Diversity of the herbaceous flora and their indigenous medicinal uses at Theeing Valley, District Astore, Gilgit-Baltistan, Pakistan

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Research

Abstract

Background: The study was conducted during the years 2022 to 2024 in Theeing Valley, District Astore, Gilgit-Baltistan, Pakistan, with the aim of creating an inventory of herbaceous flora and documenting indigenous knowledge from local communities and plant experts.

Methods: We collected ethnomedicinal information from the study area via questionnaires, close and open interviews, involving 42 local inhabitants during the entire field survey. To assess plant species importance, we used indices like relative frequency citation, fidelity level, use value, Informant Consensus Factor.

Results: The research documented 62 herbaceous plants for therapeutic use in different ailments, followed by 49 genera which belongs to 26 different families. Among these, the Asteraceae family found predominant with (10) species. The study totally focused on herbaceous flora, among parts use in the recorded flora, the leaves (25%) were the dominating part of the plants, while the prevalent preparation method was decoction (58%). Whereas the life form hemicryptophyte and leaf spectra nanophyll dominance indicates a harsh climate in the region. The highest RFC (0.952), UV (0.905), for *Delphinium brunonianum*. FL (100%) reported for *Thymus linearis* and *Delphinium brunonianum* whereas the highest ICF (0.97) for the Urinary tract infection indicates the importance in the current study area. Pearson correlation analysis showed a strong positive correlation ($r = 0.701$, $r^2 = 0.492$) between RFC and UV. ANOVA revealed significant differences in UV ($F = 80.01$) and RFC ($F = 108.76$) across the three clusters, with $p < 0.0001$, indicating notable variation in cluster means.

Conclusions: The research highlights how indigenous communities use medicinal plants for different ailments. Despite elders having valuable indigenous knowledge, it is declining due to oral transmission only. Emphasizing the need for documentation is crucial to preserve this wisdom for future research.

Keywords: Astore, Ethnobotany, medicinal plants, Parishing, traditional knowledge

Background

The utilization of wild plant species for medicinal purposes is a longstanding practice deeply embedded in the ancient history of human civilization (Pradhan *et al.* 2020; Jan *et al.* 2020). These plants grow naturally without human intervention (Motti, 2022). These are harvested from the untamed, natural environment, free from human cultivation (Rehman *et al.* 2024; Nazar *et al.* 2022). During food shortages, health issues, wild edible and medicinal plants provide vital sustenance, supporting food security and well-being in vulnerable households (Borelli *et al.* 2020; Motti, 2022).

With 700 million people facing severe food shortages globally, wild edible plants serve as their best alternative food source (Rehman *et al.* 2024; Dejene *et al.* 2020). 35,000 to 70,000 plant species are used in folk medicine globally, showing diverse cultural reliance on natural remedies (Noor *et al.* 2012). Indigenous plants provide about 75% of plant-based medicines, crucial for human health globally (Zareef *et al.* 2023).

Around 6,000 species of flowering plants are documented in Pakistan, with approximately 2,000 species deeply embedded in the nation's cultural heritage and significance (Abbas *et al.* 2024). In the 1950s, about 84% of Pakistanis used traditional medicine for health, possibly less today (Goodman and Ghafoor, 2011). The documentation of herbaceous diversity in Pakistan is notably insufficient. From 6000 plant species, only 400 to 600 are officially recognized for their medicinal benefits. (Ikramullah *et al.* 2007).

The richness of traditional medicine in Gilgit-Baltistan (GB) stems from its diverse ethnicities and historical connections to various civilizations, making it uniquely abundant in healing practices (Caroe and Biddulph 1972). GB, with its rugged mountainous landscape, is predominantly rural, where agriculture and livestock farming form the backbone of the local economy. In these remote areas, traditional medicine is widely favored for its effectiveness, low cost, and deep cultural roots, particularly in the absence of modern healthcare alternatives (Bibi *et al.* 2014). Medicinal plants are vital to indigenous healthcare, with local communities relying on their healing properties for generations. This traditional knowledge is an essential part of the region's cultural heritage, highlighting the deep connection between the people and their environment. Additionally, many modern pharmaceuticals originate from these plants, indicating a significant potential for new drug discoveries (Hussain *et al.* 2024). Influenced by its ties with neighboring Chinese regions, the region boasts rich biodiversity. Within this dynamic ecosystem, around 300 species of medicinal and aromatic plants flourish, contributing to its vibrancy (Khan *et al.* 2011; Bano *et al.* 2014; Wali *et al.* 2022). The increasing utilization of plants in medicinal applications is attributed to their minimal side effects, cost-effectiveness, and superior efficacy when compared to synthetic drugs (Abbas *et al.* 2022; Abbas *et al.* 2016).

Astore Valley has long been the top exporter of medicinal plants in Gilgit-Baltistan, considered as key hub for medicinal plants (Khadim *et al.* 2024; Noor *et al.* 2014; Shinwari and Gilani 2003). Medicinal plants in the Gilgit-Baltistan region are facing significant peril attributed to extensive grazing, uprooting, soil erosion, natural calamities, and climate change, collectively compromising their sustainability within the area (Khadim *et al.* 2024; Shedayi 2012; Arshad *et al.* 2014). Traditional knowledge of medicinal plants is widely held among rural populations, with its preservation relying primarily on verbal transmission across generations (Bibi *et al.* 2014). Exploring how various cultures utilize herbaceous plants is vital for preserving traditional wisdom. These studies are key to safeguarding valuable knowledge from being lost forever (Hyder *et al.* 2013). By understanding how plants are used in different communities, we can ensure that centuries-old practices are not forgotten. This effort is crucial for maintaining the richness of cultural heritage for future generations (Khadim *et al.* 2024; Kunwar and Bussmann, 2008).

In the study area, herbaceous plants are crucial not only for their medicinal properties but also for their nutritional benefits. They are intricately woven into cultural traditions, enhancing rituals and crafts that shape community identities. Protecting this plant diversity is essential for the well-being of both the local population and their livestock, particularly during the challenging winter months. The study site has not yet explored the diversity of herbaceous medicinal plant species. This study aims to fill that gap by documenting the diversity of herbaceous flora and the indigenous knowledge of medicinal plants in the area.

Materials and Methods

Study area

The research area “Theeing” (Paeen and Bala) lies between latitudes 35°23'45.9"N and 74°58'08.6"E longitude and the altitude between 2700m to 5000m. The area, with its snowy peaks and mountainous terrain, boasts rich biodiversity shaped by sunlight, rainfall, soil, wind, and living organisms. The inhabitants of this region primarily rely on agriculture and natural resources, growing crops like wheat, barley, potatoes, and various vegetables, and raising livestock such as yaks, sheep, and goats. Due to inadequate healthcare services and the absence of nearby medical facilities, the community depends on a small dispensary that serves three villages. This dispensary, however, is not equipped to handle serious medical conditions. Consequently, the native people frequently turn to herbal medicine to meet their healthcare needs. The area is very captivating for its beautiful tourist places and lakes. (Khadim *et al.* 2024a, 2024b). Study area illustrated in (Fig. 1).

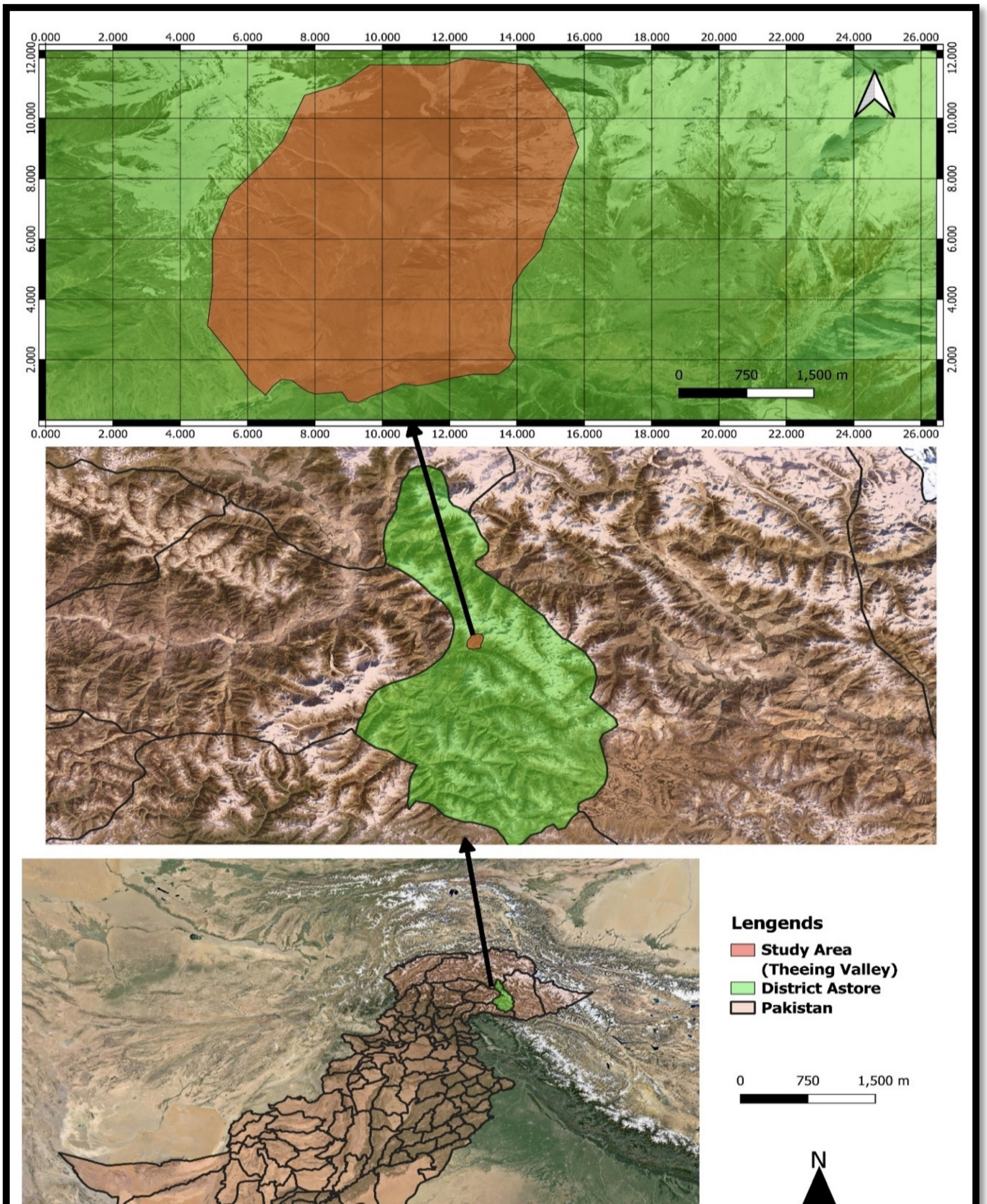

Figure 1. Map of study area.

The climate varies at different elevations within the research area. Winter, which runs from November to March, is marked by extreme cold and snow, January and February typically see the most snowfall, temperature on average (-8°C). Particularly, snowfall was delayed until February last year, possibly because of climate change. During the winter, residents depend on their saved food supplies (Khadim *et al.* 2024). During spring (April to mid-June), agricultural practices started. Summer (mid-June to August) lush greenery around the high mountains and surroundings, with July being the hottest month, temperature on average (20 °C). However, due to altitude variations, heavy rains occur during this season, bringing a cooling effect. Harvesting practices begin in August and continue thereafter. Autumn (September to October) is a brief but beautiful season. In mountainous areas, biodiversity is enhanced by differing altitudes, which support varying species distributions and flowering patterns across small geographical regions. (Khadim *et al.* 2024).

Field surveys and data collection

Field surveys were conducted in the years 2022 to 2024. On the field visit, we meticulously collect plant specimens through random sampling technique from various locations within the study area. Photographs were properly taken during field depicted in (Fig. 2).

Data preservation

Collected plant specimens were dried, pressed, and treated with a 1% $HgCl_2$ preservative before mounting on herbarium sheets. Then these species were affixed to herbarium sheets of a standardized size measuring 11.5 × 17.5 inches (Ahmad *et al.* 2017). Identification was assisted by Dr. Sujjad Hyder, and data authentication was ensured through comparisons with the KIU herbarium, taxonomic literature, manuals, and the Flora of Pakistan (Ali and Nasir, 1989-1991; Ali and Qaiser, 1993-2022; Nasir and Ali, 1970-1989). Voucher specimen numbers were assigned to each plant following the methodology outlined by (Jain and Rao, 1977). Information about plant specimens was noted on labels attached to herbarium sheets, and these specimens were then stored at the KIU herbarium for future research.

Collection of ethnobotanical information

Ethnomedicinal information was documented using open and semi-structured questionnaires, surveys, interviews, participant observations, and guided field walks (Khadim *et al.* 2024a, 2024b; Wali *et al.* 2022; Cavendish, 2012). While conducting the field survey, we engaged with 42 residents, including 29 males and 13 females. This interaction revealed the wealth of their traditional knowledge. The predominant native language spoken was Shina (Astori), and the entire population identified with the Islamic faith.

The study followed ethical guidelines, securing informed consent for interviews, and respecting intellectual property rights. We obtained explicit consent from participants and used interviews to collect systematic information on medicinal plant use.

Statistical analysis

The collected quantitative data was statistically examined, employing essential quantitative indices: Relative Frequency of Citation (RFC), Use Value (UV), Fidelity Level (FL), Pearson's coefficient correlation (PCC) and Informant Consensus Factor (ICF).

Relative Frequency of Citations (RFC)

Relative Frequency of Citations (RFC) as a method was used to gauge the importance of plant species cited by the participants (Nyasvisvo *et al.* 2024).

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

(0 < RFC < 1) It shows how important each plant species is by using Frequency of Citation (FC), where 'FC' is the number of informants mentioning a species, and 'N' is the total number of informants. (Abbas *et al.* 2024; Shah *et al.* 2023; Pradhan *et al.* 2020).

Use Value (UV)

The Use Value (UV) is used to express the relative importance of each plant as utilized by indigenous people. Ranging from zero to a positive value, the UV metric signifies higher importance with greater UV values and lower importance with lower UV values (Ud Din *et al.* 2024; Perveen *et al.* 2024; Zhou *et al.* 2023). Following the formula:

$$\mathbf{UV} = \frac{\boldsymbol{\Sigma Ui}}{\boldsymbol{N}}$$

Here, 'ΣUi' represents the total number of use reports from each respondent, and N denotes the overall number of respondents.


A
B
C
D

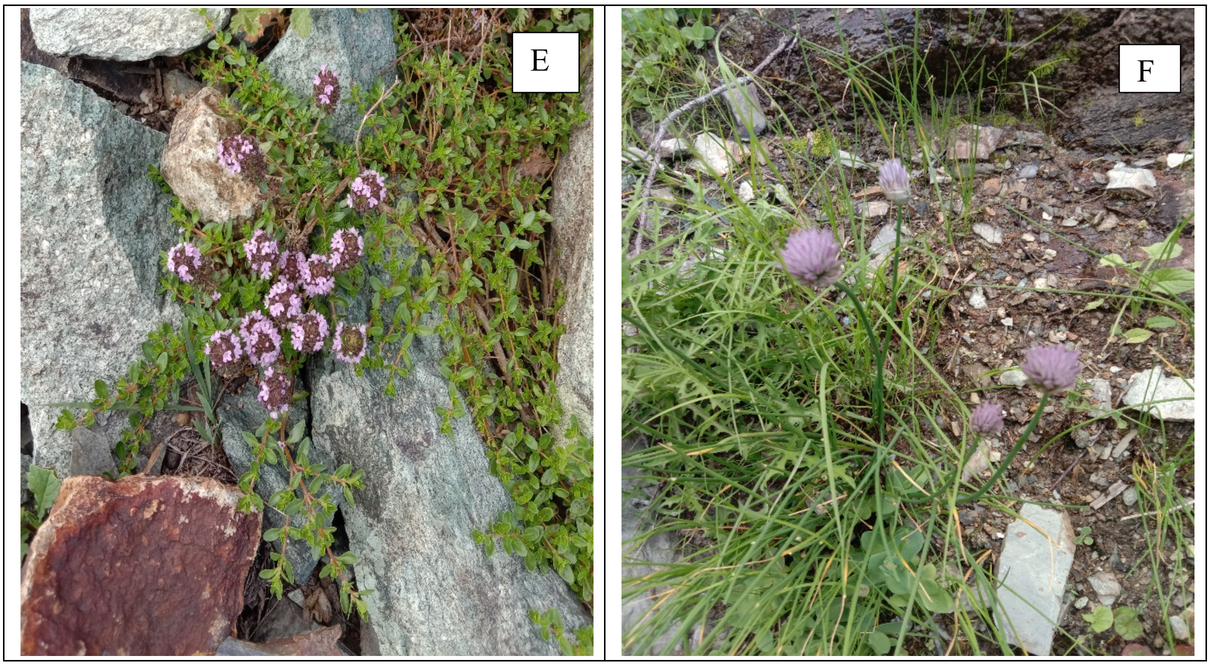

Figure 2. (A) The study area, (B and C) Herbaceous plant specimen collection, (D) Gathering ethnobotanical information, (E) *Thymus linearis*, and (F) *Allium schoenoprasum*.

Fidelity Level (FL)

The Fidelity Level is the percentage of respondents in the research area who reported using a specific plant species to treat a particular disease.

$$\mathbf{FL} = \frac{\boldsymbol{Np}}{\boldsymbol{N}} \times \mathbf{100}$$

Here, 'Np' stands for the specific number of citations for a particular ailment, while 'N' represents the total number of informants mentioning the species for any disease. (Hankiso *et al.* 2023).

Informant Consensus Factor (ICF)

Following the collection of ethnobotanical data, we computed the Informant Consensus Factor (ICF). In traditional medicine, there is a common practice of using the same plant for various unrelated ailments. To assess the consistency of ethnomedical knowledge, we applied ICF to evaluate the agreement among respondents concerning the utilization of plant species in each disease category (Heinrich 2000, Trotter and Logan, 1986).

$$\mathbf{ICF} = \frac{\boldsymbol{Nur} - \boldsymbol{Nt}}{\boldsymbol{Nt} - \mathbf{1}}$$

In this context, 'Nur' denotes the number of use reports for each disease category, and 'Nt' represents the count of species used in that category by all informants. The ICF values, ranging from 0 to 1, indicate the level of agreement among respondents. A greater ICF indicates a clear standard for choosing species to address a particular disease category (Horackova *et al.* 2023).

Pearson correlation

Pearson Correlation analysis was executed using SPSS version 20 to examine the relationship between RFC and UV. Furthermore, the calculation of r^2 was performed to quantify the cross-species variability in RFC explained by the variance in UV (Amjad *et al.* 2017).

K-means algorithm

We used Origin2024b software to apply K-means clustering, identifying patterns by grouping similar data points. Hierarchical clustering with dendrograms was then performed to explore similarities in plant species' UV and RFC distribution (Ali *et al.* 2022).

Results and Discussion

Demographic details

For the ethnobotanical data, we interacted with 42 local informants at the study site. The study investigated that the higher proportion of male is 29 (69%) and female is 13 (31%). The difference can be explained by the fact that women in rural areas tend to exhibit more reserved behavior and have lower levels of education compared to men. The age distribution of respondents revealed that 10 were between 25 and 40 years old, 15 were between 41 and 50, and 17 were over 51 depicted in (Table 1).

Table 1. Demographic details of informants.

Variables	Categories	No. of Individuals	%
Informants	Local	42	100
Gender	Male	29	69
	Female	13	31
Age	25-40	10	23.8
	41-50	15	35.7
	51 and above	17	40.5
Villages	Theeing Bala	21	50
	Theeing Paeen	21	50
Educational Background	Former	24	57
	Elementary school	7	17
	Secondary school	8	19
	College	3	7

Medicinal plant diversity

The current research documented a total of 62 medicinal plant species within the herbaceous flora, utilized for traditional healing. These plants belong to 49 genera and 26 families, The medicinal plants offer valuable insights into their distribution and significance (Table 2). Among these families, Asteraceae stands out as the most common, with 10 species, highlighting its abundance in the local flora used in traditional medicine. The dominant families having highest number of genera and species shown in (Fig. 3). Following closely were Polygonaceae with 9 species and Ranunculaceae with 5 species, underscoring their substantial presence in the study area. Similar findings in previous studies also highlight the prevalence of the Asteraceae family (Khadim *et al.* 2024, Shaheen *et al.* 2023).

Habit

The study focused on only herbaceous plant species, the recorded herbs were 62 species (100%) used to cure different ailments by the people of the study site, showcasing their adaptability. Previous studies also indicated that herbs were at the leading position to use in traditional medicine, (Khadim *et al.* 2024, Perveen *et al.* 2024, Shedayi *et al.* 2016, Cooper *et al.* 2005, Teklehaymanot 2009, Ahmad *et al.* 2014, Bahadur *et al.* 2023, Guo *et al.* 2023). The prevalence of herbs is ecologically significant, contributing to biodiversity and potentially holding cultural or medicinal importance within the community.

Life form

Plants were classified into life forms according to their functions, structures, and how they react to the surrounding environmental conditions. Various researchers conducting floristic studies worldwide have documented the prevalence of different plant life forms (Yatsenko *et al.* 2021). Raunkiaerian classification revealed dominancy of hemicryptophyte 45 species (74%), contributed very essential role in indigenous traditional medicines to treat different ailments, followed by Chaemephyte 11 species (18%), therophyte 3 species (5%) and cryptophyte 2 species (3%) and the lowest found in herbaceous flora of the study area the details depicted in (Fig. 4). The results dissimilar with (Parveen *et al.* 2021) their study showed dominancy of therophytes. The prevalence of hemicryptophytes in the study area indicates challenging climatic conditions, similar results with (Karima *et al.* 2024, Arif & Haider 2022).

Table 2. Comprehensive Inventory of Herbaceous Flora, Including Life Forms, Habit Categories, and Medicinal Uses in the Study Area.

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
	Amaryllidaceae										
1	*Allium fedtschenkoanum* Regel **SK-2223**	Cr	ME	Herb	**Paloon**	L	Decoction, Direct	onion substitute, digestive disorders	0.429	0.31	67
2	*Allium schoenoprasum* L. **SK-2224**	Cr	ME	Herb	**Paloon**	L	Decoction, Direct	onion substitute, digestive disorders	0.381	0.286	60
	Apiaceae										
3	*Pleurospermum govanianum* (DC.) Benth. ex C.B. Clarke **SK-2225**	He	N	Herb	**Not known**	WP	Direct	Used as forage, tonic for animals	0.119	0.19	17
4	*Carum carvi* L. **SK-2281**	He	L	Herb	**Hayoo**	S	Direct	Seeds: Anthelmintic, Cardioprotective, Premature seeds: Vertigo, respiratory disorders, Carminative, Hypotensive,	0.429	0.881	93
5	*Pleurospermum stylosum* C.B. Clarke **SK-2285**	He	L	Herb	**Khushy**	WP	Direct	Used as forage, tonic for animals	0.143	0.095	12
	Asteraceae										
6	*Anaphalis nepalensis* (Spreng.) Hand. -Mazz. **SK-2226**	He	N	Herb	**Chikee**	L	Decoction, powder	Digestive disorders, Aroma	0.286	0.119	33
7	*Anaphalis virgata* Thomson ex C.B. Clarke **SK-2227**	He	N	Herb	**Sangopaje**	WP	Decoction, Smoke	insect killers, respiratory disorders, Aroma	0.214	0.071	29
8	*Artemisia scoparia* Waldst. & Kit **SK-2228**	Ch	N	Herb	**Jaa**	WP	Decoction	Pain and Inflammation	0.452	0.571	64
9	*Artemisia rutifolia* Stephan ex Spreng. **SK-2229**	Ch	N	Herb	**Zoon**	WP	Decoction	Microbial infections, dermatitis	0.524	0.857	90
10	*Artemisia santolinifolia* Turcz. ex Besser	Ch	N	Herb	**Zoon**	WP	Decoction		0.595	0.833	86

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
	SK-2230							Inflammation, antibacterial and Tumor			
11	*Cousinia thomsonii* C.B. Clarke **SK-2231**	He	N	Herb	**Cahcukony**	WP	Direct, Decotion	Pain and inflammation, respiratory disorders, dermatitis	0.214	0.31	60
12	*Echinops echinatus* Roxb **SK-2232**	He	ME	Herb	**Jacheer**	WP	Juice	Digestive disorders, respiratory disorders, Pain and inflammation, Microbial infections	0.19	0.262	38
13	*Leontopodium nanum* (Hook. f. & Thomson ex C.B. Clarke) Hand.-Mazz. **SK-2233**	He	N	Herb	**Jangli kch**	WP	Decoction	used as forage, tonic	0.143	0.119	19
14	*Scorzonera virgata* DC. **SK-2234**	He	M	Herb	**Gori phool**	FL	Decoction	pain and inflammation, dermatitis	0.19	0.167	17
15	*Taraxacum officinale* L. **SK-2235**	Ch	ME	Herb	**Ishkanache**	L, R	Powder, juice	diuretic, blood purifier, Jaundice, Digestive dorders, respiratory disorders	0.619	0.31	36
					Boraginaceae						
16	*Arnebia euchroma* (Royle ex Benth.) I.M. Johnst. **SK-2236**	He	L	Herb	**Kono phoonar**	R	Powder	respiratory disorders, Menstrual disorders	0.333	0.095	14
17	*Cynoglossum glochidiatum* Wall. ex Benth. **SK-2237**	He	N	Herb	**Chiery**	AP	Decoction	Infertility disorders	0.167	0.143	17
18	*Lindelofia anchusoides* (Lindl.) Lehm. **SK-2238**	He	N	Herb	**Sharing**	P	Decoction	Dermitits, Fever, Pain	0.262	0.333	21
					Brassicaceae						
19	*Thlaspi arvense* L. **SK-2239**	Th	N	Herb	**Brigah**	S	Decoction	Diuretic, Tonic, antibacterial and antimicrobial	0.31	0.357	31

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
	Caryophyllaceae										
20	*Dianthus orientalis* Adams **SK-2240**	Ch	L	Herb	**Jangli kach**	S	Decoction	Dental Pain	0.143	0.548	26
	Crassulaceae										
21	*Hylotelephium ewersii* (Ledeb.) H. Ohba **SK-2241**	He	L	Herb	**Loyoun**	AP	Direct, Decoction	Appetizer	0.548	0.286	29
22	*Hylotelephium pakistanicum* (G.R.Sarwar) G.R.Sarwar **SK-2242**	He	N	Herb	**Rabrd**	WP	Decoction	respiratory disorders, Fever	0.286	0.214	17
23	*Rhodiola heterodonta* (Hook. f. & Thomson) Boriss. **SK-2243**	He	N	Herb	**Jangli**	L	Decoction	Digestive disorders, coagulant	0.262	0.143	21
24	*Rhodiola wallichiana* (Hook.) S.H. Fu **SK-2244**	He	L	Herb	**Not Known**	L	Decoction with milk, juice, paste	Wounds, cuts and burns	0.286	0.333	24
	Fabaceae										
25	*Cicer microphyllum* Royle ex Benth. **SK-2245**	He	N	Herb	**Khokooni**	S, FL	Direct	Digestive Disorders, vomiting	0.381	0.548	55
26	*Medicago sativa* L **SK-2246**	Ch	M	Herb	**Ishpit**	AP	Decoction, seeds	tonic, Arthritis	0.667	0.643	81
27	*Oxytropis chiliophylla* Royle ex Benth. **SK-2247**	He	L	Herb	**Haloskar**	AP	Decoction	Pain and inflammation	0.381	0.333	31
28	*Trifolium pratense* L. **SK-2259**	Th	N	Herb	**Chepatii**	L	Decoction	Respiratory disorders, Meningitis	0.214	0.429	55
	Gentianaceae										
29	*Gentianodes tianschanica* (Rupr.) Omer, Ali & Qaiser **SK-2248**	He	M	Herb	**NilKach**	L	Decoction, paste	Digestive Problems, wounds and cuts	0.571	0.31	38

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
30	*Gentianopsis vvedenskyi* (Grossh.) Pissjauk. **SK-2249**	He	M	Herb	**Shadny**	R	Decoction	Digestive disorders	0.333	0.262	31
					Geraniaceae						
31	*Geranium pratense* L. **SK-2250**	He	M	Herb	**Kurtakasho**	AP	Powder	Wounds and cuts, Arthritis, Urinary tract infections	0.31	0.167	26
					Lamiaceae						
32	*Mentha longifolia L.* **SK-2251**	He	N	Herb	**Phileel**	L	Juice	Arthritis, Fever, Respiratory disorders, Digestive disorders	0.833	0.738	76
33	*Mentha royleana* Benth. **SK-2252**	He	N	Herb	**Fileel**	L, ST	Decoction	Digestive Disorders	0.81	0.548	74
34	*Nepeta discolor* Royle ex Benth. **SK-2253**	He	N	Herb	**Shaye**	AP	Decoction	used against ringworms	0.381	0.548	29
35	*Thymus linearis* Benth. **SK-2254**	He	N	Herb	**Tumoro**	AP	Decoction	Respiratory disorder, digestive disorder, weight loss, decrease obesity, decrease cholesterol	0.904	0.834	100
					Onagraceae						
36	*Epilobium angustifolium* L. **SK-2255**	He	M	Herb	**Danoye**	L	Decoction, Paste	The digestive disorder, pain, and inflammation, gastrointestinal issues, wounds and cuts, dermatitis	0.214	0.095	19
					Orchidaceae						
37	*Dactylorhiza hatagirea* (D. Don) Soó **SK-2256**	He	ME	Herb	**Karah**	AP	Decoction	Kidney diseases, men's sexual issues (increase semen production)	0.357	0.262	19

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
38	*Epipactis gigantea* Douglas ex Hook. **SK-2257**	He	M	Herb	**Kachh**	R	Decoction	Tonic	0.119	0.048	12
	Oxalidaceae										
39	*Oxalis corniculata* L. **SK-2258**	He	N	Herb	**Char**	AP	Decoction	Digestive disorders	0.429	0.262	55
	Parnassiaceae										
40	*Parnassia nubicola* Wall. ex Royle **SK-2260**	He	N	Herb	**Shayee phoonar**	WP	Decoction	Digestive disorders	0.19	0.286	17
	Plantaginaceae										
41	*Picrorhiza kurrooa* Royle ex Benth. **SK-2261**	He	M	Herb	**Kardho**	R	Decoction	Digestive disorders, purifying blood, nervous pain, appetizer	0.357	0.405	33
	Podophyllaceae										
42	*Podophyllum emodi* Wall. ex Royle **SK-2262**	He	ME	Herb	**Ishmandy / Ishmanay**	RH, FR	Decoction	Rhzomes (Hepatic disease, Hair issues) Fruit: (digestive disorders) and tonic	0.571	0.738	55
	Polygonaceae										
43	*Aconogonon alpinum* (All.) Schur **SK-2263**	Ch	N	Herb	**Lamy**	WP	Direct	fever, heart issues and fodder for animals	0.357	0.262	76
44	*Bistorta vivipara* (L.) Gray **SK-2264**	Ch	N	Herb	**Rengle**	R, ST	Decoction	Respiratory disorders, hemorrhoids, digestive disorders, wounds and cuts	0.286	0.143	60
45	*Bistorta affinis* (D. Don) Greene **SK-2265**	He	N	Herb	**Rengle**	S, RH	Powder	Dysentery, pain and inflammation, Astringent (taken with milk)	0.31	0.143	64

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
46	*Oxyria digyna* (L.) Hill **SK-2266**	Th	N	Herb	**Chorko**	ST	Direct	fever and purifies the blood	0.405	0.31	29
47	*Rheum emodi* Wall **SK-2267**	He	ME	Herb	**Chuntal**	WP	Juice, Direct	Respiratory disorders, Mild astringent, Hair issuses, Blood purifier, digestive disorders	0.667	0.881	93
48	*Rumex patientia* L. **SK-2268**	He	ME	Herb	**Hobabal**	L, R	Decoction	Digestive disorders, dermatitis, respiratory disorders	0.571	0.405	76
49	*Rumex acetosa* L. **SK-2269**	He	ME	Herb	**Chirkhi**	L, R	Decoction	Digestive disorders, Arthritis	0.333	0.214	21
50	*Rumex nepalensis* Spreng. **SK-2270**	Ch	M	Herb	**Hobabal**	R	Decoction, powder	Digestive disorders, Arthritis, Pus remedy, respiratory disorders, Wounds, pain and inflammation	0.548	0.357	60
	Ranunculaceae										
51	*Aconitum violaceum Jacquem*. ex Stapf var. Violaceum **SK-2271**	He	M	Herb	**Booma**	R	Decoction, powder	Leprosy, sciatica and pain	0.31	0.262	33
52	*Aconitum violaceum* var. weileri (Gilli) Riedl **SK-2272**	He	M	Herb	**Bzoumolo**	RH	Direct, Paste	Arthritis Caution: Overdosing can lead to fatalities or mental health issues.	0.81	0.738	90
53	*Aquilegia fragrans* var. kanawarensis (Jacquem. ex Cambess.) Riedl **SK-2273**	He	N	Herb	**Shash**	WP	Decoction, ornamental	Astringent, Urinary tract infection, Used as an ornamental purpose	0.286	0.119	19
54	*Delphinium brunonianum* Royle **SK-2274**	He	Me	Herb	**Makhutii**	FL	Decoction	Heart disease, High BP, respiratory disorders,	0.905	0.952	100

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
								Arthritis, Dysentery, antidandruff			
55	*Pulsatilla wallichiana* (Royle) Ulbr. **SK-2275**	He	N	Herb	**Makhoty**	R, FL	Decoction	digestive disorders, menstrual disorders, fever, dermatitis	0.31	0.19	24
	Rosaceae										
56	*Fragaria nubicola* (Hook. f.) Lindl. ex Lacaita **SK-2276**	He	N	Herb	**Borsay**	FR., L R	Direct, Juice	digestive disorders, Antiseptic, Astringent, Diuretic, sexual disease	0.381	0.286	64
57	*Geum elatum* Wall. ex G. Don **SK-2277**	He	M	Herb	**Phonar**	R	Decoction	digestive disorders, astringent	0.19	0.071	17
	Saxifragaceae										
58	*Bergenia stracheyi* (Hook. f. & Thom.) **SK-2278**	Ch	ME	Herb	**Shapur**	L	Decoction	wounds and cuts, purifying blood, analgesics, digestive disorders, kidney stones	0.667	0.524	76
59	*Bergenia ciliata* Sternb. **SK-2279**	Ch	ME	Herb	**Shapur**	L	Decoction	Digestive disorders, wounds and cuts, purifying blood, kidney stones	0.619	0.571	74
	Scrophulariaceae										
60	*Verbascum thapsus* L. **SK-2280**	He	M	Herb	**Rangkato**	L	Decoction	Fever, respiratory disorders, digestive disorders, haemostatic, anti-enlargement(prostate), Lactogenic, anti-dandruff, anti-baldness.	0.738	0.381	69
	Urticaceae										

S. No	Family, Species and voucher number	Life Form	Leaf Spectra	Habit	Local Name	Plant Parts	Method of use	Purpose	UV	RFC	FL
61	*Urtica dioica* L. / **SK-2282**	He	M	Herb	**Juumii**	AP	Decoction	Vegetable, Hepatitis, digestive disorders, Arthritis, dermatitis, Wounds and cuts, respiratory disorders	0.643	0.571	76
					Violaceae						
62	*Viola biflora* L. / **SK-2283**	He	M	Herb	**Lilio**	WP	Decoction	respiratory disorders, kidney disease, hepatic disorders, dermatitis	0.619	0.333	60

Legends:
Life form: He Hemicryptophyte, Ch Chamaephyte, Cr cryptophytes, Th Therophytes **Plant parts** L leaves, FL flowers, AP aerial parts, R roots, WP whole plant, S Seed, FR Fruit, R Root, ST Stem, RH Rhizome

Leaf size spectra

The leaf size spectra analysis of plant communities in the studied area indicates dominance by Nanophyll species (44%), used in traditional medicine, followed by microphyll (24%), mesophyll (21%), and Leptophyll (11%) depicted in (Fig. 5). Microphylls are characteristic of steppes, while Nanophylls and Leptophyll are indicative of hot deserts (Cain & Castro 1959).

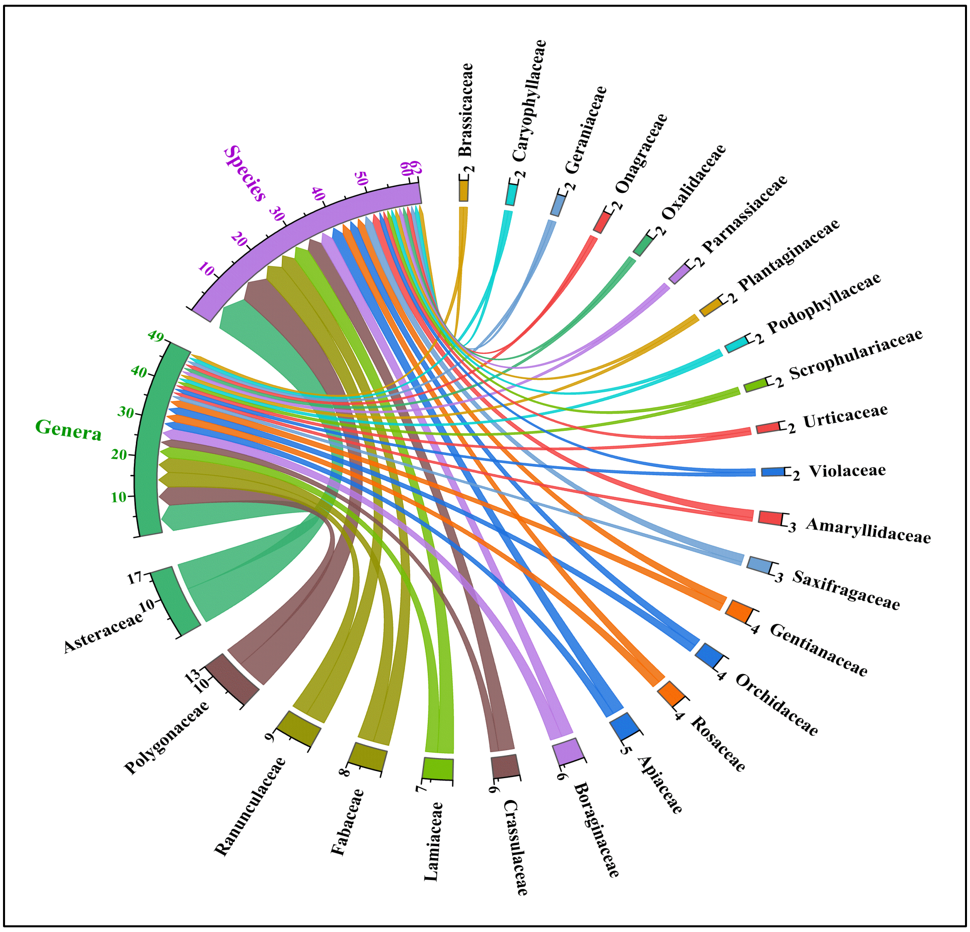

Figure 3. Highlighted the dominant families with number of genera and species in the study area.

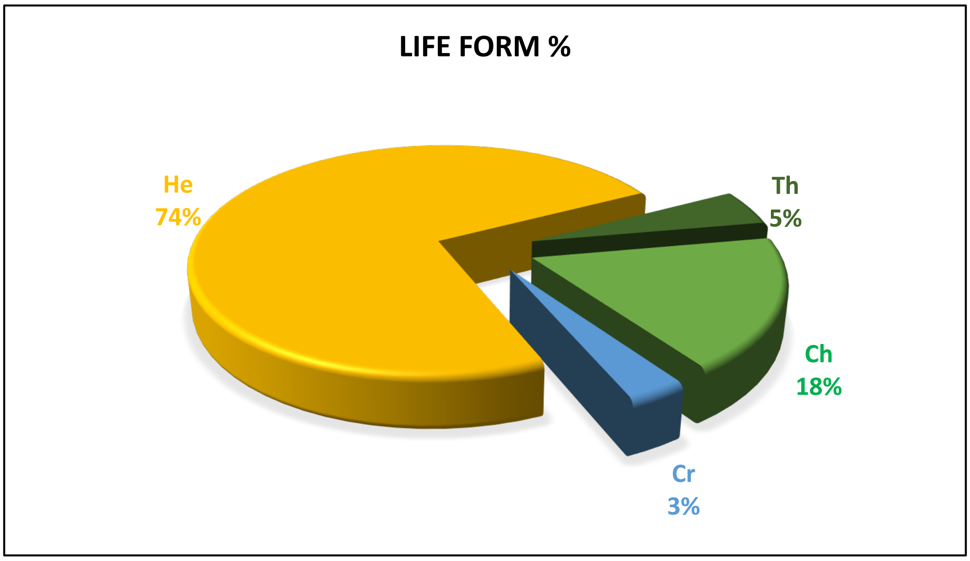

Figure 4. Life form percentages of herbaceous plants used to treat different diseases in the study area.

Parts used

The current research investigated the utilization of different plant parts for medicinal purposes in the study area. The utilization of different plant parts varies based on the application category (Gillani *et al.* 2024). The findings reveal that leaves were the most widely used plant part, constituting 25% of traditional medicinal practices shown in (Fig. 6). Other studies have found similar results (Khadim *et al.* 2024a, 2024b, Gillani *et al.* 2024, Kayani *et al.* 2024, Manzoor *et al*. 2023).

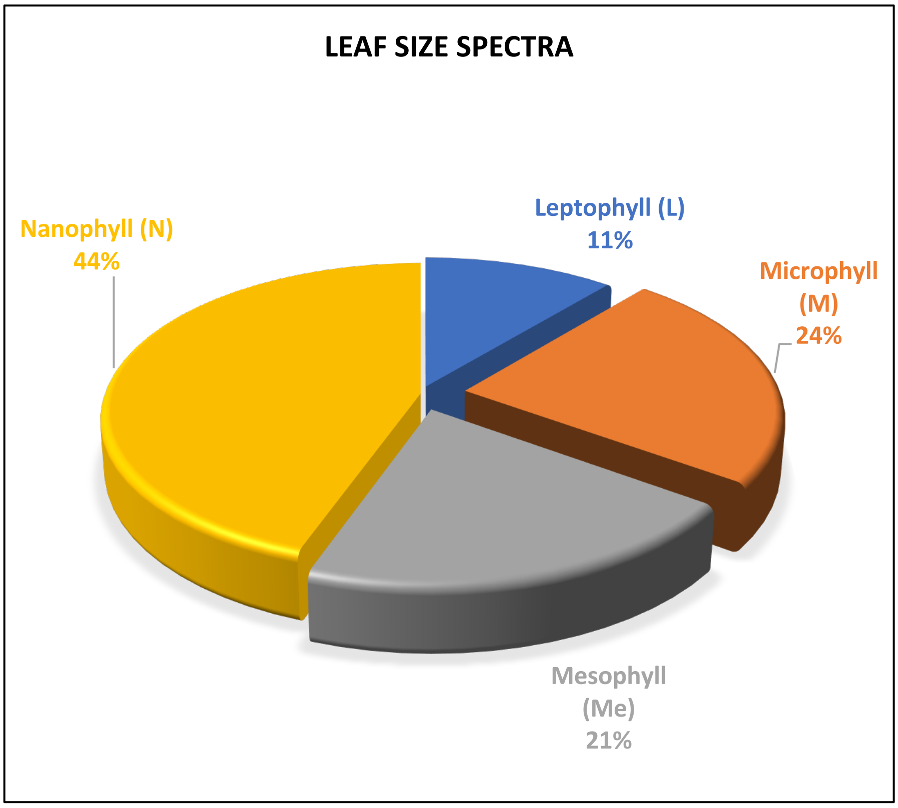

Figure 5. Leaf size spectra and percentages of medicinal herbaceous plants.

Leaves are highly valued for their abundant reservoir of advantageous compounds, including alkaloids and flavonoids. Their ease of harvest proves advantageous, ensuring extraction without detriment to the entire plant. This makes leaves a sustainable and valuable source of beneficial phytochemicals. (Panmei *et al.* 2019). Leaves are widely valued for medicinal use, rich in bioactive compounds (Abbas *et al.* 2023). Aerial parts and roots 17% each used for traditionally treating different ailments, while fruits/barriers and rhizomes each constitute 4%, being the least utilized. Despite lower prevalence, rhizomes may hold specific medicinal properties, influenced by cultural and regional factors. This diverse distribution emphasizes leaves as a prevalent and versatile resource, with rhizomes potentially significant in specific traditional practices.

Preparation and administration Method

Plant parts were used in different forms by the local people for treating different ailments. The details of preparation different methods are depicted in (Fig. 7). The most used method was decoction (58%), followed by direct parts used (17%) and least method smoke (1%) was used for traditional medicinal applications. Similar results were found in different regions of Pakistan by (Amjad *et al.* 2017, Bahadur *et al*. 2023). The community utilized this method in which they boiled either powdered plant material or the actual plant part directly in water. The resulting extract was used as medicine for various ailments, and they also utilized the pure plant part to make tea for traditional medicinal purposes. In the area, people commonly took medicine orally, and the tropical method was also widely used. This trend corresponds with earlier studies highlighting the widespread preference for taking medication orally (Bahadur *et al*. 2023, Tahir *et al.* 2023). *Delphinium brunonianum*, locally referred to as "Makhoti," was used by the indigenous population for the management of pneumonia and respiratory tract infections through the administration of a decoction. Furthermore, a preparation involving a paste of the plant, conjoined with favored oils, particularly mustard oil, was topically administered to the hair. This application served a dual function, encompassing the removal of dandruff and the promotion of overall hair health. The data reveals the local utilization of *Thlaspi arvense* (local name "Brigah") as a decoction to treat the burning sensation during urination. This traditional practice reveals the community's belief on herbal remedies for focusing specific health concerns.

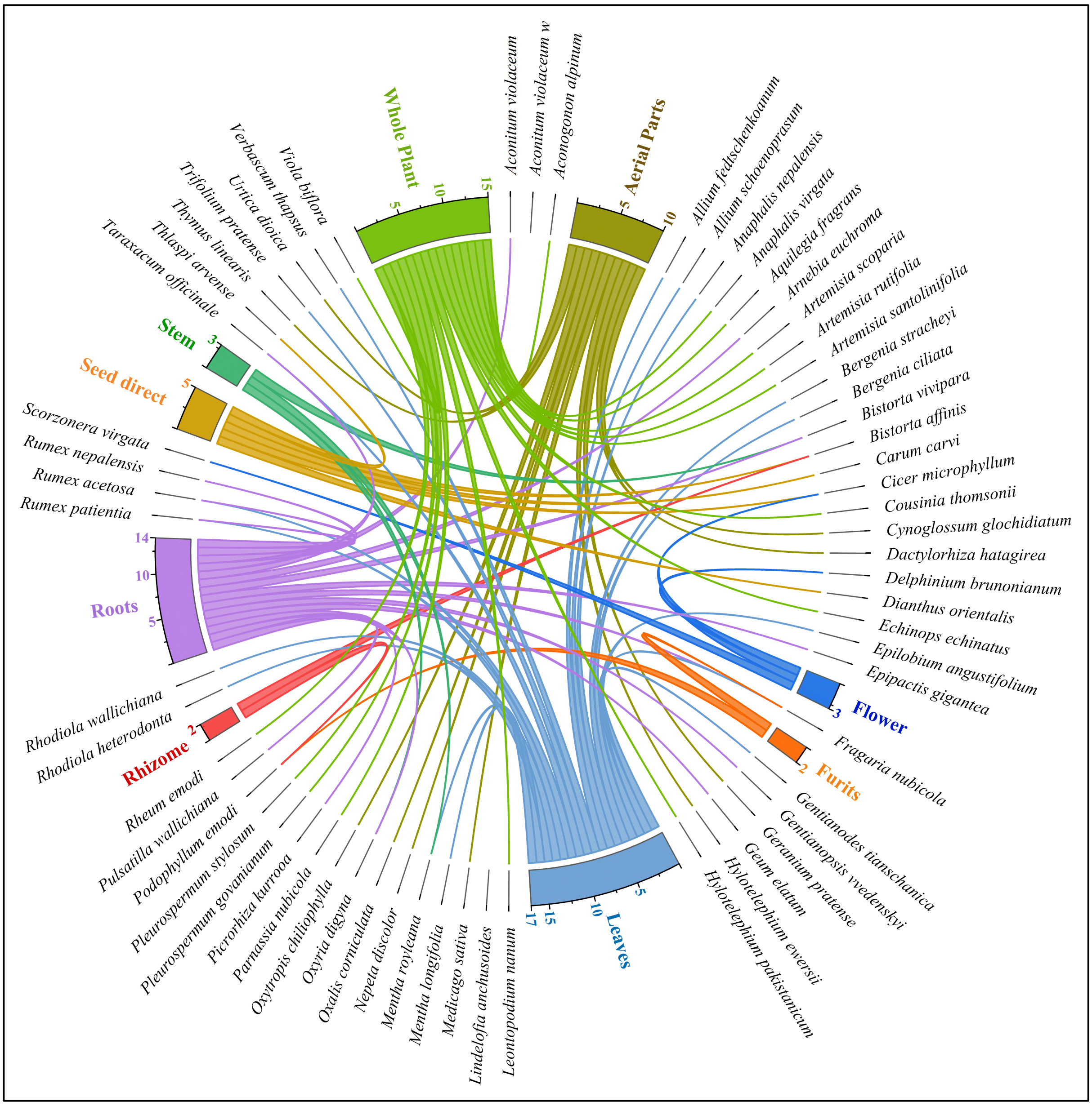

Figure 6. Highlights plant parts used in different disease in the study area.

Allium fedtschenkoanum and *Allium schoenoprasum* were regarded by residents as effective remedies for alleviating abdominal pain in the study area. According to interviews, these plants have historically functioned as substitutes for onions, with no prevalent cultivation of traditional onions. The fresh leaves of these plants used in culinary practices for vegetable preparation, serving as a substitute for onions in various dishes, as confirmed by respondents during interviews. However, it is noteworthy that the utilization of these plants was comparatively lower than that reported by their forefathers.

Quantitative data analysis of ethnomedicinal applications

Relative Frequency Citation (RFC)

The RFC serves as a crucial metric in current research, indicating the frequency with which specific plant species were cited by informants for various purposes (Shah *et al*. 2023). It also indicates how popular a plant is among the informants (Arshad *et al.* 2023). The results revealed that the plant species *Delphinium brunonianum* had higher RFC of (0.952), *Carum carvi* and *Rheum emodi* each had RFC (0.881) while least RFC for *Anaphalis virgata* (0.048), *Geum elatum* and *Epipactis gigantea* with RFC (0.071) for each (Table 2). The locals commonly used these preferred species for various ailments. The informants frequently mention a specific plant species for various purposes. This repeated citation is attributed to the plant's easy accessibility, effectiveness, and the fact that it tends to have minimal side effects referred to Relative frequency citation (RFC) (Kayani *et al.* 2015, Pradhan *et al.* 2020).

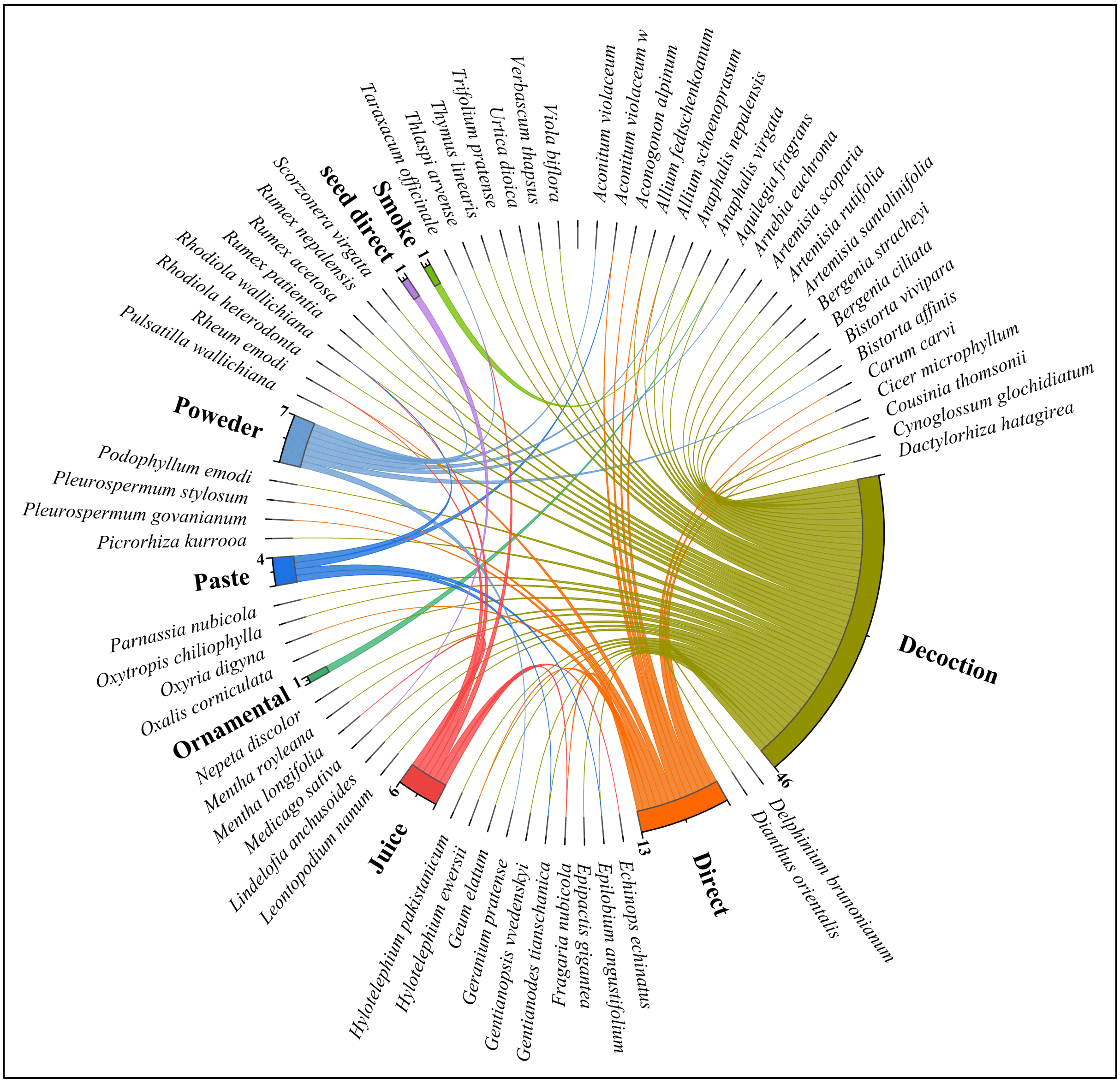

Figure 7. Preparation methods of medicinal herbaceous plants in the study area.

Use Value (UV)

The use value (UV) is the number of use reports mentioned by the people for specific plant species. This use report tells us about the medicinal properties of that plant as practiced in the ethnic community (Perveen *et al.* 2024). The Use Value (UV) is a metric that highlights the importance of various plants in indigenous practices, ranging from 0 to 1 value. Higher UV values signify greater significance, while lower values indicate lesser importance. *Delphinium brunonianum* (0.905) *Mentha longifolia* (0.833), *Aconitum violaceum* (0.810) demonstrated the highest UV, emphasizing their considerable importance in indigenous utilization. *Pleurospermum stylosum* (0.143), *Pleurospermum govanianum* (0.119), and *Epipactis gigantea* (0.119) had lower UV values, indicating they are less important in indigenous practices. This data illustrates the varying degrees of importance attached to different plants within the context of indigenous usage depicted in (Table 2).

K-Means Clustering Algorithm

The K-Means cluster analysis of 62 medicinal plants categorizes them into three clusters based on UV (Use Value) and RFC (Relative Frequency of Citation). The mean UV, indicating the average number of uses per plant, is 0.41132 with a standard deviation of 0.20786, while the mean RFC, showing the proportion of informants citing each plant, is 0.371 with a standard deviation of 0.23983. Cluster 1 contains 15 plants, Cluster 2 has 11, and Cluster 3 includes 36 plants, with within-cluster sum of squares (indicating variance) of 0.36933, 0.39893, and 0.69036, respectively. The average distances within clusters, reflecting intra-cluster similarity, range from 0.12541 to 0.17948, and maximum distances range from 0.2011 to 0.35074. Distances between final cluster centers, indicating separation between clusters, show significant separation, especially between Clusters 2 and 3 (0.71251). ANOVA results reveal highly significant differences among clusters for both UV and RFC, with F values of 80.00753 and 108.75524, and *p*-values less than 0.0001, suggesting that the cluster means for these variables differ significantly (Table 3).

The PCA biplot of 62 medicinal plants shows three distinct clusters based on UV (Use Value) and RFC (Relative Frequency of Citation). Cluster 1 (black stars) is centrally located with moderate values for both components, indicating average UV and RFC. Cluster 2 (red stars) on the right shows high PC1 values, reflecting higher UV and RFC, while Cluster 3 (blue stars) on the left has low PC1 values, indicating lower UV and RFC. The tight grouping within each cluster suggests similarity among the plants in each respective cluster. This visualization supports the significant differences between clusters observed in the K-Means analysis (Fig. 8).

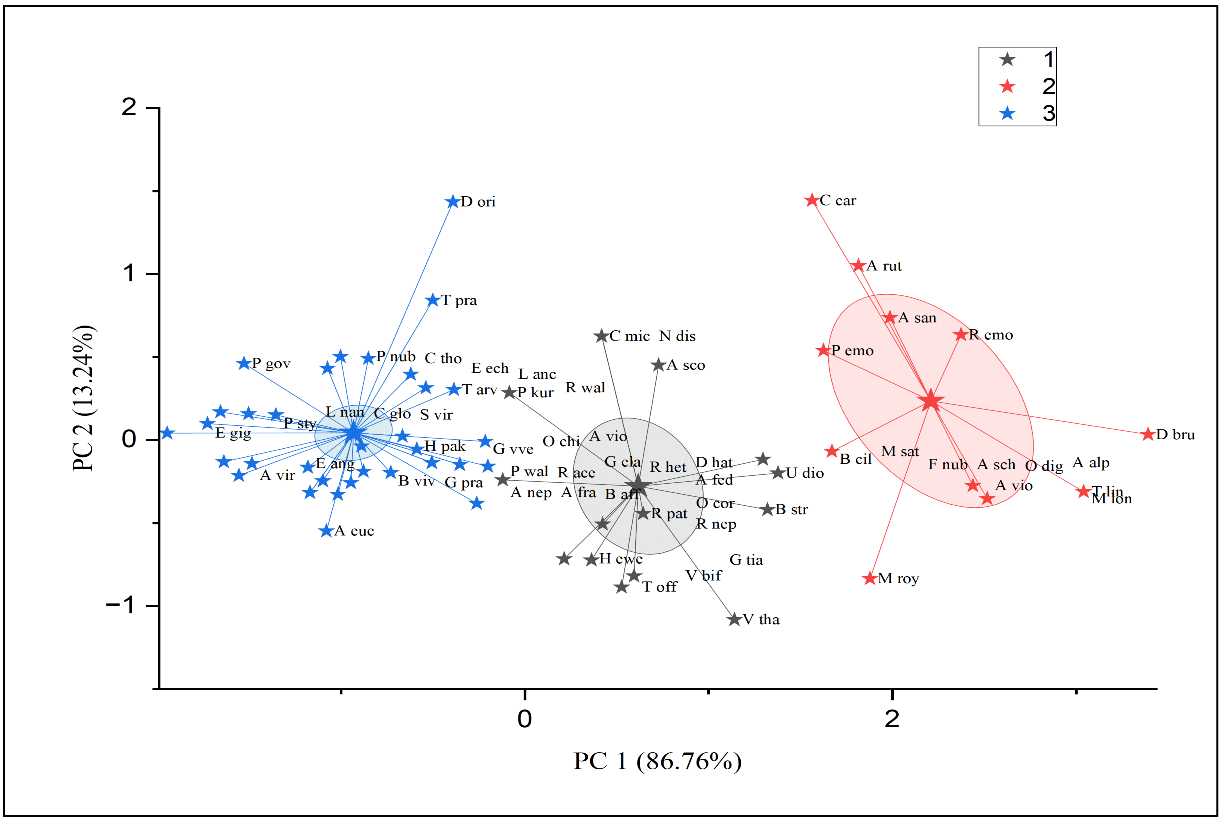

Figure 8. PCA biplot of 62 medicinal plants showing three distinct clusters based on UV and RFC.

Table 3. K-Means cluster analysis of 62 medicinal plants, detailing cluster sizes, variances, and significant differences in UV and RFC

Descriptive Statistics				
	Mean	Standard Deviation	N analysis	N missing
UV	0.41132	0.20786	62	0
RFC	0.371	0.23983	62	0

Cluster Summary				
	Number of Observations	Within Cluster Sum of Square	Average Distance	Maximum Distance
Cluster1	15	0.36933	0.15015	0.2011
Cluster2	11	0.39893	0.17948	0.28855
Cluster3	36	0.69036	0.12541	0.35074

Distance between Final Cluster Centers						
	Cluster1	Cluster2	Cluster3			
Cluster1	0	0.39066	0.34504			
Cluster2	0.39066	0	0.71251			
Cluster3	0.34504	0.71251	0			
ANOVA						
	Cluster DF	Cluster SS	Error DF	Error SS	F Value	Prob>F
UV	2	0.96278	59	0.01203	80.00753	<0.0001
RFC	2	1.37999	59	0.01269	108.75524	<0.0001

The dendrogram indicates the hierarchical clustering of 62 medicinal plants based on their similarity in UV (Use Value) and RFC (Relative Frequency of Citation). The graph shows three main clusters: Cluster 1 (red), Cluster 3 (green), and Cluster 2 (blue). Clusters 1 and 3 are more similar to each other, joining at a lower similarity level (around 60%), while Cluster 2 is distinctly separate, joining the combined Cluster 1 and Cluster 3 at a higher level (around 40%), indicating less similarity. This hierarchical clustering supports the distinction of Cluster 2 observed in the K-Means and PCA analyses, highlighting its unique characteristics compared to the other clusters (Fig. 9).

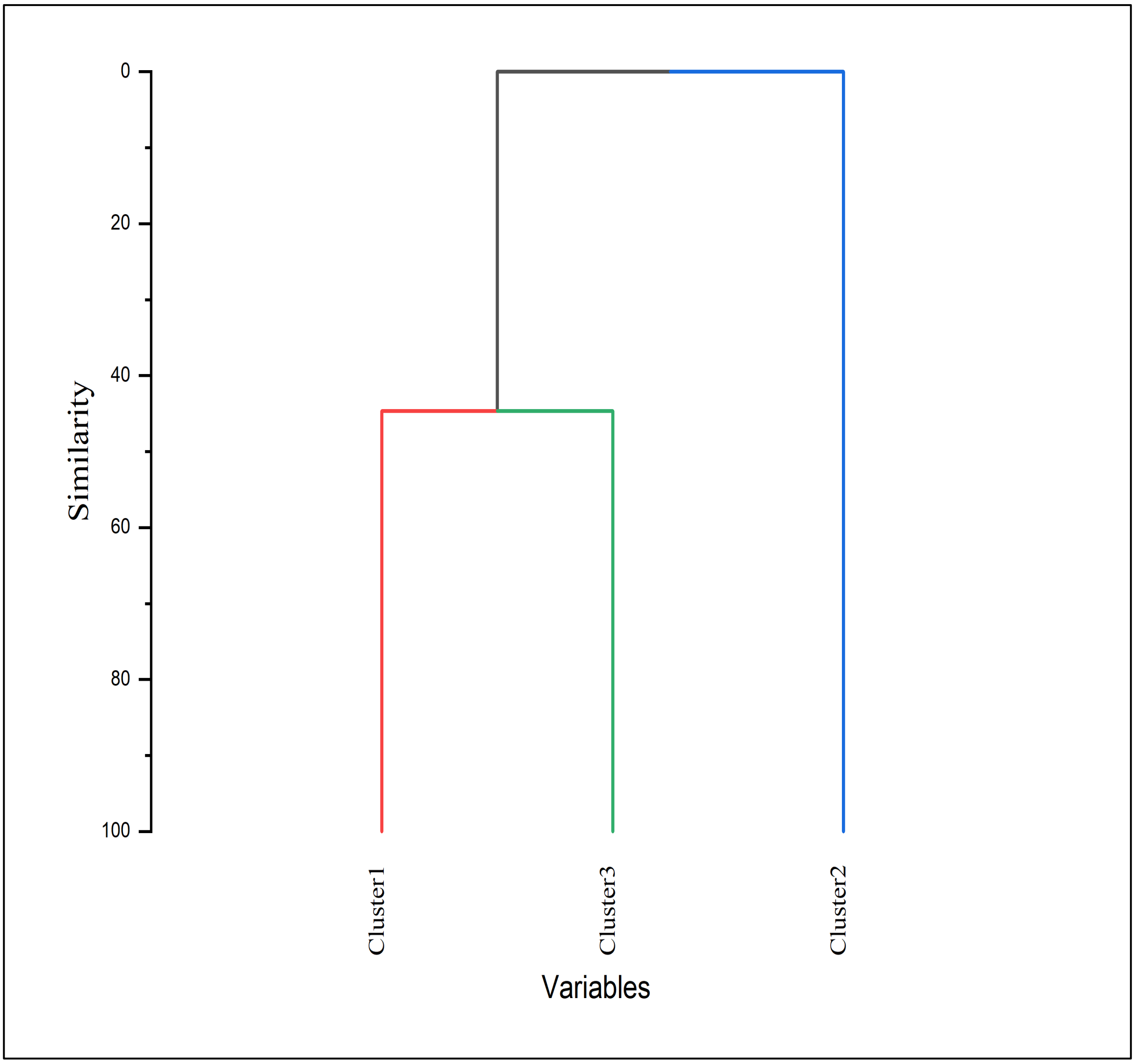

Figure 9. Dendrogram of 62 medicinal plants showing three main clusters with distinct similarities based on UV and RFC.

Fidelity level (FL)

(Table 2) reveals varying reliability (fidelity level, FL) for plant species in treating specific illnesses, ranging from 100% to 12%. *Delphinium brunonianum* really has the highest FL of 100%, indicating it's consistently referenced for a specific ailment for pneumonia and respiratory tract infections. Followed by *Carum carvi* and *Rheum emodi* have high FL of 93%, followed by *Aconitum violaceum* and *Artemisia rutifolia* with 90% FL. This high FL suggests that these plants are commonly utilized and trusted within communities for treating particular diseases. Preserving this traditional knowledge is very important for plant conservation and developing herbal remedies for specific health concerns (Hussain *et al.* 2019, Awan *et al.* 2023). On the other hand, the lowest fidelity level reported for species *Epipactis gigantea* and *Pleurospermum stylosum* each comprising (12%).

Statistical analysis of the link between Relative Frequency Citation (RFC) with Use Value (UV)

The Pearson correlation analysis has found a very strong, positive correlation between RFC and UV for all the different species a. This means that species with more citations, in general, tend to have higher use values, and the opposite as well. This connection is further confirmed by the high correlation coefficient r (0.701**) with *p* value is less than 0.01 < 0.000. The values depicted in (Table 4) and the r-squared (r^2) value of (0.492) details depicted in (Fig. 10). It shows a trend where higher RFC typically goes hand in hand with higher UV across all species (Ahirwar & Gupta 2024, Bano *et al.* 2014). The study revealed corresponding with those observed in studies of a comparable nature conducted in diverse regions across the globe (Vijaykumar *et al.* 2015, Amjad *et al*. 2017).

Table 4. Descriptive analysis of Pearson's correlation coefficient between RFC and UV.

Correlations			
		UV	RFC
UV	Pearson Correlation	1	.701**
	Sig. (2-tailed)		.000
	N	62	62
RFC	Pearson Correlation	.701**	1
	Sig. (2-tailed)	.000	
	N	62	62
**. Correlation is significant at the 0.01 level (2-tailed).			

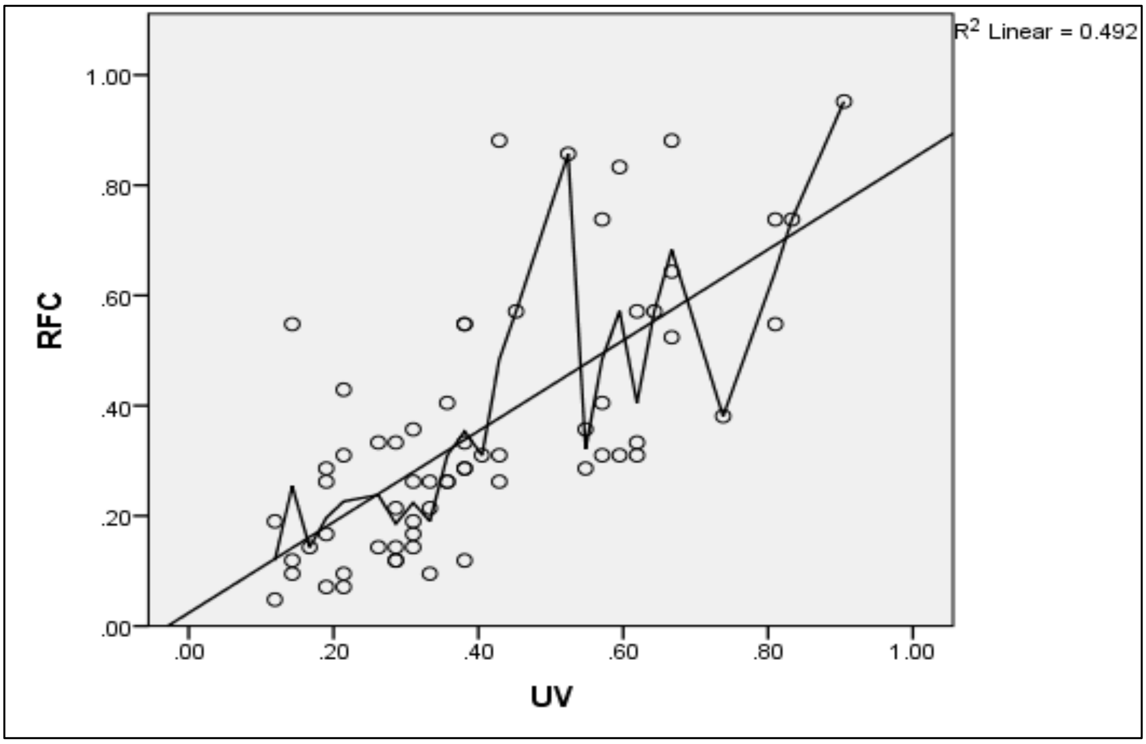

Figure 10. Relationship between Relative Frequency Citation (RFC) and Use value (UV).

Informant consensus factor (ICF)

The Informant Consensus Factor (ICF) was computed to assess the consensus among informants regarding the selection of plant species for various ailment classifications (Boro *et al.* 2023). The documentation meticulously recorded the percentage of plant species utilized for treating diseases showed in (Table 4), the disease categories included Jaundice, Wounds and cuts, Digestive Disorder, Fever, Arthritis, Dermatology, Reproductive health, Blood purifies, Dental, Respiratory Disorder, Pain and inflammation, Urinary tract infection, Heart issues, Kidney disorders, Hepatic disorders, Others (Hair issues, insect killers, Tonic, hemorrhoids).

In this study, significant findings reveal a substantial ICF value shown in (Table 4) for the Urinary tract infection (0.97), indicating a high level of agreement among informants in the utilization of specific plant species shown in (Fig. 11). Similar study was done by (Ahmad *et al*. 2017). Fever closely follows with a notable ICF value of 0.92. Conversely, the category labeled as blood purifies demonstrates the lowest ICF value of 0.67, This discrepancy arose from disagreements among informants in selecting taxa for specific ailment categories. The high FIC value signifies a consistent pattern in how common people use plants, relying on only one or a limited number of plants for treating specific ailment categories (Boro *et al.* 2023). The use of herbal treatments for various ailments are common practice worldwide. Over the past few decades, there has been increasing attention in research on medicinal plants and their uses in various parts of Pakistan (Bahadur *et al.* 2023). In the last few years, a wealth of information has been compiled, shedding light on how ethnic communities worldwide, Pakistan included, rely on plants for traditional healing practices. (Jimenez-Arellanes *et al.* 2003, Kayani *et al.* 2014, Bahadur *et al.* 2023).

Table 5. Ailment categories and their respective Informant Consensus Factor (FIC)

Disease category	N_{ur}	N_{ur} %	N_t	N_t %	N_{ur}-N_t	N_{ur}-1	ICF= (N_{ur}-N_t) / (N_{ur}-1)
Jaundice	9	1.2	2	1.7	7	8	0.88
Wounds and cuts	37	4.9	7	6.1	30	36	0.83
Digestive Disorder	195	25.7	29	25.2	166	194	0.86
Fever	76	10.0	7	6.1	69	75	0.92
Arthritis	44	5.8	6	5.2	38	43	0.88
Dermatology	33	4.3	7	6.1	26	32	0.81
Reproductive health	18	2.4	5	4.3	13	17	0.76
Blood purifies	13	1.7	5	4.3	8	12	0.67
Respiratory Disorder	134	17.7	17	14.8	117	133	0.88
Pain and inflammation	79	10.4	14	12.2	65	78	0.83
Urinary tract infection	34	4.5	2	1.7	32	33	0.97
Heart issues	8	1.1	2	1.7	6	7	0.86
Kidney disorders	13	1.7	4	3.5	9	12	0.75
Hepatic disorders	11	1.4	2	1.7	9	10	0.90
Others (Hair issues, insect killers, Tonic, hemorrhoids	55	7.2	6	5.2	49	54	0.91
Mean (ICF)							0.85

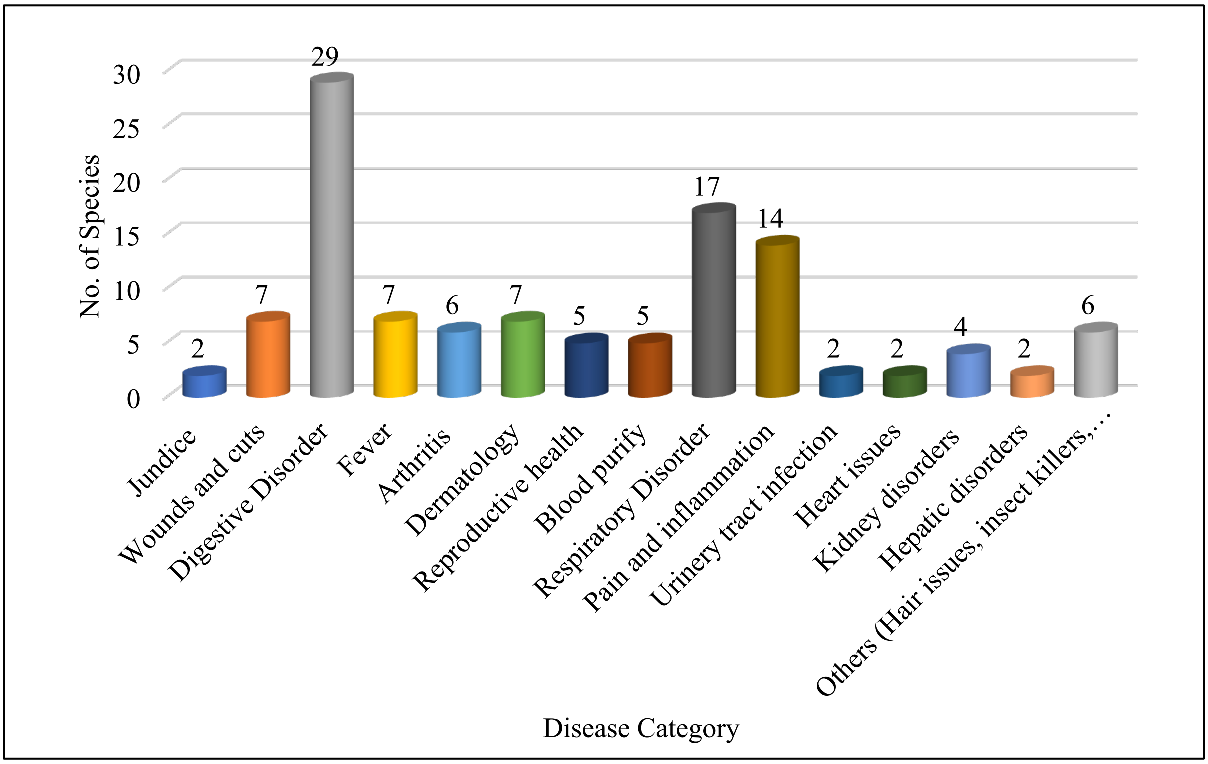

Figure 11. Distribution of medicinal herbaceous plant species used for treating various disease categories in the study area.

Conclusion

This study underscores the rich ethnomedicinal knowledge of Theeing Valley's indigenous communities, documenting 62 herbaceous plants used for various ailments. The Asteraceae family is predominant, with leaves being the most utilized plant part and decoction the common preparation method. Key species like *Delphinium brunonianum* and *Thymus linearis* exhibit high medicinal importance. The strong correlation between RFC and UV emphasizes the plants' significance. The local population possesses valuable knowledge about medicinal plants, which is traditionally passed down orally to younger generations. Therefore, documenting this indigenous knowledge is essential for future research endeavors. The herbaceous flora in the area faces significant threats due to anthropogenic pressure, grazing, soil erosion, and the ongoing medicinal use of these plants without any management. The research suggests involving locals in documenting medicinal plant knowledge, promoting sustainable grazing practices, educating youth on medicinal plants, collaborating with the government on awareness campaigns, establishing biodiversity monitoring systems, and encouraging the cultivation of alternative medicinal plants to ease pressure on the herbaceous flora.

Declarations

List of abbreviations: UV use value; RFC relative frequency citation, FL fidelity level, Nur number of use reports, Nt Number of taxa, ICF informant consensus factor, He Hemicryptophyte, Ch Chamaephyte, Cr cryptophytes, Th Therophytes, L leaves, FL flowers, AP aerial parts, R roots, WP whole plant, S Seed, FR Fruit, R Root, ST Stem, RH Rhizome

Ethics approval and consent to participate: All interviewees gave their poral prior informed consent.

Consent for publication: All persons shown in images gave their poral prior informed consent to have their images shown.

Availability of data and materials: Not applicable

Competing interests: The authors declare that there is no conflict of interest

Funding: No funding has been received for the study.

Author contributions: SK, the lead author, orchestrated the entire research process, from designing and scheduling field surveys to specimen collection, identification, data analysis, and drafting the manuscript until its final approval. SH and AAS played pivotal roles in designing the study, aiding in specimen identification, and critically reviewing the manuscript. TZ contributed significantly by collecting plant specimens and ethnomedicinal data. TZ and KA helped in data analysis and manuscript modification.

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