, they were found to be highly effective against various ailments. These species hold potential for broader therapeutic applications and could be valuable in the development of human pharmaceuticals (Rehman et al. 2017; Balkrishna et al. 2024).

Fidelity level (FL)

The FL was calculated for each identified plant species in the study area, indicating the frequency and intensity of their use by local informants. The FL values ranged from 11.76 to 76.47 (Table 3), with *Aconitum heterophyllum* recording the highest FL (76.47), followed by *Bergenia ciliata* (64.71). *Asparagus racemosus*, *Berberis lyceum*, and *Dactylorhiza hatagirea* each had an FL value of 52.94 (Table 3). These species were the most commonly used plants in the study area. The high FL values of these plants were consistent with their high RFC values, reflecting their widespread use for distinct medicinal purposes. These species are predominantly found in high-altitude regions and are frequently used to treat local ailments (Kumar 2017a, b; Ballabh et al. 2017).

The FL value of each plant was calculated within the specific ailment category that represents the uses of ethnomedicinal plants within the category (Table 5). In category 1, a total of 5 plants were used that ranged between 20 and 90 FL values; the maximum FL was recorded for *Dactylorhiza hatagirea* (90), followed by *Rheum australe* (40), and each remaining plant (*Arisaema propinquum*, *Cannabis sativa*, *Paris polyphylla*) had 20 FL value. Under category 2, a total of 6 plants were used that ranged between 12.50 and 68.75 FL values; the *Aconitum heterophyllum* was recorded for its higher FL value for this category. Under category 3, a total of 10 plants were discussed by the respondents among them *Aconitum heterophyllum* recorded the highest 58.82 FL value. In category 4, a total of 2 plants were used and both had 42.86 FL value. Under category 5, a total of 2 plants were used among them *Nardostachys jatamansi* had 66.67 FL and *Malus domestica* had 33.33 FL value. In category 6, a total of 3 plants were used among them *Berberis lyceum* had 50 FL while the remaining plants had 25 FL values. Categories 7 and 8 were represented by a single plant each and had 100 FL values. In Category 9, a total of 2 plants



Table 5 Fidelity level (FL) of identified ethnomedicinal plants within the selected ailment categories

Ailment categories	Ethnomedicinal plants	Taxa informants	Total informants	FL
Category 1	<i>Arisaema propinquum</i> Schott	2	10	20.00
	<i>Cannabis sativa</i> L.	2	10	20.00
	<i>Dactylorhiza hatagirea</i> (D.Don) Soó	9	10	90.00
	<i>Paris polyphylla</i> Sm.	2	10	20.00
	<i>Rheum australe</i> D.Don	4	10	40.00
Category 2	<i>Aconitum heterophyllum</i> Wall. ex Royle	11	16	68.75
	<i>Cannabis sativa</i> L.	3	16	18.75
	<i>Fritillaria cirrhosa</i> D.Don	2	16	12.50
	<i>Quercus leucotrichophora</i> A. Camus	4	16	25.00
	<i>Swertia chirayita</i> (Roxb.) H.Karst.	5	16	31.25
	<i>Taxus wallichiana</i> Zucc.	2	16	12.50
Category 3	<i>Aconitum heterophyllum</i> Wall. ex Royle	10	17	58.82
	<i>Ajuga integrifolia</i> Buch.-Ham. ex D.Don	4	17	23.53
	<i>Allium humile</i> Kunth	2	17	11.76
	<i>Angelica glauca</i> Edgew.	4	17	23.53
	<i>Berberis lycium</i> Royle	2	17	11.76
	<i>Cannabis sativa</i> L.	3	17	17.65
	<i>Carum carvi</i> L.	2	17	11.76
	<i>Malus domestica</i> (Suckow) Borkh.	4	17	23.53
	<i>Paris polyphylla</i> Sm.	2	17	11.76
	<i>Quercus leucotrichophora</i> A. Camus	3	17	17.65
	<i>Berberis lycium</i> Royle	3	7	42.86
Category 4	<i>Rheum australe</i> D.Don	3	7	42.86
	<i>Malus domestica</i> (Suckow) Borkh.	2	6	33.33
Category 5	<i>Nardostachys jatamansi</i> (D.Don) DC.	4	6	66.67
	<i>Berberis lycium</i> Royle	4	8	50.00
Category 6	<i>Juglans regia</i> L.	2	8	25.00
	<i>Prunus cerasoides</i> Buch.-Ham. ex D.Don	2	8	25.00
	<i>Bergenia ciliata</i> (Haw.) Sternb.	11	11	100.00
Category 7	<i>Taxus wallichiana</i> Zucc.	4	4	100.00
Category 8	<i>Asparagus racemosus</i> Willd.	3	4	75.00
Category 9	<i>Thalictrum foliolosum</i> DC.	4	4	100.00

were used among them *Thalictrum foliolosum* had a 100 FL value and *Asparagus racemosus* had 75 FL values (Table 5).

Category 1, which encompasses dermatological disorders, is notably common in the study area, where plants are frequently used to treat skin conditions like boils, cuts, and wounds. *Dactylorhiza hatagirea* exhibited the highest FL value in this category due to its high medicinal value, being widely used for ailments such as dysentery, diarrhea, chronic fever, cough, stomachache, burns, fractures, and general weakness (Chandra et al. 2022; Jodh et al. 2022). Other plants like *Rheum australe*, *Arisaema propinquum*, *Cannabis sativa*, and *Paris polyphylla* also demonstrated high FL values, reflecting their frequent usage in the study area (Kumar 2017a, b; Singh and Dixit 2017; Monika et al. 2020; Kumar et al. 2020, 2023; Tiwari et al. 2020; Painuli et al. 2021). *Aconitum heterophyllum* had the highest FL in

Categories 2 and 3, which represent ailments such as fever, cough, and cold (Category 2), and metabolic disorders like diabetes, diarrhea, dysentery, jaundice, stomachache, and hyperuricemia (Category 3). This plant effectively treats these symptoms (Singh et al. 2017; Singh and Dixit 2017; Kumar and Singhal 2019; Devi et al. 2024). *Berberis lyceum* and *Rheum australe* showed higher FL values in Category 4, which addresses internal injuries and muscular pain, as both plants are widely used for such conditions (Ballabh et al. 2017; Bhat et al. 2021; Jan et al. 2021). *Nardostachys jatamansi* and *Malus domestica* were highly effective in treating cardiac-neurological disorders (Category 5). Similar patterns of these symptom control were recorded in earlier studies (Bhattacharjee and Chakraborty 2018; Mukne et al. 2024). Meanwhile, *Berberis lyceum*, *Juglans regia*, and *Prunus cerasoides* were used for bone-related ailments,

including arthritis, joint pain, bone fractures, and toothache (Category 6). The earlier studies also suggest these plants for similar disease management (Jabeen et al. 2009; Maqsood et al. 2022). In Category 7, *Bergenia ciliata* was frequently employed to treat calculus, a finding consistent with previous studies (Saha et al. 2014; Paudel et al. 2018; Kumar et al. 2018; Balkrishna et al. 2024). *Taxus wallichiana*, native to the Himalayas, had a high FL value in Category 8 due to its use in treating cancer and ulcers. This plant is the source of taxol, a potent anticancer agent effective against breast and ovarian cancers (Kovács et al. 2007; Juyal et al. 2014), and its ethnobotanical importance is similar to the earlier studies (Bisht et al. 2013; Devi et al. 2024; Balkrishna et al. 2024). Finally, in Category 9, which addresses genito-urinary ailments such as sexual disorders, spermatorrhea, and urinary diseases, *Asparagus racemosus* and *Thalictrum foliolosum* were found to be highly effective. While *Asparagus racemosus* has been well-documented for treating these conditions (Alok et al. 2013; Vyas et al. 2018; Ashwinidevi et al. 2021; Arya et al. 2023), *Thalictrum foliolosum* showed the highest FL value in this category, despite no prior records of its use for such ailments. This discrepancy highlights the need for further evaluation of *Thalictrum foliolosum*, exploring its potential for pharmaceutical applications and broader benefits for human welfare.

Relative importance level (RIL)

The importance of a plant species increases when it is used by informants to treat more diseases. Plants with high RIL values may be ascribed to both their great effectiveness and the local population's understanding of their specific application in herbal medicine. Here, the RIL ranged between 0.09 and 0.59 (Table 3). *Aconitum heterophyllum* had the highest reported RIL values at 0.59, while *Swertia chirayita* came in second with 0.50 RIL. The RIL value increases

proportionally with the number of respondents, indicating that more widely known plants tend to have higher RIL values (Umair et al. 2019). In this study, *Aconitum heterophyllum* and *Swertia chirayita* possesses high RIL values due to their widespread recognition in high-altitude regions, where a majority of respondents were familiar with their use in treating local ailments. Plant species with elevated RIL values often have a broader geographic range, and higher levels of awareness among informants, and are linked to a greater degree of cultural and medicinal significance.

Corrected fidelity level (CFL)

The CFL index was employed to rank plant species based on their FL and RIL values. In this study, CFL levels ranged from 1.07 to 45.19 (Table 3). Six plants, namely *Aconitum heterophyllum* (45.19 CFL), *Swertia chirayita* (32.35 CFL), *Rheum australe* (21.66 CFL), *Quercus leucotrichophora* (21.66 CFL), *Taxus wallichiana* (21.66 CFL), and *Carum carvi* (17.11 CFL), exhibited CFL values exceeding 10. This reflects the growing reliance on traditional medicine among the local population in the study area. These species, with high CFL values, also aligned with high RIL values, reflecting their widespread use and cultural importance. Therefore, further investigation into the medicinal properties of these species is recommended, including the screening of bioactive compounds and evaluation of pharmacological activities. This approach may not only validate traditional uses but also contribute to the discovery of new therapeutic drugs and expand scientific knowledge.

Similarity indices

This study was compared with 12 published ethnomedicinal documents from related regional sources (Table 6). The comparative analysis revealed that the similarity

Table 6 Comparison of local and neighboring areas using similarity indices (JI% and QS%)

Studied areas	*	**	JI%	QS%	Citation
Uttarkashi District, Uttarakhand	56	7	9.86	17.95	Rawat and Jalal 2011
Sub-Himalayan region, Uttarakhand	24	3	6.98	13.04	Sharma et al. 2013
Kumaon Himalaya, Uttarakhand	89	6	5.71	10.81	Singh et al. 2014
Tons Watershed, Uttarakhand	84	9	9.28	16.98	Kala 2015
Asi Ganga sub-basin, Uttarakhand	76	12	13.95	24.49	Nand and Naithani 2018
Jaunsari Tribe, Uttarakhand	54	5	7.04	13.16	Kumar et al. 2019
Uttarkashi District, Uttarakhand	82	4	4.00	7.69	Kumar and Singhal 2019
Bhatwari Block, Uttarkashi, Uttarakhand	60	7	9.33	17.07	Monika et al. 2020
Khatling Valley, Uttarakhand	68	12	15.38	26.67	Hussain et al. 2023
Uttarkashi District, Uttarakhand	54	8	11.76	21.05	Devi et al. 2024
Valley of Flowers, Uttarakhand	53	9	13.64	24.00	Basotra et al. 2024
Tribal Communities, Uttarakhand	238	17	7.00	13.08	Balkrishna et al. 2024

*No. of species in cited studied, **No. of species common in cited and current studies



index for 22 documented medicinal plants ranged from 4 to 15.38% in terms of JI%, and from 7.69 to 26.67% for QS% (Table 6). Jaccard's and Sørensen's similarity indices were used to assess floral similarity by comparing this case study with earlier reports. The Jaccard's index is traditionally used in community ecology, it is increasingly applied to compare pharmacopeias and medicinal flora (Rahman et al. 2019). Statistically, both indices exhibited a strong positive correlation ($y = 0.5579x$, $r^2 = 0.993$) with one another. A detailed summary of these indices is provided in Table 8. The analytical approach of Jaccard's and Sørensen's similarity indices both determines only the common floral similarity by comparison of a case study with previous documentations. The higher percentages for these indices were observed in areas geographically closer to the current study, indicating that the documented plants are commonly found in both current and previous research. The comparative study with Khatling Valley (Hussain et al. 2023) and Asi Ganga sub-basin (Nand and Naithani 2018) showed the highest similarity they probably could be attributed to the similar culture of ethnobotanical knowledge. The lower similar index means the cultural loss of ethnobotanical knowledge, and change in floral diversity among the studied areas.

Table 7 Pearson's correlation coefficient matrix among variables in the documented ethnomedicinal plants ($p = 0.05$)

	RFC	UV	FL	RIL	CFL
RFC	1.00				
UV	−0.01	1.00			
FL	1.00	−0.01	1.00		
RIL	1.00	−0.01	1.00	1.00	
CFL	0.98	−0.01	0.98	0.98	1.00

Table 8 Summary statistics of different indices at 95% of significant level

Variables	Mean	Median	Mode	Standard error	Standard deviation	Minimum	Maximum	Sign
Variables for documented ethnomedicinal plants								
RFC	0.30	0.24	0.24	0.04	0.19	0.12	0.76	0.09
UV	1.24	1.00	1.00	0.09	0.42	1.00	2.50	0.19
FL	29.68	23.53	23.53	4.12	19.34	11.76	76.47	8.57
RIL	0.23	0.18	0.18	0.03	0.15	0.09	0.59	0.07
CFL	9.56	4.28	4.28	2.55	11.96	1.07	45.19	5.30
Variables for different ailment categories								
ICF	0.83	0.78	0.75	0.03	0.10	0.73	1.00	0.08
FL	54.25	47.06	23.53	9.34	28.02	23.53	100.00	21.54
Variables for previous and current studies comparison								
JI	9.49	9.31	—	1.03	3.57	4.00	15.38	2.27
QS	17.17	17.03	—	1.71	5.93	7.69	26.67	3.77

Pearson correlation coefficient matrix

The Pearson correlation coefficient measures the strength of the linear association between two variables. In this study, different indices (RFC, UV, FL, RIL, CFL) for the quantitative measurements of ethnomedicinal plants were analyzed and correlated at a 95% significance level ($p = 0.05$) (Table 7). The correlation between RFC and UV was non-significant, showing a negative association ($y = 2.9809x$, $r^2 = -2.668$). RFC displayed a strong positive correlation with FL ($y = 100x$, $r^2 = 1$), RIL ($y = 0.7727x$, $r^2 = 1$), and CFL ($y = 40.32x$, $r^2 = 0.804$). Conversely, UV exhibited a very strong negative correlation with all the indices: FL ($y = 0.0298x$, $r^2 = -885$), RIL ($y = 3.8577x$, $r^2 = -2.668$), and CFL ($y = 0.052x$, $r^2 = -5.533$). FL showed a strong positive correlation with both RIL ($y = 129.41x$, $r^2 = 1$) and CFL ($y = 2.1898x$, $r^2 = 0.594$). The correlation between RIL and CFL was also strongly positive ($y = 0.0169x$, $r^2 = 0.594$). Summary statistics for these indices are presented in Table 8.

Market value of valuable ethnomedicinal plants

In national and international markets, the trade in medicinal plants is quite important. In 2017, the National Medicinal Plants Board (NMPB) estimated the global trade value of medicinal plants to be approximately US\$120 billion, with an annual growth rate of 2.4%. This highlights the significant economic importance of medicinal plants in global markets, driven by increasing demand for natural remedies and herbal products. By 2050, this global market is predicted to have grown to US\$5 trillion due to its fast expansion (Alamgir 2017). Asian nations are significant contributors to this trade, especially India, which comes in second place to China (Vasisht et al. 2016; Caporale et al. 2020). The Indian medicinal plant market was estimated to be worth Rs. 4.2 billion (US\$56.6 million) in 2019 and is expected to reach

Rs. 14 billion (US\$188.6 million) by 2026 (Gautam et al. 2023). Due to their scarcity, endemism, dispersed populations, and capacity to treat a variety of illnesses, Himalayan medicinal plants are highly sought among traded plants (Gautam and Raina 2016, 2019; Raina and Gautam 2020; Gautam et al. 2023). Based on the RFC, FL, and CFL indices, this study indicates *Aconitum heterophyllum*, *Bergenia ciliata*, *Asparagus racemosus*, and *Berberis lycium* as plants of substantial value. *Allium humile* and *Paris polyphylla* are recognized for having strong UV and RIL indices. Furthermore, the Himalayan region makes great use of and values *Swertia chirayita* and *Angelica glauca*.

The native range of *Aconitum heterophyllum* is from the Central Himalaya to North Pakistan. It is a perennial or tuberous geophyte mostly found in the temperate biome. Due to its numerous therapeutic applications in treating microbiological infections, fever, vomiting, coughing, diarrhea, and indigestion, it is one of the ingredients in many Ayurvedic formulations where it is considered as 'Ativisha' (Ayurvedic Pharmacopoeia of India 2008; Kumar et al. 2019). According to the National Medicinal Plants Board of India, the product is traded annually in 100–200 metric tons for 4000 Rs/kg (Wani et al. 2022). This indicates a significant market demand.

Allium humile is a highly favored herbal spice in the wild, and families in the Niti valley of the Nanda Devi Biosphere Reserve gather roughly 1220 kg of it each year, for an estimated maximum of Rs 5098.62 per family (Maikhuri et al. 2017). *Allium humile* is native to North Pakistan, West Himalaya, and China. It is mostly found in the temperate biome and is a bulbous geophyte. It is employed as a blood purifier, an anti-inflammatory, an anti-asthmatic, an anti-diabetic, and a seasoning agent in Indian medicine because of its significant effect against various diseases. Additionally, it is employed as an anti-cancer agent and to treat cardiovascular diseases, gastrointestinal issues, asthma, jaundice, and other conditions (Anees et al. 2024).

Angelica glauca is a medicinal herb that is endangered and endemic to the Himalaya. It is found in Uttarakhand, ranging from 2600 to 3700 m above sea level (Arya et al. 2015). *Angelica glauca* is native to East Afghanistan, West Tibet, and the West Himalaya. It grows mainly in the temperate biome and is a perennial. In the market, its roots are sold for 900 Rs/kg (Arya et al. 2015). It is highly prized for both culinary and medicinal uses. While the entire plant is edible and medicinally significant, the roots are primarily responsible for the plant's bioactive potential, which is used to treat a variety of conditions including bronchitis, dysmenorrhea, anorexia, rheumatism, amenorrhea, polycystic ovary syndrome, and disorders of the female reproductive system (Sood et al. 2019; Kumar et al. 2022; Gautam et al. 2023).

Asparagus racemosus is a well-known Ayurvedic rasayana that is used to treat a variety of conditions including

nerve disorders, dyspepsia, tumors, inflammation, neuropathy, and hepatopathy. It also increases lifespan, improves mental performance, and energy, and adds vitality to the body (Alok et al. 2013). Its native is tropical Africa to North Australia. It grows mostly in the seasonally dry tropical habitat and is a climber. By 2023, the extract's worldwide market is anticipated to be valued at US\$ 635 million, growing at a compound annual growth rate of 4.1% between 2023 and 2033 (FMI 2024). It is significant for the various Ayurvedic formulations; the Indian National Medicinal Plants Board estimates that it is traded up to 2000–5000 metric tons annually.

Berberis lycium is an evergreen shrub and its native range is from East Afghanistan to Himalaya and India. It is a shrub that thrives mostly in the temperate biome. Many illnesses, including those of the skin and liver, oral ulcers, stomach issues, piles, jaundice, conjunctivitis, bone fractures, leprosy, and rheumatism, can be effectively treated with it (Sevik et al. 2012; Ali et al. 2015; Wang et al. 2018). Furthermore, it is utilized for antiglycation, diabetes, ocular conditions, menorrhagia, fever, diarrhea, intestinal colic, and internal wounds (Adhikari et al. 2019; Ahmad et al. 2024). It is particularly vital for the various Ayurvedic formulations. Its market price is around 3–6 USD/kg (Ahmad et al. 2020), and the National Medicinal Plants Board of India estimated that its trade is about 1000–2000 metric tons annually.

Bergenia ciliata is a very important plant for the various Ayurvedic formulations. Its native range is from West Himalaya and South-West Nepal. It grows best in the temperate biome and is a perennial. The rhizome of *Bergenia ciliata* has been used for a century to treat lung infections, piles, leucorrhea, and kidney and bladder stones (Ahmad et al. 2018; Koul et al. 2020). The National Medicinal Plants Board of India calculated that the plant is traded for between 1000 and 2000 metric tons annually, with an average market price of 169.29 Rs/kg.

Paris polyphylla is native to the Himalaya, Central China, and North Myanmar. It is a rhizomatous geophyte and is mostly found in the temperate biome. It is utilized in many medical systems to treat a variety of illnesses due to its immense therapeutic qualities. People all around the world benefit from its anti-microbial, anti-viral, and immunomodulating qualities (Thakur et al. 2023). It is well-known for the therapeutic qualities of its roots, and the Medicinal Plants Board of India estimates that its average market price is 3374 Rs/kg annually.

Swertia chirayita grows mostly in the temperate biome and is either annual or biennial. Its native ranges from Himalaya to Asam. It has a wide range of pharmacological properties and is used in traditional medicine to treat several disorders, including diabetes, liver diseases, and malaria. The medicinal use of this plant is extensively recorded in several ancient medical systems such as Ayurveda, Unani, Siddha,



and the Indian Pharmaceutical Codex, as well as in the British and American Pharmacopoeias (Mazumder et al. 2023). The National Medicinal Plants Board of India estimated that its yearly trade is about 500–1000 metric tons at an average price of 480 Rs/kg.

Conclusions

The traditional plant medicine practices of the Himalayan region, particularly those relying on medicinal plant species, are rooted in the ethnobotanical knowledge of local communities, with older generations serving as key repositories of this wisdom. In the high altitudes, plant families like Apiaceae, Ranunculaceae, Rosaceae, and Taxaceae dominate due to their abundance, with a particular focus on their roots, which hold high medicinal value due to their dormancy during harsh winter months. The study highlights the frequent use of medicinal plants for treating metabolic disorders, with plants such as *Angelica glauca*, *Aconitum heterophyllum*, *Berberis lycium*, *Carum carvi*, *Malus domestica*, *Quercus leucotrichophora*, and *Cannabis sativa* being central to traditional remedies. The ICF reveals that stone problems (Category 7) are highly prevalent in the region, often treated using *Bergenia ciliata*. In terms of medicinal plant use, species like *Aconitum heterophyllum*, *Bergenia ciliata*, *Asparagus racemosus*, *Berberis lycium*, and *Dactylorhiza hatagirea* show the highest RFC and FL, indicating their common use and importance. Additionally, *Malus domestica* shows the highest UV due to its widespread availability and significance among respondents. Notably, this study documents the use of *Thalictrum foliolosum* for genito-urinary ailments (Category 9) for the first time, offering new insights into its ethnomedicinal potential. However, several of these medicinal plants are under threat, with species like *Aconitum heterophyllum*, *Angelica glauca*, and *Dactylorhiza hatagirea* classified as endangered, and *Nardostachys jatamansi* considered critically endangered due to overexploitation driven by their high market value. Immediate conservation measures are essential to protect these species and their habitats. The findings of this study provide a valuable foundation for future research aimed at preserving indigenous ethnomedicinal knowledge, exploring the bioactive compounds of key medicinal plants, and identifying the most significant flora for conservation in the Himalayan region.

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Data availability The data is provided in the article, this is own collected data and not generated from any source.

Declarations

Conflict of interest Authors declared there is no conflict of interest.

Research involving human and animal participants None of the authors have experimented on humans or animals for this study.

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