DOI: https://doi.org/10.71317/kjard.2.11.2026.1061

Kashmir Journal of Academic Research and Development

Journal homepage: https://rjsaonline.org/index.php/KJARD

Diversity of Lower Plant Species and Their Traditional Uses from Soon Valley, Punjab, Pakistan

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ARTICLE INFO

Received:
October 08, 2026
Revised:
October 25, 2026
Accepted:
November 07, 2026
Available Online:
November 17, 2026

Keywords:
Soon Valley, Traditional medicine, Ecology, Floristic composition, Frequency, Pharmacology

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ABSTRACT

The present study was conducted on the culturally rich lower plants (algae, bryophytes and pteridophytes) of Soon Valley, which is an ecologically rich area in Khushab, Punjab, Pakistan, to obtain an in-depth ethnobotanical study of these plants. Lower plants are often overlooked in traditional ethnobotanical surveys, which tend to focus mainly on angiosperms, although they are important in their role. The semistructured interviews, personal interviews, and direct observations of local informants were used in field surveys to document therapeutic uses of plants, habitats and plant species across the region, involving 170 local informants. The recorded flora were evaluated for their cultural and medicinal values using quantitative ethnobotanical indices such as the relative frequency of citation (RFC), use value (UV), family use value (FUV), informant consensus factor (ICF) and Jaccard index (JI). In total, there were 55 lower plant taxa in 26 families, with a high degree of taxonomic and ecological diversity, the majority being terrestrial (49%) and lithophytic (25%). Of the families recorded, Bartramiaceae had the highest family use value (FUV = 1.33), followed closely by the Aspleniaceae family. Species-level citation analysis revealed that Chlorella vulgaris had the highest citation frequency (RFC = 0.21), followed by Pteris vittata (0.18) and Marsilea minuta (0.16); on the other hand, the highest individual Use Values (UV = 2.00) were recorded for Asplenium fontanum and Asplenium viride. Across the 15 ailments, the highest informant consensus factor was found with eye ailments (ICF = 1.00) and antidote/antitoxin applications (ICF = 0.56), and prominent use categories were dermatological, infectious and hepatic ailment categories. The floristic and ethnobotanical similarities were compared using the Jaccard Index with previous national and global studies that showed low to moderate similarities (0.00% to 9.43%) to the indigenous knowledge of Soon Valley, indicating the regional specificity of the knowledge. The study provides essential baseline information on the underutilized flora of the region and provides important clues for future research on the phytochemical and pharmacological benefits of the region as well as highlighting the need to protect the biodiversity of the region and indigenous ecological knowledge.

Introduction

Plants will be vital in people's lives, as they supply food, medicine, shelter and other resources that are key to health and well-being. Local communities have used plants for centuries to heal a range of illnesses and to treat common ailments. Traditional medicine is still considered an essential component of health care largely in rural areas where easy access to modern health care facilities is limited (Ssegawa & Kasenene, 2007; Kumar, 2018). In addition to their medicinal usage, plants play a crucial role in ecosystems by playing part in natural environmental processes, biodiversity and ecosystem stability. Despite the considerable attention given to flowering plants in botanical and ethnobotanical studies, the diversity and use of lower plants is understudied.

Lower plants (or cryptogams) contain a variety of plant groups that reproduce primarily by spores rather than seeds. Algae, bryophytes and pteridophytes are included in this group in the present study. These organisms are found in all types of habitats, such as water, soil, rocks, or shady areas, and play a role in the ecosystem. They are not only significant for biodiversity, but some species are known to have traditional medicinal, ecological and other useful applications. Documentation of these plants is thus valuable for the knowledge of distribution, natural value and possible role in natural resource conservation.

Algae are plants that have chlorophyll and grow in water or damp places. They vary in size from microscopic to larger seaweeds and are important for primary production and the generation of oxygen. They are also important components of aquatic food chains and useful as compounds for food, pharmacological and biotechnological uses. There are several algal products that have been utilized in a variety of industries, and bioactive algal compounds have been of interest due to their potential biological activities (Scieszka & Klewicka, 2019; Liang et al., 2020). Algal diversity is structurally and ecologically important and practically useful, and the documentation of algal diversity is valuable, especially in regions of the country where freshwater habitats and other more suitable habitats are available for algal growth.

Bryophytes are nonvascular plants, such as mosses, liverworts and hornworts, and are often found in wet, shady places. They play a crucial role in terrestrial ecosystems, as they help to stabilize water, participate in the formation of soil, and react to changes in the environment. They are also sensitive to moisture and environmental contaminants, making them beneficial for ecological and environmental research (Azuelo et al., 2011; Halder & Mitra, 2020). Bryophytes serve a variety of ecological functions and have a traditional use history in various communities. They have been reported to be useful in wound healing and other medicinal uses, and their chemical constituents have been the subject of growing scientific interest (Asakawa et al., 2013; Benek et al., 2022). However, their role is not always recognized compared to the role of flowering medicinal plants.

The spore-producing vascular plants are an important group of plants called pteridophytes, which include ferns and their allies. They are found in various habitats and play a role in the structure of vegetation, nutrient cycling and ecological stability. There are several species of pteridophytes used traditionally for medicinal, edible, ornamental and other uses. Ethnobotanical studies have indicated that they are used to treat skin, respiratory, digestive and inflammatory ailments (Sureshkumar et al., 2018; Baskaran et al., 2018). Although many uses for ferns have been reported, the traditional knowledge of many fern species is still under documented. However, as knowledge is passed down from generation to generation, there may be other threats to this knowledge, such as changes in people's lifestyles (Khoja et al, 2022).

Soon Valley, in the state of Punjab in Pakistan, is an ecologically diverse region with various habitats and plant species. Algae, bryophytes and pteridophytes can form naturally because of their natural vegetation and diverse environmental conditions. Local communities have long engaged with plant resources in their vicinity and gained knowledge of their traditional uses. However, there is limited systematic documentation of the diversity of lower plants and their associated traditional uses in Soon Valley. This lack of knowledge suggests that research should focus on both the botanical and local community significance of these groups.

Hence, the diversity of lower plant species and their traditional uses in Soon Valley, Punjab, Pakistan were documented in the present study. The local communities were consulted for the collection of information, which included the collection of plant names, reported use and associated ethnobotanical knowledge. The collected data were analysed using the quantitative ethnobotanical indices relative frequency of citation (RFC), use value (UV), family use value (FUV), informant consensus factor (ICF) and Jaccard index (JI). The results serve as baseline data on the diversity and traditional significance of lower plants in the study area, which can be used for further taxonomic, ecological and ethnobotanical studies and for conservation of local biodiversity and indigenous knowledge.

Methodology

The district Khushab, Punjab, Pakistan, forms the northwest of the district where Soon Valley is a unique and ecologically valuable area with a variety of plant species and habitats (Ali et al., 2025). The area is divided into rangelands (40%), agricultural land (22%) and forestland (38%). Dodonaea viscosa, Acacia modesta and Olea ferruginea are the predominant plant species. Ecological stability, resilience and the function of ecosystems are enhanced through the development and maintenance of a diversity of habitats that is fostered by native plant species. Local ecological interactions and biodiversity are maintained by dominant native plants, such as Ziziphus mauritiana and Acacia nilotica, which offer vital food supplies, shelter, and breeding sites for a variety of wildlife, such as insects, birds and small mammals. Soon Valley's preservation of a diversity of plant species contributes to a variety of ecological processes and interactions that enhance the biodiversity of the area. Although the Soon Valley is of great biological importance, there are some environmental issues in this area, such as habitat fragmentation, deforestation and soil erosion.

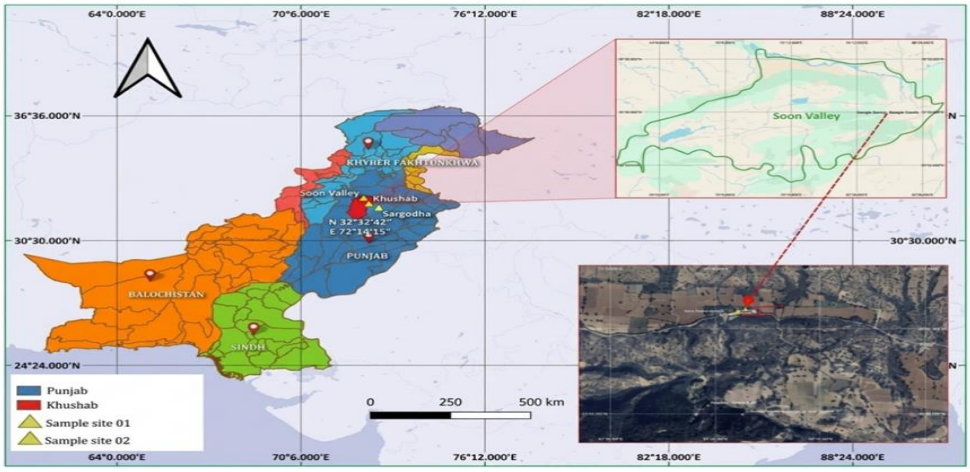


Figure 1: Map of the study area

Ethnobotanic methodology

Data documentation

The information was collected from 170 informants by semistructured questionnaires, personal interviews, informal conversations and direct observations.

Table 1: Demographic characteristics of informants (N=170)

Attributes	Number (N)	Percentage (%)
Gender		
Male	105	61.76
Female	65	38.24
Age group (years)		
25-35	25	14.70
36-45	37	21.76
46-55	49	28.82
56-65	38	22.35
>65	21	12.35
Educational status		
Illiterate	48	28.24
Primary	40	20.0
Middle	38	19.0
Matric	30	15.0
Intermediate	28	10.5
Graduate & above	11	9.0
Occupation		
Agricultural Practitioner	55	32.35

Pastoralist	41	24.11
Traditional healer (Hakeem)	04	2.3
Government employee	18	10.58
Private employee	06	3.5
Student	13	7.64
Laborer	10	5.88
Housewife	23	13.52

Collection, Identification and Preservation of Plants

Lower plant specimens, including bryophytes, pteridophytes and algae, were collected using standard botanical methods. Specimens were identified using their morphological characteristics, taxonomic literature, regional floras, identification keys and authentic online databases. The collected materials were cleaned, dried or preserved appropriately, and herbarium specimens were prepared. Each specimen was labelled with a voucher number and relevant collection details, including date, locality, habitat and collector, before deposition in the Department of Botany herbarium for future reference.

Data analysis and processing

For compilation and initial processing, data collected from field surveys, semistructured interviews, questionnaires and direct observation were arranged and entered into Microsoft Excel. Prior to analysis, the information collected was carefully examined for accuracy and consistency. Taxonomic categorization, including family, scientific name, common name, habit and documented traditional uses, was followed to arrange the plant specimens. To assess the importance of the documented medicinal plants. Quantitative indices, including relative frequency citation (RFC) and usage value (UV), informant census factor (ICF), Jaccard Index (JI), and family use value (FUV), were then used to further evaluate the gathered data.

Relative frequency citation (RFC)

The formula used for calculating the RFC value of plant taxa used by indigenous people is given below (Tardio & Pardo-de-Santayana, 2008):

$$RFC=\frac{\text{number of informants who mention the use of species (FC)}}{\text{number of informants participating in the survey (N)}}\times 100$$

The RFC index value was determined mathematically using the following formula:

$$RFC_{s=}\frac{FC}{N}(o<RFC<1)$$

Use report (UR) and Use value (UV)

The UV (calculate the relative value of a useful taxon known to locals). It was computed using the formula provided by (Phillips *et al.*, 1994).

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

where "n" is the total number of informants who were interviewed for species, and "U" is the total number of reports or data collected from a single informant for a single species.

Family use value (FUV)

Cadena-Gonzalez *et al.*, (2013) proposes a formula FUV to determine the importance of plant families by using the following formula:

$$FUV=\frac{UVs}{ns}$$

Where

UVs mean ‘use values of the species’, and ns mean ‘total number of species’ within each family.

Informant consensus factor (ICF)

Trotter and Logan, (1986) calculated the informant consensus value using the following formula:

$$ICF= N_{ur}-N_t/N_{ur-1}$$

N_{ur} is the total number of usage reports (UR) for any type of ailment, whereas Nt indicates the number of plant species/taxa utilized for that particular reason. In that case, each plant species's usage report was considered a single use report. The ICF values ranged from 0 to 1, where "1" indicates the maximum level of informant agreement (Gazzaneo *et al.*, 2005).

Jaccard Index (JI)

Gonzalez-Tejero *et al.*, (2008) used this index to evaluate data in ethnobotanical research and created the following mathematical formula:

$$JI = \frac{c}{(a+b-c)} \times 100$$

Where

"a" is the recorded number of species of the study area "A" (here, Soon Valley)

"b" is the number of species cited by the indigenous community "B"

"c" is the number of species reported by both "A" and "B" indigenous communities

Data presentation

Data are presented in tabulated form as well as in the form of pie and column charts.

Questionnaire

Diversity of Lower Plant Species and Their Traditional Uses from Soon Valley, Punjab, Pakistan

A. Information of Informant

1. **Informant name:** _____

2. Date of interview: _____

3. Village/locality: _____

4. Gender:

☐ Male ☐ Female

5. Age:

☐ 25–35 years ☐ 36–45 years

☐ 46–55 years ☐ 56–65 years

☐ 66 years and above

6. Occupation:

☐ Agricultural Practitioner ☐ Pastoralist

☐ Government employee ☐ Private employee

☐ Student ☐ Traditional healer

7. Educational status:

☐ Illiterate ☐ Primary

☐ Middle ☐ Matric

☐ Intermediate ☐ Graduate & above

8. Residence:

☐ Rural ☐ Urban

B. Information Related to Lower Plant Species

1. Name of the lower plant species/taxon:

2. Habitat of the plant:

3. Which health condition or ailment is traditionally treated with this plant?

4. What is the present availability of this plant in the study area?

☐ Abundant ☐ Common

☐ Occasional ☐ Rare

Results

Ethnobotanical Importance and Taxonomic Distribution of Plant Families

The family use value (FUV) was subjected to quantitative analysis that revealed that there was a significant difference in the ethnobotanical values of the plant families assessed. The highest relative value was in Bartramiaceae ca. 1.33, followed by Aspleniaceae at 1.23, and Cyatheaceae, Aytoniaceae, Mniaceae, and Pottiaceae with their maximum consensus FUV of 1.00. The moderately high FUV was noted in Marchantiaceae (0.79), Salviniaceae (0.75), Bryaceae (0.73), Polytrichaceae (0.72), Meteoriaceae (0.70) and Conocephalaceae (0.64). Intermediate values of Pelliaceae (0.50), Dicranaceae (0.50), Polypodiaceae (0.41), Funariaceae (0.38), Aneuraceae (0.33), Hypnaceae (0.33) and Dumortieraceae (0.33) were recorded. All other families recorded lower values than those in Osmundaceae (0.14), Marsileaceae (0.14), and Chlorellaceae (0.09), with lower values in Equisetaceae (0.29), Pteridaceae (0.29), Selaginellaceae (0.25), and Lepidoziaceae (0.23). Nonuniform taxonomic composition was detected by familywise parallel assessment of species distribution. The two most rich species were in two dominant families, both with 8 species, followed by 6, 4, and 3 species in separate families. Four families were represented by 2 species, while most of the recorded families had only one species per family, with 17 families reporting only one species (Figure 2).

Habitat Diversity and Life Form Distribution of Reported Lower Plants

Terrestrial adaptations were found to be dominant in the reported lower plant species, followed by rock and subterranean adaptations. Almost half of the flora was terrestrial (49%) and was the predominant life form in the study area. Lithophytic growth on rock substrate made up one-quarter of the recorded lower plants (25%), and subterranean or subterranean perennating growth formed 13% of the recorded lower plants. The epiphytic species associated with host plants accounted for 5% of the reported taxa, with aquatic species growing in aquatic environments following, accounting for 4%. Minor proportions of specialized niche habitats were represented, with epixylic species (decaying wood habitats) at 2% and corticolous species (tree bark habitats) at 2% of the total distribution (Figure 3).

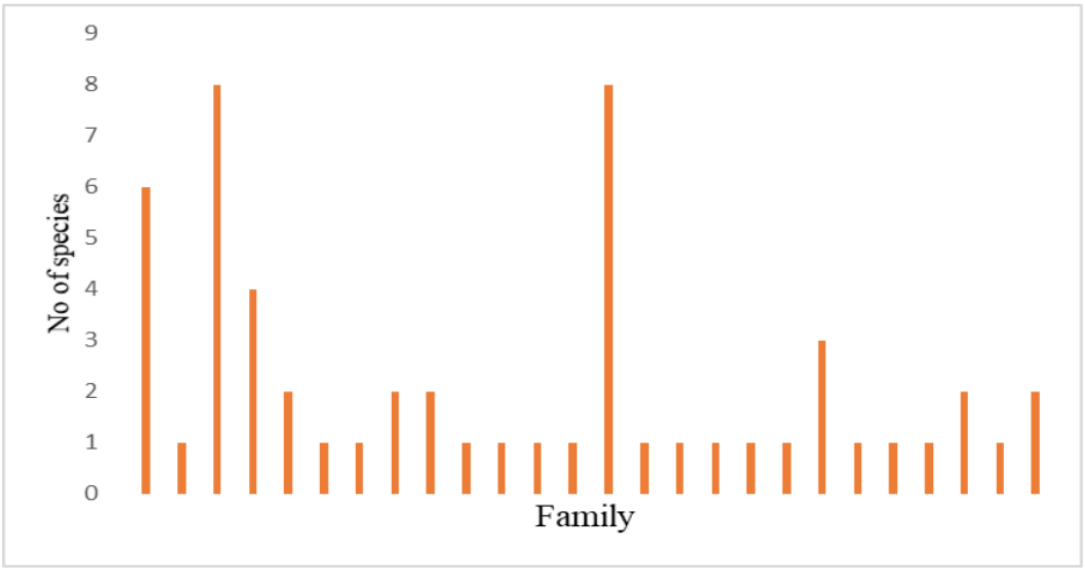


Figure 2: Number of documented species in each plant family

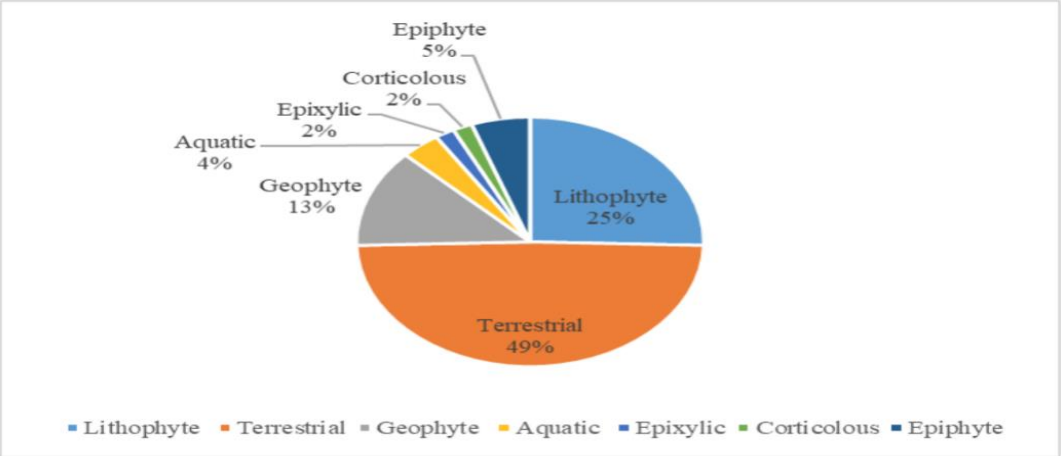


Figure 3: Life form of reported lower plants.

Quantitative data analysis

Ethnobotanical quantitative parameters such as relative frequency citation (RFC), use value (UV), informant consensus factor (ICF), Jaccard Index (JI) and family use value (FUV) were used to evaluate the traditional knowledge and ethnobotanical importance of lower plants used by local people in Soon Valley, Punjab, Pakistan. These indices were used to quantify both species recognition and the degree of diversity in the reported uses, both in family-level importance and agreement among informants with respect to the therapeutic uses and similarity of reported uses with previous ethnobotanical studies.

RFC and UV of documented plant taxa

The documented lower plants had RFC ranging from 0.00 to 0.21; Chlorella vulgaris had the highest RFC (0.21), followed by Pteris vittata (0.18), Marsilea minuta (0.16), Dryopteris barbigera (0.15), Adiantum capillus-veneris (0.12) and Marchantia linearis (0.11). The UV values ranged from 0.00 to 2.00. Asplenium fontanum, Asplenium viride, Ceterach officinarum and Woodwardia unigemmata all had the highest UV (2.00).

FUV of documented plant families

The family use value (FUV) was calculated to assess the ethnobotanical importance of the documented lower-plant families in Soon Valley, Punjab, Pakistan. The FUV values ranged from 0.09 to 1.33 among the 26 recorded families. Bartramiaceae exhibited the highest FUV (1.33), represented by a single documented species, indicating a relatively high use value attributed to that family. Aspleniaceae ranked second, with an FUV of 1.23, based on eight species and a cumulative use value of 9.83. Aytoniaceae, Cyatheaceae, Mniaceae and Pottiaceae each recorded an FUV of 1.00. Marchantiaceae and Salviniaceae showed FUV values of 0.79 and 0.75, respectively, whereas Bryaceae, Polytrichaceae and Conocephalaceae had FUV values of 0.73, 0.72 and 0.64, respectively. The lowest FUV was observed in Chlorellaceae (0.09), followed by Marsileaceae and Osmundaceae, each with 0.14. The results demonstrate considerable variation in family-level ethnobotanical importance. However, a high FUV does not necessarily indicate greater species richness, as it is influenced by the cumulative use values and the number of species within each family (Table 2).

Table 2: Floristic Composition and Quantitative Analysis of Plant Taxa in Soon Valley, Pakistan.

Botanical name / Author's name	Family	Common name / Voucher No.	Habit	Therapeutic use(s) / value(s)	FC	RFC	UR	UV	Previous Studies for Comparison
Adiantum capillus-veneris / L.	Pteridaceae	Maidenhair fern LPT-001	Lithophyte	Vascular disease, diabetes, antitoxin, hormonal problems, gynecological issues,	21	0.12	7	0.33	1*,2*,3*,4*,5■,6■,7*,8■,9▲,10▲

Botanical name / Author's name	Family	Common name / Voucher No.	Habit	Therapeutic use(s) / value(s)	FC	RFC	UR	UV	Previous Studies for Comparison
				pulmonary issues and hair growth.					
Adiantum caudatum / L.	Pteridaceae	Walking fern LPT-033	Epiphyte	Urinary tract infection, diabetes, dermatological and stomach problems	17	0.1	4	0.24	1*,2*,3*,4*,5*,6■,7*, 8*,9▲,10▲
Adiantum incisum/ Forssk.	Pteridaceae	Torn maidenhair fern LPT-003	Lithophyte	Respiratory ailments, jaundice	5	0.03	2	0.4	1*,2*,3*,4*,5■,6*,7*, 8*,9*,10■
AerobryidiumFilamentosum/ (Hook.) M.Fleisch.	Meteoriaceae	Not reported LPT-032	Epiphyte	Neutralize toxins and burns	3	0.02	2	0.7	1■,2*,3*,4*,5*,6*,7*, 8*,9*,10*
Asplenium adiantum/ Hoffm.	Aspleniaceae	Guewtheer, black spleenwort LPT-016	Lithophyte	Asthma, laxative, pneumonia and urinary issues	7	0.04	3	0.43	1*,2*,3*,4*,5▲,6*,7*, 8■,9▲,10▲
Asplenium fontanum / (L.) Bernh.	Aspleniaceae	Sheen-ghass LPT-052	Lithophyte	Asthma, Emphysema	1	0.01	2	2	1*,2*,3*,4*,5*,6*,7*, 8■,9*,10*
Asplenium septentrionale/ (L.) Hoffm.	Aspleniaceae	Forked spleenwort, northern spleenwort LPT-041	Lithophyte	Not reported	1	0.01	0	0	1*,2*,3*,4*,5*,6*,7*, 8*,9*,10*
Asplenium trichomanes/ Thunb.	Aspleniaceae	Guewtheer LPT-002	Lithophyte	Anti-inflammatory, anti-cancer	5	0.03	2	0.4	1*,2*,3*,4*,5■,6*,7*, 8■,9■,10■
Asplenium viride/ Huds.	Aspleniaceae	Green spleenwort LPT-046	Lithophyte	Skin damage, inflammation	1	0.01	2	2	1*,2*,3*,4*,5*,6*,7*, 8■,9*,10*
Asterellaangusta/ (Steph.) Pande, K.P.Srivast. & Sultan Khan	Aytoniaceae	Not reported LPT-034	Terrestrial	Skin infections, anti-inflammatory, seasonal infections	2	0.01	3	1.5	1*,2*,3*,4*,5*,6*,7*, 8*,9*,10*
Atrichumundulatum/ (Hedw.) P.Beauv.	Polytrichaceae	Smoothcap LPT-007	Terrestrial	Neuronal damage, immune activity, seasonal infection	7	0.04	3	0.43	1■,2*,3*,4*,5*,6*,7■,8*,9*,10*
Azollapinnata/ R.Br.	Salviniaceae	Mosquito fern	Aquatic	Microbial infections,	4	0.02	3	0.75	1*,2*,3*,4*,5*,6*,7*, 8*,9■,10■

Botanical name / Author's name	Family	Common name / Voucher No.	Habit	Therapeutic use(s) / value(s)	FC	RFC	UR	UV	Previous Studies for Comparison
		LPT-038	(Free-floating)	hepato and renal ailments					
Bartramiaithyphylla/ Brid.	Bartramiaceae	Straight-leaved Apple-moss LPT-055	Lithophyte	Relieve anxiety, nerve tonic, convulsive disorders, heart palpitations	5	0.03	4	1.33	1■,2*,3*,4*,5*,6*,7*,8*,9*,10*
Bazzaniatrilobata/ (L.) Gray	Lepidoziaceae	Greater whipwort LPT-009	Terrestrial	Skin ailments	8	0.05	1	0.13	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*
Bryumargenteum/ Hedw.	Bryaceae	Silver moss LPT-036	Terrestrial	Nasal inflammation, fungal infections, detoxification, pyrexia	3	0.02	4	0.8	1▲,2*,3■,4■,5*,6*,7*,8*,9*,10*
Bryumcapillare / Hedw.	Bryaceae	Capillary thread-moss LPT-019	Terrestrial	Bacterial and fungal infections, dysentery, heat-related illnesses, pyrexia ,body pain	9	0.05	6	0.66	1▲,2*,3■,4*,5*,6*,7*,8*,9*,10*
Ceterachofficinarum/ Willd.	Aspleniaceae	Rusty-back LPT-040	Lithophyte	Nephrolithiasis, liver disorders	1	0.01	2	2	1*,2*,3*,4*,5*,6*,7*,8*,9■,10■
Cheilanthesfarinosa/ (Forssk.) Kaulf.	Pteridaceae	Floury cloak fern, mealy cloak fern LPT-004	Lithophyte	Gastric pain, skin disorders, urinary tract ailments	9	0.05	3	0.33	1*,2*,3*,4*,5*,6■,7*,8*,9■,10▲
Cibotiumbarometz / (L.) J.Sm.	Cyatheaceae	Golden chicken fern LPT-012	Terrestrial	Rheumatism, physical health	2	0.01	2	1	1*,2*,3*,4*,5*,6*,7*,8*,9■,10■
Conocephalumconicum/ (L.) Dumort	Conocephalaceae	Snake liverwort, great scented liverwort LPT-039	Terrestrial	Skin diseases, anti-inflammatory, bone fractures, fungal and microbial infections, jaundice, antipyretic	11	0.06	7	0.64	1▲,2■,3■,4▲,5*,6*,7▲,8*,9*,10*
Chlorella vulgaris/ Beij.	Chlorellaceae	Chlorella, Green microalga	Aquatic	Theraputicuses ,lipid level,	35	0.21	3	0.09	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*

Botanical name / Author's name	Family	Common name / Voucher No.	Habit	Therapeutic use(s) / value(s)	FC	RFC	UR	UV	Previous Studies for Comparison
		LPT-030		inflammatory disorders					
Cystopterisfragilis / (L.) Bernh.	Aspleniaceae	Brittle bladder fern LPT-043	Lithophyte	Pulmonary infection	1	0.01	1	1	1*,2*,3*,4*,5■,6*,7*,8*,9■,10*
Dicranumscoparium/ Hedw.	Dicranaceae	Broom forkmoss LPT-037	Terrestrial	Microbial infections	2	0.01	1	0.5	1*,2■,3▲,4*,5*,6*,7*,8*,9*,10*
Dryopteris barbigera/ (Hook.) Kuntze	Polypodies	Wood ferns, Kaw-dead LPT-014	Terrestrial	Intestinal lesions, relieve constipation	25	0.15	2	0.08	1*,2*,3*,4*,5*,6*,7*,8■,9■,10▲
Dryopteris blanfordii/ (C.Hope) C.Chr.	Polypodiaceae	Hapat-daed LPT-053	Terrestrial	Analgesic, epilepsy, nervous disorders	8	0.05	3	0.38	1*,2*,3*,4*,5■,6*,7*,8■,9*,10*
Dryopteris chrysocoma/ (Christ) C.Chr.	Polypodiaceae	Hay-scented LPT-011	Terrestrial	Rheumatic pain and inflammation, sciatic nerve pain	5	0.03	2	0.4	1*,2*,3*,4*,5*,6*,7*,8*,9*,10▲
Dryopteris cochleata/ (D.Don) C.Chr.	Polypodiaceae	Buckler fern LPT-045	Terrestrial	Antitoxin, joint pain, epilipsy, leprosy, minor injuries	7	0.04	4	0.6	1*,2*,3*,4*,5*,6▲,7*,8*,9■,10▲
Dryopteris ramosa/ (C.Hope) C.Chr.	Polypodiaceae	Kunji, pakha LPT-018	Terrestrial	Bacterial infections, edible	1	0.01	1	1	1*,2*,3*,4*,5*,6*,7*,8■,9*,10*
Dumortierahirsuta/ (Sw.) Nees	Dumortieraceae	Dumortier's liverwort LPT-006	Terrestrial	Bacterial infections	3	0.02	1	0.33	1▲,2■,3*,4▲,5*,6*,7■,8*,9*,10*
Equisetum arvense / L.	Equisetaceae	Field horsetail LPT-019	Terrestrial	Tumors, urinary tract ailments, bone repair, dyspepsia	14	0.08	4	0.29	1*,2*,3*,4*,5▲,6■,7*,8■,9■,10▲
Funaria hygrometrica / Hedw.	Funariaceae	Bonfire-moss LPT-042	Terrestrial	Hematemesis, nasal and sinus inflammation, baldness, tonsillitis, dermatological issues	13	0.08	5	0.38	1▲,2*,3■,4▲,5*,6*,7*,8*,9*,10*
Hyophilainvoluta/ (Hook.) A. Jaeger	Pottiaceae	Rolled-leaf wet-ground moss LPT-013	Terrestrial	Lacerations	1	0.01	1	1	1■,2*,3■,4*,5*,6*,7*,8*,9*,10*

Botanical name / Author's name	Family	Common name / Voucher No.	Habit	Therapeutic use(s) / value(s)	FC	RFC	UR	UV	Previous Studies for Comparison
Hypnum cupressiforme/ Hedw.	Hypnaceae	Cypress-leaved plaitmoss LPT-044	Corticolous	Microbial and mycotic infections	6	0.04	2	0.33	1*,2*,3*,4*,5*,6*,7▲, 8*,9*,10*
Lepidoziareptans/ (L.) Dumort.	Lepidoziaceae	Creeping fingerwort LPT-017	Epixylic	Swelling and inflammation	3	0.02	1	0.33	1*,2*,3*,4*,5*,6*,7*, 8*,9*,10*
Marchantialinearis/ Lehm. &Lindenb.	Marchantiaceae	Not reported LPT-008	Terrestrial	Dermatological problems	18	0.11	0	0	1*,2▪,3*,4*,5*,6*,7*, 8*,9*,10*
Marchantiapaleacea/ Bertol.	Marchantiaceae	Money liverwort LPT-047	Terrestrial	Hepatic disorders, fever, skin inflammation	2	0.01	3	1.5	1▲,2▪,3*,4▲,5*,6*,7*, 8*,9*,10*
Marchantiapolymorpha/ L.	Marchantiaceae	Common liverwort LPT-005	Terrestrial	Anti-acne, antitoxin, CVD, cystolithiasis, hepatic disorders, scalds	7	0.04	6	0.86	1▪,2▪,3▲,4▪,5*,6*,7▲, 8*,9*,10*
Marsileaminuta/ L.	Marsileaceae	Water clover LPT-020	Geophyte	Ocular ailments, Dyspepsia, unguent, aphrodisiac	28	0.16	4	0.14	1*,2*,3*,4*,5▪,6▪,7*,8▪,9▪,10▪
Osmundaregalis/ L.	Osmundaceae	Flowering fern LPT-021	Geophyte	Open skin injuries	7	0.04	1	0.14	1*,2*,3*,4*,5*,6▪,7*, 8*,9*,10▪
Pelliaendiviifolia/ (Dicks.) Dumort.	Pelliaceae	Endive pellia LPT-026	Terrestrial	Dermatological diseases, microbial infections	4	0.02	2	0.5	1*,2*,3*,4*,5*,6*,7▲, 8*,9*,10*
Plagiochasmaappendiculatum/ Lehm. &Lindenb.	Aytoniaceae	Patharshali LPT-051	Lithophyte	Vesicular skin lesions, burn injuries, wounds	6	0.04	3	0.5	1▲,2▪,3▪,4▪,5*,6*,7*,8*,9*,10*
Plagiochasma intermedium / Lindenb. &Gottsche	Aytoniaceae	Not reported LPT-022	Lithophyte	Fungal infections	1	0.01	1	1	1*,2▪,3*,4*,5*,6*,7▲, 8*,9*,10*
Plagiochasmarupestre / (J.R. Forst. & G. Forst.) Steph.	Aytoniaceae	Cliff waxwort LPT-028	Lithophyte	Renal disorders, dizziness and fainting	3	0.02	3	1	1▲,2*,3*,4*,5*,6*,7*, 8*,9*,10*
Plagiomniumcuspidatum/ (Hedw.) T.J. Kop.	Mniaceae	Woodsy thyme-moss LPT-025	Terrestrial	Hemorrhage, bleeding	1	0.01	2	2	1*,2*,3*,4*,5*,6*,7*, 8*,9*,10*

Botanical name / Author's name	Family	Common name / Voucher No.	Habit	Therapeutic use(s) / value(s)	FC	RFC	UR	UV	Previous Studies for Comparison
Pogonatumcirratum/ (Sw.) Brid.	Polytrichaceae	Crisped pogonatum LPT-035	Terrestrial	Cardiac and neurotic disorders	2	0.01	2	1	1*,2*,3▲,4*,5*,6*,7*,8*,9*,10*
Pohlianutans / (Hedw.) Lindb.	Mniaceae	Nodding thread-moss LPT-029	Terrestrial	Not reported	4	0.02	0	0	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*
Polystichumaculeatum/ (L.) Roth	Polypodiaceae	Kaw-daed LPT-048	Terrestrial	Bacterial infections	3	0.02	1	0.33	1*,2*,3*,4*,5*,6*,7*,8■,9*,10*
Polystichumlonchitis/ (L.) Roth	Polypodiaceae	Holly fern LPT-024	Geophyte	Not reported	5	0.03	0	0	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*
Polystichumsquarrosum/ (D.Don) Fee	Polypodiaceae	Jungle-daed LPT-054	Terrestrial	Edible	2	0.01	1	0.5	1*,2*,3*,4*,5■,6*,7*,8■,9*,10*
Pteriscretica/ L.	Pteridaceae	Cretan brake fern, ribbon fern LPT-049	Geophyte	Tissue repair, wound healing, hemostatic, boils	7	0.04	2	0.29	1*,2*,3*,4*,5■,6■,7*,8▲,9*,10▲
Pterisvittata/ L.	Pteridaceae	Chinese brake fern LPT-015	Geophyte	Diarrhea, cough, pyrexia, cold	31	0.18	4	0.13	1*,2*,3*,4*,5■,6■,7*,8*,9*,10▲
Riccardiamultifida / (L.) Gray	Aneuraceae	Comb liverwort LPT-027	Terrestrial	Anti-cancer	3	0.02	1	0.33	1*,2*,3*,4▲,5*,6*,7▲,8*,9*,10*
Selaginellachrysocaulos/ (Hook. &Grev.) Spring	Selaginellaceae	Christmas club-moss LPT-050	Geophyte	Bacterial infections	2	0.01	1	0.5	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*
Selaginellaoregana/ D.C.Eaton	Selaginellaceae	Oregon spike-moss LPT-023	Epiphyte	Not reported	3	0.02	0	0	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*
Woodwardia Unigemmata/ (Makino) Nakai	Aspleniaceae	Chain fern LPT-031	Geophyte	Allergic reactions, itching	1	0.01	2	2	1*,2*,3*,4*,5*,6*,7*,8*,9■,10*

1. Motti *et al.*, (2023); 2. Das *et al.*, (2022); 3. Benek *et al.*, (2022); 4.Yayintus and Irkin, (2018); 5 Irfan *et al.*, (2021); 6. Dogan, (2016); 7. Sabovljevic *et al.*, (2016); 8. Khoja *et al.*, (2022); 9. Goswami *et al.*, (2016); 10. Kimta *et al.*, (2025)

FC: Frequency citation, **RFC**: Relative frequency citation, **UR**: Use report, **UV**: Use value

**** (▲) - Same report, (■) - different report, (*) - No report**

Ethnobotanical Index Correlation

Interrelationships among the quantitative ethnobotanical indices (frequency of citation (FC), relative frequency of citation (RFC), use report (UR), and use value (UV)) of recorded plant species were determined using Pearson correlation analysis. A high positive linear correlation was found between FC and RFC, indicating that the number of citations is mathematically directly proportional to the number of informants. Some moderate positive correlations were found between the number of informants (FC) and the number of use reports (UR) ($r = 0.42$) and between the number of informants (RFC) and the number of use reports (UR) ($r = 0.40$), suggesting that species cited by more informants tended to have more cumulative use reports. On the other hand, negative linear relationships were shown between FC and UV ($r = -0.48$) and between RFC and UV ($r = -0.47$), indicating inverse relationships between the broad citation frequency and the calculated use value per species. Finally, there was a very low and nonsignificant positive correlation between the total number of use reports and the relative use value measure ($r = 0.08$) for the species evaluated (Figure 4).

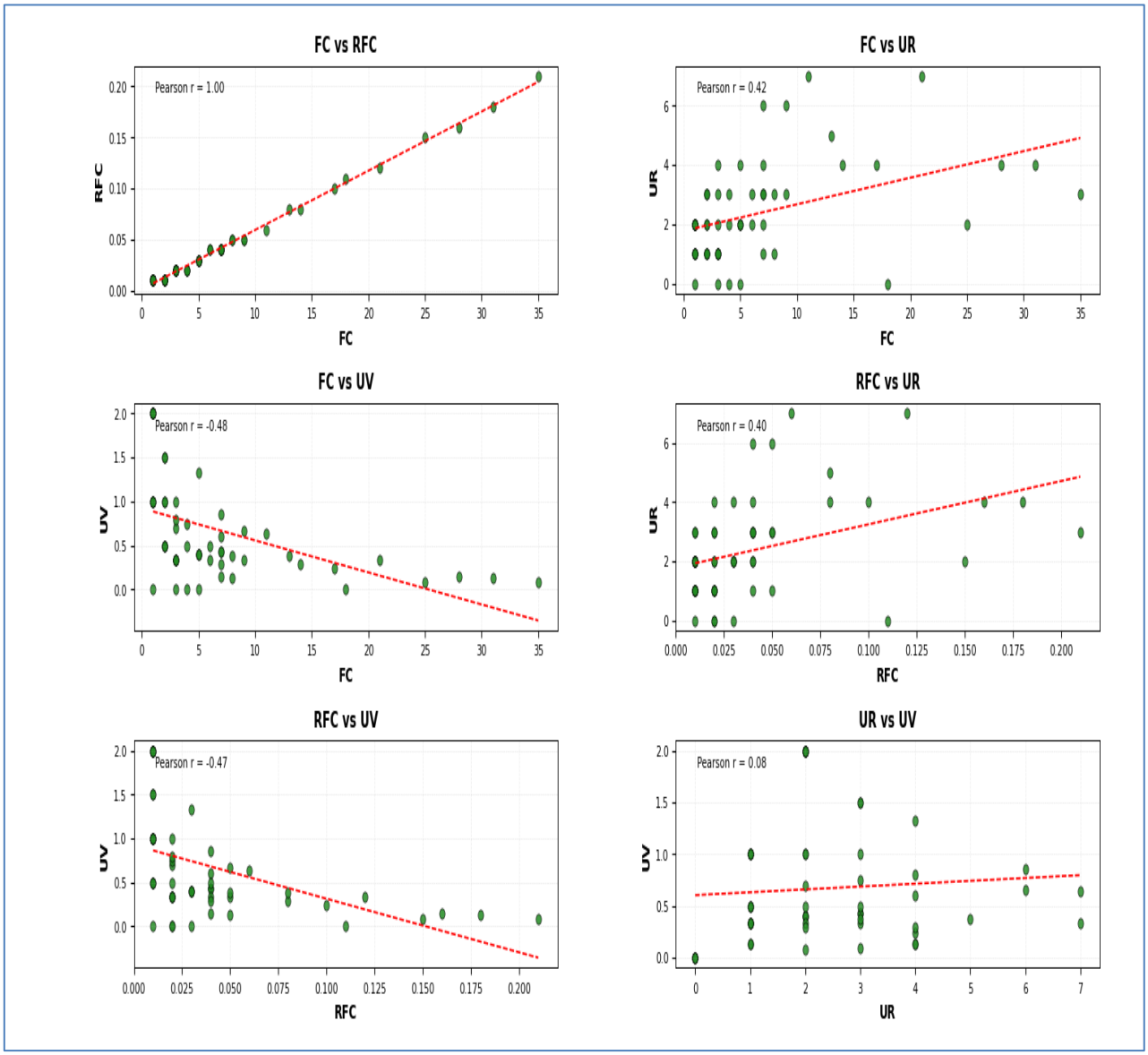


Figure 4: Correlation analysis among ethnobotanical indices of recorded plant species.

Family Use Value (FUV) Analysis of Documented Plant Species

The family use value (FUV) was quantitatively evaluated, showing significant differences among the 26 plant families based on two variables: the sum of species use values (UVs) and the number of species (n_s) recorded per plant family. Bartramiaceae had the highest overall FUV score of 1.33 (UVs = 1.33, n_s = 1) and was closely followed by Aspleniaceae with an FUV score of 1.23 (UVs = 9.83, n_s = 8). Four families—Aytoniaceae (UVs = 4, n_s = 4), Cyatheaceae (UVs = 1, n_s = 1), Mniaceae (UVs = 2, n_s = 2), and Pottiaceae (UVs = 1, n_s = 1)—each achieved a unified FUV of 1.00. High FUV values were also recorded for Marchantiaceae (0.79, n_s = 3), Salviniaceae (0.75, n_s = 1), Bryaceae (0.73, n_s = 2), Polytrichaceae (0.72, n_s = 2), Meteoriaceae (0.70, n_s = 1), and Conocephalaceae (0.64, n_s = 1). Moderate use values were documented for Dicranaceae (0.50, n_s = 1), Pelliaceae (0.50, n_s = 1), Polypodiaceae (0.41, n_s = 8), Funariaceae (0.38, n_s = 1), Aneuraceae (0.33, n_s = 1), Dumortieraceae (0.33, n_s = 1), and Hypnaceae (0.33, n_s = 1). Lower values were identified in Equisetaceae (0.29, n_s = 1), Pteridaceae (0.29, n_s = 6), Selaginellaceae (0.25, n_s = 2), and Lepidoziaceae (0.23, n_s = 2). The lowest family use values in the study site were in Osmundaceae (0.14, n_s = 1), Chlorellaceae (0.09, n_s = 1) and Marsileaceae (0.14, n_s = 1) (Table 3).

Table 3: Family use value (FUV) of documented plant species.

Family name	UVs	ns	FUV
Aneuraceae	0.33	1	0.33
Aspleniaceae	9.83	8	1.23
Aytoniaceae	4	4	1

Bartramiaceae	1.33	1	1.33
Bryaceae	1.46	2	0.73
Chlorellaceae	0.09	1	0.09
Conocephalaceae	0.64	1	0.64
Cyatheaceae	1	1	1
Dicranaceae	0.5	1	0.5
Dumortieraceae	0.33	1	0.33
Equisetaceae	0.29	1	0.29
Funariaceae	0.38	1	0.38
Hypnaceae	0.33	1	0.33
Lepidoziaceae	0.46	2	0.23
Marchantiaceae	2.36	3	0.79
Marsileaceae	0.14	1	0.14
Meteoriaceae	0.7	1	0.7
Mniaceae	2	2	1
Osmundaceae	0.14	1	0.14
Pelliaceae	0.5	1	0.5
Polypodiaceae	3.29	8	0.41
Polytrichaceae	1.43	2	0.72
Pottiaceae	1	1	1
Pteridaceae	1.72	6	0.29
Salviniaceae	0.75	1	0.75
Selaginellaceae	0.5	2	0.25

UVs: Sum of use values of the species included in that family

ns: Total number of species belonging to that family

FUV: Calculated family use value

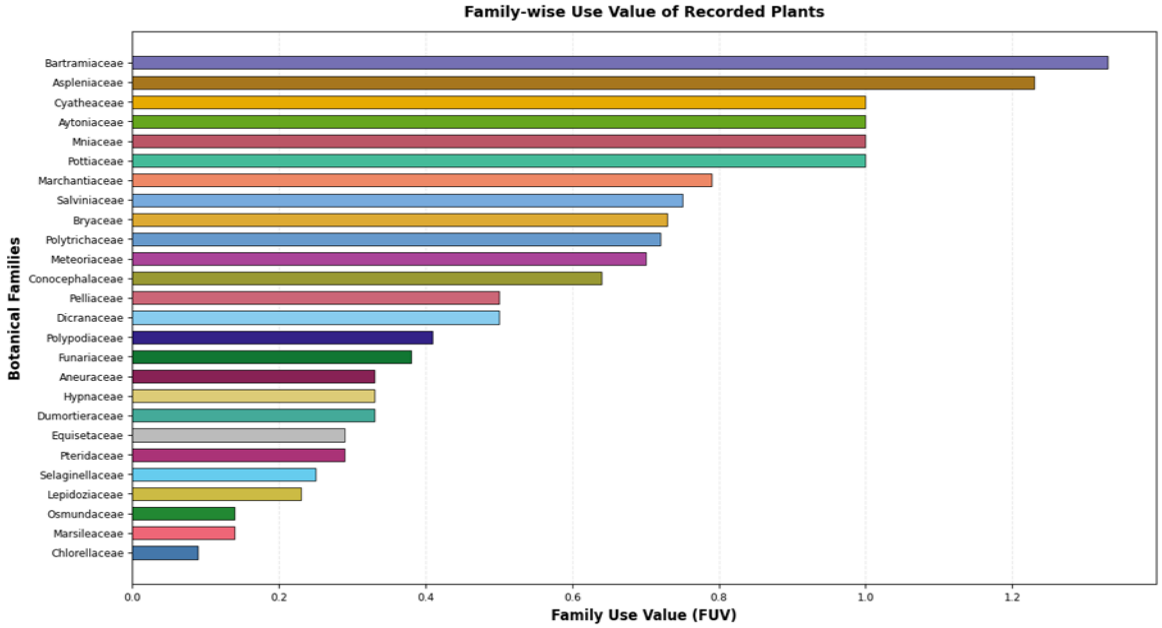


Figure 5: Familywise Distribution of Family Use Value (FUV) among Recorded Plant Species.

ICF - Informant Consensus Factor on Reported Complaint Categories

The informant consensus factor (ICF) was quantified over 15 informant-reported ailment categories to determine informant consensus on the selection of medicinal plants for each ailment category. The ICF scores calculated were between 0.00 and 1.00, indicating that there was a range of consensus among the communities. The maximum ICF value was found for the category “eye ailments”, with 1.00 for 2 use reports (Nur) and a single taxon (Nt). There was also a high level of consensus for antidote/antitoxin applications (ICF = 0.56 [Nur = 10, Nt = 5]). Informant agreement was excellent for the three separate

categories of illness (fever (Nur = 7, Nt = 4), infectious diseases (Nur = 19, Nt = 10), and liver complaints (Nur = 9, Nt = 5), all of which had ICF values of 0.50. Dermatological complaints were the most highly cited total (Nur = 24, Nt = 14, ICF = 0.43), and moderate consensus agreement was obtained for these complaints. Following kidney/renal complaints (ICF 0.38; Nur = 9, Nt = 6), miscellaneous ailments grouped under 'others' (ICF 0.37; Nur = 9, Nt = 6) came next. Gastrointestinal complaints and neurological complaints had moderate consensus values of 0.36 for both. Cardiovascular complaints (ICF = 0.29, Nur = 8, Nt = 6), respiratory complaints (ICF = 0.22, Nur = 10, Nt = 8) and musculoskeletal complaints (ICF = 0.20, Nur = 6, Nt = 5) were associated with lower informant agreement (Table 4).

Table 4: Informant Consensus on Reported Complaint Categories

Category of Ailments	Number of Use Reports (N_{ur})	Number of Taxa Used (N_t)	ICF
Antidote/Antitoxin	10	5	0.56
Cardiovascular complaints	8	6	0.29
Dermatological complaints	24	14	0.43
Diabetes	2	2	0.00
Eye ailments	2	1	1.00
Fever	7	4	0.50
Gastrointestinal complaints	12	8	0.36
Infectious diseases	19	10	0.50
Kidney/Renal complaints	9	6	0.38
Liver complaints	9	5	0.50
Musculoskeletal complaints	6	5	0.20
Neurological complaints	12	8	0.36
Oncology	4	3	0.03
Respiratory complaints	10	8	0.22
Others	9	6	0.37

- **ICF**: Informant consensus factor

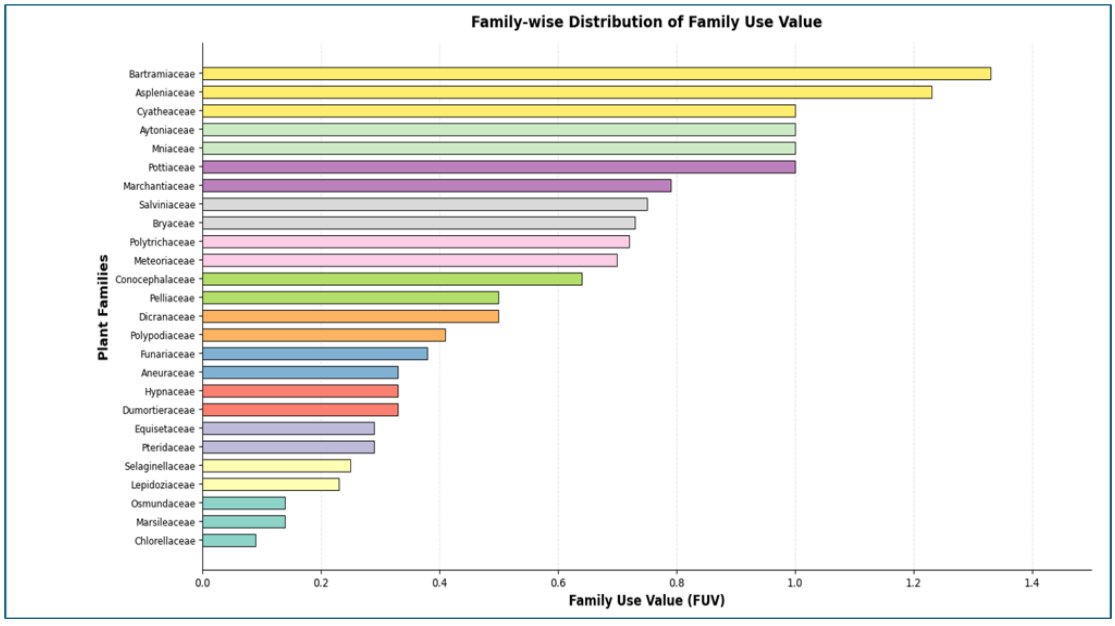


Figure 6: Familywise distribution of family use value (FUV) across evaluated plant families.

Comparative Analysis of the Present Study with Previous National and Global Studies (Jaccard Index)

The current study was compared with ten previous studies at both the national and global levels using the Jaccard Index (JI) to assess novel ethnobotanical uses and regional floristic affinity. The comparative metrics compared were total taxa, shared taxa (similar and dissimilar uses), unaligned regional taxa, and calculated similarity percentages between the literature referenced.

The most similar floristic composition and ethnobotanical information was found compared to Kimta et al. (2025), with the highest Jaccard Index (JI) of 9.43%. This study had 17 taxa common with the current research site, which was 27.42% of the total taxa reported in this study; 10 of these taxa were common with similar medicinal use (16.13%), and 7 taxa were common with dissimilar medicinal use (11.29%). The other similar and dissimilar uses were also higher, with Motti et al. (2023) sharing 13 similar and 8 dissimilar taxa (JI 5.26%), Yayintus and Irkin (2018) sharing 8 similar and 5 dissimilar taxa (JI 4.95%) and Sabovljevic et al. (2016) sharing 8 similar and 2 dissimilar taxa (JI 5.41%).

They were found to have moderate similarity indices compared to Benek et al. (2022), which was 2.68% (9 shared taxa, 3 similar, and 6 dissimilar uses), and Irfan et al. (2021), which was 2.08% (11 shared taxa, 2 similar, and 9 dissimilar uses). Comparative studies on larger floristic inventories, such as Goswami et al. (2016), which included 213 total taxa, gave lower similarity indices (JI = 1.34%, 14 shared taxa). Likewise, Khoja et al. (2022) found a low Jaccard Index value of 0.92% (13 shared taxa) with a higher percentage of dissimilar usage patterns (20.69% dissimilar), and Dogan (2016) found a low value of 0.91% (9 shared taxa) and a higher percentage of dissimilar use patterns (14.29% dissimilar).

The lowest similarity was found compared to Das et al. (2022), with a Jaccard index of 0.00%. The number of medicinal plants used in both study areas is completely different, as is the rate of similarity in ethnobotanical uses, which was 0% in both areas, even though 8 taxa appeared in both areas (representing 20.51% of the reported flora) (Table 5).

Table 5: Comparison of the present studies with previous studies at the national and global levels - Jaccard Index (JI).

Reference	Total no. of reported taxa	No. of taxa with similar uses	No. of taxa with dissimilar uses	Sum of taxa found in both areas	Taxa percentage found in both areas (%)	Taxa reported only in aligned area	Taxa confined to study area	Percentage with similar use (%)	Percentage with dissimilar use (%)	JI* (%)
Motti *et al.*, (2023)	109	8	5	13	11.93	96	42	7.34	4.59	5.26
Das *et al.*, (2022)	39	0	8	8	20.51	31	47	0	20.51	0.00
Benek *et al.*, (2022)	67	3	6	9	13.43	58	46	4.48	8.96	2.68
Yayintus and Irkin, (2018)	49	5	3	8	16.33	41	47	10.20	6.12	4.95
Irfan *et al.*, (2021)	40	2	9	11	27.5	39	44	5	22.5	2.08
Dogan, (2016)	56	1	8	9	16.07	47	46	1.79	14.29	0.91
Sabovljevic *et al.*, (2016)	60	6	2	8	13.33	52	47	10	3.33	5.41
Khoja *et al.*, (2022)	58	1	12	13	22.41	45	43	1.72	20.69	0.92
Goswami *et al.*, (2016)	213	3	11	14	6.57	199	41	1.43	5.16	1.34
Kimta *et al.*, (2025)	62	10	7	17	27.42	45	38	16.13	11.29	9.43

Discussion

Diversity and ethnobotanical significance of lower plants

In the present study, lower plants of Soon Valley, Punjab, Pakistan, were studied, and 55 taxa of 26 families were recorded, showing a significant diversity of lower plants found in the study area. The flora reported included pteridophytes, bryophytes

and algae, some of which were reported by local inhabitants for their traditional medicinal uses. The use of these plants in a wide variety of medical ailments illustrates the wide applications of the lower plants as part of the indigenous medicine of the region.

The results also suggested that the local communities have been consistently recognizing and utilizing the ecological diversity of Soon Valley, thus supporting the maintenance and transmission of traditional ethnobotanical knowledge across generations, which led to the establishment of appropriate habitat spaces for many lower-plant taxa. The results are of special value, as quantitative ethnobotanical studies of lower plants are far less numerous than those of angiosperms. Although bryophytes are found in various traditional medicinal systems, there is relatively little information available (Motti *et al.*, 2023). Thus, the current results represent a distinct regional aspect of Pakistan's ethnobotanical literature.

It was demonstrated in an earlier study conducted in Soon Valley that locals have extensive knowledge about the medicinal uses of native plants. In the specific Soon Valley area, 63 informants' ethnomedical knowledge was documented, and plant use was statistically assessed using the Jaccard index, frequency citation and relative frequency citation. However, this study did not examine lower plants as a distinct group; instead, it concentrated on plants used to treat malaria and related symptoms(Shah & Rahim, 2017). As a result, the current study offers an alternative perspective on Soon Valley's ethnobotanical character by looking at taxa that are frequently neglected in traditional surveys of medicinal plants.

Ecological Distribution and Habitat Diversity of Lower Plants

The 55 taxa identified in this study were distributed among a number of different growth and habitat types. The largest category (27 species) was terrestrial, followed by lithophytes (14), geophytes (7), epiphytes (3), aquatic taxa (2), and one taxon each of corticolous and epixylic habits. This pattern suggests that Soon Valley's lower-plant collection is not limited to a particular environment. Rather, plants are found on the surfaces of other plants, rocky substrates, dirt, and aquatic environments. The dominance of terrestrial taxa can be correlated with the abundance of soil-based microhabitats that are appropriate for mosses, liverworts and terrestrial ferns. Bryophytes are especially well adapted to colonizing a variety of habitats ranging from aquatic to somewhat dry terrestrial habitats, although abundance is greatly influenced by moisture and other local environmental factors.

Bryophytes grow in a wide range of habitat types from xeric to aquatic (Motti *et al.*, 2023), while their relatively small size and generally low biomass have contributed to their comparatively limited recognition in ethnomedicine (Sabovljevic *et al.*, 2020). Representative lithophytic taxa also have ecological significance. Of the 14 taxa of the present research, several were related to rocky substrates, such as those of Aspleniaceae and Pteridaceae. *A. adiantum*, *A. fontanum*, *A. septentrionale*, *A. trichomanes*, *A. viride*, *Ceterach officinarum* and *Cystopteris fragilis* were all found as lithophytes, while *Adiantum incisum* and *Cheilanthes farinosa* were equally recorded. The association of the rocks with numerous rock-associated ferns indicates that the rock and topographic features of Soon Valley also make a significant contribution to the flora of the lower plants.

This also reflects the general trend that pteridophyte diversity is linked to habitat characteristics in the Western Himalayas and traditional knowledge (Khoja *et al.*, 2022). It should not be assumed that the lower number of aquatic taxa in the research means that they are less ethnobotanically important. In fact, there was a significant difference in citation frequency and use value between the two aquatic taxa *Chlorella vulgaris* and *Azolla pinnata*. The highest FC and RFC were obtained for Chlorella vulgaris, while the lowest FC and comparatively high value of UV were obtained for *Azolla pinnata* from the results. This contrast illustrates an important feature of ethnobotanical indices: ecological abundance, familiarity and breadth of use can influence different quantitative measures in different ways.

Taxonomic Composition and Family-Level Diversity of Pteridophytes

In the taxonomic classification used in the present results, Aspleniaceae and Polypodiaceae were the two most abundant families, with eight taxa each, and Pteridaceae was third with six taxa. The 22 taxa recorded were distributed among these 3 families. The two together illustrate that lower plants are a significant element of the diversity of ferns in Soon Valley. The dominance of these families is similar in a general sense to other studies that were conducted in other parts of Pakistan and other parts of the world, but the order of family richness varies between the different regions. Khyber Pakhtunkhwa ferns (taxa) distributed under 10 families (families of plants used as medicines among different ethnic groups). As per their study, the family Pteridaceae is the largest family, comprising 12 taxa, while genera such as Asplenium, Adiantum and Dryopteris are among the most represented genera (Irfan *et al.*, 2021). Their results differ from the present study; this may be explained by the fact that Soon Valley has a different ecological condition and the present inventory is a compilation of bryophytes, algae and ferns.

The regular occurrence of the fern families Pteridaceae and Asplenium/Adiantum in various ethnobotanical investigations conducted in Pakistan suggests high ethnobotanical representation within these families. A wider survey of the pteridophytes from Mansehra and adjoining areas carried out by the same group recorded 60 taxa used traditionally, 16 families and 26 genera. Of these, 56 taxa were reported as medicinal (Dogan, 2016). The total number of pteridophyte taxa reported in that study is comparable to the total taxa of lower plants reported in Soon Valley, although not a true comparison since bryophytes and algae are included in the present study. It is clear from the comparison that the mountainous and physiographically variable areas of Pakistan can have significant traditional knowledge about nonflowering plants.

Aspleniaceae was represented by eight taxa, namely, *Asplenium adiantum*, *A. fontanum*, *A. septentrionale*, *A. trichomanes*, *A. viride*, *Ceterach officinarum*, *Cystopteris fragilis* and *Woodwardia unigemmata*, according to the classification used in the present research. The family was not only taxonomically prominent but also ethnobotanically important, as the FUV was 1.23, which is significantly more than the FUV of Polypodiaceae (0.41) and Pteridaceae (0.29). Members of this family were assigned various roles. There were asthma, pneumonia, laxative use and urinary problems associated with *Asplenium adiantum*, asthma and emphysema with *A. fontanum*, anti-inflammatory and anticancer applications with *A. trichomanes*, skin damage and inflammation with *A. viride*, nephrolithiasis, and liver disorders with *Ceterach officinarum* and pulmonary infection with *Cystopteris fragilis*.

Allergic reactions and itching were recorded for *Woodwardia unigemmata*. Therefore, the values of FUV of the Aspleniaceae are based not only on the number of species but also on other wide spectra of therapeutic value. Partially, this finding was found to be consistent with the finding of (Irfan *et al.*, 2021), who found 4 taxa of Asplenium in KPK and noted the use of these plants mainly for respiratory, urinary, intestinal and skin diseases. The uses in Soon Valley related to the respiratory system are more or less similar: asthma, emphysema and pneumonia are among the Aspleniaceae uses, and respiratory disorders were among the major uses reported for ferns in Khyber Pakhtunkhwa. The reoccurrence of these uses among geographically distinct

communities in Pakistan has led us to believe that the respiratory uses of ferns may be a more enduring part of the Pakistani ethnobotanical knowledge.

Quantitative Ethnobotanical Importance of Documented Lower Plants

It is also seen in the present results that not all species in a family need to be cited frequently to be of high FUV importance. For instance, the FCs for *Asplenium fontanum* and *A. viride* were only 1 each, while the FC for *Asplenium adiantum* was 7 and the UV was 0.43. Hence, the FUV of Aspleniaceae was not calculated from the total number of informants for each species but from the overall spectrum of uses that were spread across the various members. It is also noteworthy that the presence of *Ceterach officinarum* is mentioned for nephrolithiasis and liver disorder. The medicinal use of fern taxa to treat urinary and renal disorders is not limited to Soon Valley. A few ferns have been reported to treat urinary disorders in Khyber Pakhtunkhwa, and the general literature on *Adiantum capillus-veneris* has reported traditional anti-urolithiatic and diuretic uses. Although traditional reports cannot be used as a positive indicator of clinical efficacy, the recurrence of urinary-related applications in these studies is helpful for comparison (Irfan *et al.*, 2021).

Polypodiaceae was also represented by 8 taxa, including five *Dryopteris* taxa and three *Polystichum* taxa in the present research. The therapeutic uses of this family differed from those of Aspleniaceae. Gastrointestinal, neurological, musculoskeletal and infectious uses were particularly evident. *Dryopteris barbigera* was reported for intestinal lesions and constipation; *D. blanfordii* for analgesic, epilepsy and nervous disorders; *D. chrysocoma* for rheumatic and sciatic pain; *D. cochleata* for antitoxin activity, joint pain, epilepsy, leprosy and minor injuries; and *D. ramosa* for bacterial infections and food use. The prominence of *Dryopteris* in the present inventory corresponds with observations from Khyber Pakhtunkhwa. It was reported that *Dryopteris* is among the genera with the highest representation, together with *Adiantum* and *Asplenium (Irfan et al., 2021)*.

The Mansehra study documented extensive traditional use of pteridophytes, illustrating the continued importance of fern resources in northern Pakistani communities (Dogan, 2016). Among the Polypodiaceae taxa, *Dryopteris barbigera* was particularly prominent in terms of citation frequency, with FC = 25 and RFC = 0.15, despite having a comparatively low UV of 0.08. This is an important distinction between the frequency of knowledge and the diversity of applications. The species appears to be widely recognized by informants, but its reported applications were comparatively narrow. In contrast, *Dryopteris cochleata* had a lower FC of 7 but a substantially greater UV of 0.60 because several different uses were attributed to it. Therefore, the two indices describe different dimensions of ethnobotanical importance and should not be interpreted interchangeably. *Dryopteris ramosa* provides a particularly useful comparison with previous Pakistani research. In Soon Valley, it was reported for bacterial infections and as an edible plant. It has been reported that *D. ramosa,* as an ethnomedicinal plant of the Galliyat region of Pakistan, is used for gastrointestinal ailments, particularly those associated with bacterial infections. Their study subsequently isolated a bioactive compound from the aqueous fraction and investigated its antibacterial activity (Ishaque *et al.*, 2021).

The agreement between the present traditional use for bacterial infections and the Galliyat ethnomedicinal record is therefore particularly noteworthy. It also represents one of the stronger examples in the present research where a locally recorded use corresponds to an independently investigated biological activity. The food use of *D. ramosa* in the present study further illustrates that the ethnobotanical importance of pteridophytes is not necessarily restricted to medicine. Similarly, pteridophytes in Mansehra were collected not only for medicinal purposes but also for food and other practical applications (Dogan, 2016). This indicates that traditional recognition of ferns can incorporate multiple dimensions of plant utility.

Pteridaceae constituted the third largest family with six taxa: *Adiantum capillus-veneris*, *A. caudatum*, *A. incisum*, *Cheilanthes farinosa*, *Pteris cretica* and *Pteris vittata*. Although its FUV was lower than that of Aspleniaceae, several members of the family had comparatively high citation frequencies. This indicates that family richness and the popularity of individual species are separate characteristics. The most prominent species was *Adiantum capillus-veneris*, which had FC = 21, RFC = 0.12 and UV = 0.33. Its recorded uses in Soon Valley included vascular disease, diabetes, antitoxin use, hormonal and gynecological problems, pulmonary disorders and hair growth. These applications show a broad therapeutic profile. The species is also well represented in the ethnomedicinal literature. In Gokand Valley, Pakistan, *A. capillus-veneris* was recorded for constipation, pneumonia and scorpion bite, with FC = 23, RFC = 0.136 and UV = 0.65. Its citation values in Gokand Valley and Soon Valley are therefore remarkably similar, although the use spectrum differs.

A broader review on *A. capillus-veneris* reported traditional applications involving respiratory, gastrointestinal, urinary, inflammatory, female reproductive and hair-related conditions, together with several experimentally investigated biological activities (Dehdari & Hajimehdipoor, 2018). This corresponds closely with several applications recorded in Soon Valley, particularly respiratory, gynecological, urinary-related and hair uses. Such correspondence does not establish therapeutic efficacy, but it strengthens the observation that *A. capillus-veneris* has a persistent ethnomedicinal reputation across different cultural regions. The use of *A. incisum* in Soon Valley for respiratory ailments and jaundice is also of interest. The genus-level review by Kumar et al. described traditional applications of *Adiantum* species for respiratory conditions, including cough, cold, fever, pneumonia and mucus-related problems. Thus, the respiratory application of *A. incisum* in Soon Valley fits within a broader pattern associated with the genus, although the specific use for jaundice represents a more localized component of the recorded knowledge.

Pteris vittata was another highly cited Pteridaceae member, with FC = 31 and RFC = 0.18, and was used for diarrhea, cough, pyrexia and cold. Its high citation frequency indicates considerable recognition within the study population. *Pteris cretica*, in contrast, had FC = 7 but was associated with tissue repair, wound healing, hemostatic activity and boils. The difference between these species again demonstrates that citation frequency reflects the distribution of knowledge, whereas UV reflects the number of uses attributed to a taxon.

The dominance of Pteridaceae in other Pakistani research provides further support for the significance of this family. Pteridaceae is the most represented family among ethnomedicinal ferns in Khyber Pakhtunkhwa, with 12 taxa (Irfan *et al.*, 2022). In contrast, Pteridaceae ranked third in the present study. This difference probably reflects regional differences in species availability and habitat composition rather than a contradiction between the two investigations. The frequency-citation results provide a different perspective from the family-level analysis. *Chlorella vulgaris* had the highest FC (35) and RFC (0.21), followed by *Pteris vittata* (FC = 31; RFC = 0.18), *Marsilea minuta* (FC = 28; RFC = 0.16), *Dryopteris barbigera* (FC = 25; RFC = 0.15), *Adiantum capillus-veneris* (FC = 21; RFC = 0.12) and *Marchantia linearis* (FC = 18; RFC = 0.11). The prominence of *Chlorella vulgaris* is one of the distinctive findings of the study because the species was represented by only one taxon within Chlorellaceae but nevertheless achieved the highest citation frequency. Its recorded applications include therapeutic use, lipid-level management and inflammatory disorders.

The result demonstrates that the ethnobotanical importance of a taxonomic group cannot be inferred from species richness alone. A single species may become highly prominent when it is familiar to many informants or has a particular perceived therapeutic value. *Pteris vittata* and *Marsilea minuta* similarly had high citation frequencies. *Marsilea minuta* was associated with ocular ailments, dyspepsia, unguent and aphrodisiac use. The presence of an ocular application is particularly relevant to the ICF result discussed below because eye ailments had the highest ICF. However, that consensus value is based on only one taxon, so it should be interpreted cautiously rather than as evidence that the species is universally effective for eye disorders. The high citation frequency of *Marsilea minuta* may also reflect its association with moist or aquatic environments, making it recognizable to people familiar with such habitats. By comparison, *Pteris vittata* is associated with more terrestrial/geophytic conditions and was cited for several common complaints, such as diarrhea, cough, fever and cold. The difference in use profile between the two frequently cited taxa suggests that local recognition is shaped not only by medicinal reputation but also by ecological availability and the types of ailments commonly addressed by the plant.

The UV values revealed several taxa that were particularly important because of the number of uses attributed to them. *Asplenium fontanum*, *Asplenium viride*, *Ceterach officinarum*, *Plagiomnium cuspidatum* and *Woodwardia unigemmata* each recorded a UV of 2.00, although some of these species had very low FC values. This is an important result because it demonstrates why citation frequency and use value should be considered separately. A species with FC = 1 may obtain a high UV if the informant provides several distinct uses, while a species cited by many informants can have a lower UV if everyone associates it with only one or two applications. *Chlorella vulgaris* illustrates the first dimension poorly but the second strongly: it had the highest FC/RFC but UV = 0.09. In contrast, *Bartramia ithyphylla* had FC = 5 but UV = 1.33, reflecting four recorded use reports. The family-level analysis further reinforces this distinction. Bartramiaceae had the highest FUV (1.33), followed closely by Aspleniaceae (1.23). Aytoniaceae, Cyatheaceae, Mniaceae and Pottiaceae each had FUV = 1.00.

Polypodiaceae and Pteridaceae, despite having eight and six taxa, respectively, had considerably lower FUV values of 0.41 and 0.29. The high FUV of Aspleniaceae is therefore especially meaningful because it combines high family richness with substantial therapeutic diversity. Bartramiaceae provides the opposite example: only one taxon was represented, yet its single species, *Bartramia ithyphylla*, was associated with anxiety, nerve tonic use, convulsive disorders and heart palpitations and consequently produced a high FUV. This shows that ethnobotanical significance at the family level can arise either through several moderately utilized species or through one particularly versatile species Farràs et al. (2022) and Xu et al. (2020).

Traditional Medicinal Uses and Informant Consensus Factor of Lower Plants

The ICF results showed considerable variation among disease categories. Eye ailments had the maximum ICF (1.00), followed by antidote/antitoxin uses (0.56), while fever, infectious diseases and liver complaints each recorded 0.50. Dermatological complaints recorded 0.43, renal complaints 0.38, gastrointestinal and neurological complaints 0.36, cardiovascular complaints 0.29, respiratory complaints 0.22 and musculoskeletal complaints 0.20. Diabetes and oncology each recorded 0.00. The ICF of 1.00 for eye ailments should be interpreted with caution. Only two use reports involving one taxon contributed to this category. A perfect ICF can therefore result from very small research and does not necessarily indicate that eye ailments constitute the most important health problem or that the reported plant has superior therapeutic efficacy. The same principle applies to categories with very low numbers of use reports. Quantitative indices are most informative when considered alongside the size and composition of the underlying dataset. Dermatological complaints represented the largest number of use reports among the categories shown in the results, with 24 uses involving 14 taxa, producing an ICF of 0.43. This moderate level of agreement indicates that local knowledge concerning skin disorders is distributed among several taxa rather than concentrated on a single plant.

The diversity of dermatological taxa is also compatible with the wider ethnobryological literature. Skin and hair care are found to be the most frequently reported medicinal category for bryophytes globally, accounting for 25% of recorded uses (Motti *et al.*, 2023). The present study therefore shows a notable parallel with global bryophyte literature in the prominence of skin-related applications. Taxa such as *Conocephalum conicum*, *Marchantia linearis*, *Marchantia paleacea*, *Marchantia polymorpha*, *Pellia endiviifolia*, *Plagiochasma appendiculatum* and *Woodwardia unigemmata* were associated with different dermatological, inflammatory, wound or related applications. Likewise, mosses have historically been used in wound healing and infection-related applications (Benek *et al.*, 2022).

The infectious-disease category recorded 19 uses involving 10 taxa and an ICF of 0.50, indicating that infectious conditions were treated using several taxa but with some degree of convergence among informants. This category included taxa from different lower-plant groups rather than being restricted to a single family. This finding is consistent with the wider literature because antimicrobial properties have been repeatedly reported from bryophytes and pteridophytes. Antimicrobial and other biological activities have been associated with bryophytes (Sabovljevic *et al.*, 2016), while antimicrobial activity has been summarized among medicinal bryophytes (Motti *et al.*, 2023).

The liver category also showed ICF = 0.50, with nine use reports involving five taxa. Several locally reported taxa were associated with hepatic conditions, including *Azolla pinnata*, *Ceterach officinarum*, *Marchantia paleacea* and *Marchantia polymorpha*. The occurrence of liver-related applications is not unusual within bryophyte ethnomedicine; previous reviews have described hepatic and related internal disorders among the traditional uses of bryophytes. Respiratory complaints had a lower ICF of 0.22 despite involving 10 use reports and eight taxa. This relatively low value indicates that knowledge concerning respiratory conditions was dispersed across several taxa. This finding contrasts with the Pakistani fern study (Irfan *et al.*, 2021), where respiratory disorders were among the major categories of fern use. The difference may be partly explained by the broader taxonomic scope of the present study and the inclusion of bryophytes and algae, which are distributed across a larger range of taxa.

Several taxa in the present inventory deserve special attention because their traditional uses correspond with findings reported independently from other regions. *Adiantum capillus-veneris* is the clearest example. In Soon Valley, it was recorded for

respiratory, urinary-related, gynecological, diabetic, vascular and hair-related applications. In Gokand Valley, it was used for constipation, pneumonia and scorpion bite, and its FC, RFC and UV were also relatively high. A broader review of the species reported respiratory, gastrointestinal, urinary, inflammatory, hair and female reproductive applications, providing substantial overlap with the Soon Valley record.

Dryopteris ramosa provides another strong comparison because its use for bacterial infections in Soon Valley agrees with ethnomedicinal evidence from the Galliyat region. The traditional use of *D. ramosa* against gastrointestinal ailments is associated with bacteria and isolated a compound showing antibacterial activity (Ishaque *et al.*, 2021). This does not validate the complete range of traditional claims recorded in Soon Valley, but it provides a scientifically relevant basis for prioritizing the species for further investigation.

The moss component also reveals correspondence with the wider literature. *Bryum argenteum* was recorded for nasal inflammation, fungal infections, detoxification and pyrexia, whereas *Bryum capillare* was associated with bacterial and fungal infections, dysentery, heat-related illness, pyrexia and body pain. (Benek *et al.*, 2022) documented the historical medicinal importance of mosses and emphasized their traditional role in wound and infection management. The similarity is therefore more evident at the level of therapeutic categories than at the level of identical species-use combinations. The results should not be interpreted solely according to the highest FC or RFC values.

Several taxa had low citation frequencies but comparatively high UV values. *Asplenium fontanum*, *Asplenium viride*, *Ceterach officinarum*, *Plagiomnium cuspidatum* and *Woodwardia unigemmata* each had UV = 2.00, while the FC for some of these species was only 1. These taxa may therefore represent specialized knowledge rather than widespread knowledge. Conversely, *Pohlia nutans*, *Polystichum lonchitis* and *Selaginella oregana* were recorded without reported therapeutic use and consequently had UV = 0 Masoodi and Sundriyal (2020). Their inclusion in the inventory is nevertheless useful because it distinguishes the presence and recognition of a taxon from actual medicinal utilization. This distinction is important in ethnobotanical surveys: a plant may be known by informants or occur in the study area without necessarily having an established medicinal role. The contrast between these taxa and highly cited species such as *Chlorella vulgaris* and *Pteris vittata* indicates that the ethnobotanical value of the lower-plant flora is heterogeneous. Some species are broadly recognized, some are associated with multiple specialized uses, and others are known locally but not currently linked with medicinal applications.

The combined results show that the lower-plant ethnobotany of Soon Valley is characterized by taxonomic diversity, ecological heterogeneity and considerable variation in the distribution of traditional knowledge. The 55 recorded taxa are not equally important from an ethnobotanical perspective. The family-level results identify Aspleniaceae and Polypodiaceae as the largest families by taxon number, while Pteridaceae occupies the third position. At the same time, FUV demonstrates that species richness alone does not determine therapeutic importance: Aspleniaceae has both high richness and high FUV, whereas Bartramiaceae achieves the highest FUV with only one recorded taxon. At the species level, the greatest informant recognition was associated with *Chlorella vulgaris*, *Pteris vittata*, *Marsilea minuta*, *Dryopteris barbigera* and *Adiantum capillus-veneris*. Their high FC/RFC values indicate that these taxa occupy visible positions within local ethnobotanical knowledge. In contrast, several taxa with low FC possessed high UV, indicating that specialized knowledge remains concentrated among fewer informants.

The three dominant families Aspleniaceae, Polypodiaceae and Pteridacea should consequently be regarded as major contributors to the ethnobotanical character of the study area, but for different reasons. Aspleniaceae combines eight taxa with a high FUV and a broad therapeutic spectrum; Polypodiaceae is characterized particularly by the representation of *Dryopteris* and its gastrointestinal, neurological, musculoskeletal and infectious applications; and Pteridaceae contains highly recognized taxa such as *Adiantum capillus-veneris* and *Pteris vittata*.

Comparisons with Pakistani studies show that these fern groups recur in traditional medicine, although their relative abundance and specific uses vary between regions. The disease-category analysis further demonstrates that local knowledge is not distributed uniformly. Dermatological complaints involved the largest number of taxa and use reports, whereas eye ailments produced the highest ICF because a single taxon accounted for the reported uses. The dermatological prominence corresponds with the global ethnobotanical pattern reported for bryophytes by (Motti *et al.*, 2023), while infectious, respiratory and urinary applications show correspondence with the Pakistani pteridophyte literature. Finally, the generally low Jaccard values demonstrate that the ethnobotanical composition of Soon Valley is not simply a repetition of knowledge documented elsewhere. Even comparisons with Pakistani studies produced relatively low similarity, while the greatest overlap occurred with literature having a broader focus on pteridophyte or bryophyte medicinal applications. This regional specificity is an important outcome of the study. This indicates that traditional knowledge concerning lower plants is closely tied to the taxa actually available in the local environment and to the particular ways in which those taxa have been incorporated into community healthcare practices.

Comparative Ethnobotanical Analysis, Jaccard Index and Conservation Implications

Comparisons with previous studies also show that although some species and therapeutic applications are shared with other regions, the relatively low Jaccard similarities indicate a considerable degree of locality and specificity in the traditional knowledge of Soon Valley. These findings emphasize that the ethnobotanical significance of lower plants cannot be assessed solely from their abundance or taxonomic diversity; rather, it is embedded in the interaction between local flora, habitat, human experience and knowledge transmission. Consequently, the present inventory provides an important baseline for future taxonomic, ecological, ethnobotanical, phytochemical and pharmacological investigations while also underscoring the need to document and conserve traditional knowledge associated with these often-neglected plant groups before changes in land use, environmental conditions and intergenerational knowledge transfer lead to its gradual loss.

Conclusion

The present study documented 55 lower plant taxa belonging to 26 families in Soon Valley, Punjab, Pakistan, based on information collected from 170 local informants. The recorded species showed considerable ecological and ethnobotanical diversity, with terrestrial and lithophytic habitats being the most common. Chlorella vulgaris had the highest RFC (0.21), while the highest UV (2.00) was recorded for the four species. Bartramiaceae showed the highest FUV (1.33). The findings highlight the importance of lower plants in local traditional knowledge and provide baseline information for future botanical and ethnobotanical research. Further phytochemical and pharmacological studies are needed to investigate the reported traditional uses, while conservation efforts should focus on protecting plant diversity and preserving indigenous knowledge.

Declarations

Ethics approval

The Institutional Ethics and Guideline Committee of the University of Sargodha (Approval No. 23-C301/2024 UOS) has allowed all the protocols used in this experiment. All the experimental methods of this study followed all the appropriate guidance and regulations.

Consent for publication

All subjects gave their “informed consent” for the publication of details within the text (“informed consent”) to be published in the above Journal and Article. Written “informed consent” was obtained from all authors for the publication of this manuscript.

Acknowledgements

The manuscript is part of the M. Phil dissertation of the first author (Tanzeela Batool). The authors are thankful to the Higher Education Commission of Pakistan (HEC) (Programme No. 20-4546/ R&D/NRPU/HEC/14/850) for financial, technical and practical support. The authors are also indebted to the laboratory of the Institute of Food Sciences and Nutrition (IFSC) for cooperation and provision of required facilities. The plant was collected from the study area (Soon Valley) and was deposited in the Herbarium of Department of Botany, University of Sargodha that was established with the financial support of ORIC Project No. UOS/ORIC/2016/43 University of Sargodha, Sargodha, Pakistan.

Authors' contributions

The manuscript is written by TB as M.Phil scholar. SR (as M.Phil supervisor) and AS (as M.Phil co-supervisor) helped in the tabulation of data. The rest of the authors NR, GS, and MA helped in the finalization of the paper. All the authors approved the final manuscript.

Availability of data and materials

Data are provided within the manuscript or supplementary information files.

Competing Interest

All authors declare that there are no competing interests.

Conflict of interest

All the authors declare no conflicts of interest.

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