



Ethnobotanical documentation and quantitative analysis of medicinal flora in Ghazi Baba, Arrang, District Bajaur, Pakistan

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Research

Abstract

Background: Ethnobotanical knowledge plays an essential role in traditional medicine, livelihood security, and conservation of biodiversity, especially in the mountain regions of Pakistan. But this knowledge is now under threat due to modernization, migration, and lack of documentation. In the present study, the medicinal and other traditional uses of the vegetal species of Ghazi Baba Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan were documented and quantitatively evaluated.

Methods: A total of eight field visits were conducted from April 2023 to March 2024 to gather ethnobotanical information. We purposively selected 36 informants, including 19 traditional healers, 11 indigenous community members, four pregnant women, and two midwives, for semi-structured interviews and questionnaires. Plant specimens were collected, taxonomically identified, and deposited in the herbarium of Ghazi Umara Khan Degree College. To evaluate the cultural value of the recorded species, Use Value (UV), Relative Frequency of Citation (RFC), and Relative Importance (RI) were calculated. Life forms, taxonomic groups, plant parts used, and major use categories were also investigated.

Results: We recorded 143 plant species across 118 genera and 55 families. Eudicots accounted for the largest number of species (118, 82.52%), followed by monocots (21, 14.69%), gymnosperms (3, 2.10%), and pteridophytes (1, 0.70%). Herbs were the predominant life form (72 species; 50.35%), followed by trees (39 species; 27.27%) and shrubs (32 species; 22.38%). The families with the highest species diversity were Poaceae and Rosaceae (11 species each), followed by Lamiaceae (9 species), Asteraceae (8 species), Solanaceae (7 species), and Fabaceae (6 species). *Fumaria parviflora* Lam. and *Portulaca umbraticola* Kunth exhibited the highest Use Values (UV = 2.7 each). Spearman's rank correlation analysis revealed a weak, statistically non-significant relationship between Relative Frequency of Citation (RFC) and UV ($\rho = -0.089$, $n = 143$, $P = 0.292$).

Medicinal uses represented the largest reported category (55%), followed by fodder (15%) and fuelwood (10%). Leaves were used most often (60 species, 41.67%).

Conclusions: The findings highlight the rich ethnobotanical knowledge preserved by local communities in Ghazi Baba, Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan, and their continued dependence on locally available plant resources for healthcare and livelihoods. The documented plant species, particularly those with high Use Value (UV) and Relative Importance (RI) values, warrant further phytochemical and pharmacological investigations. Sustainable harvesting practices, community-based conservation initiatives, and the documentation and preservation of indigenous knowledge are essential to ensure the long-term availability and sustainable utilization of these valuable plant resources.

Keywords: Ethnobotany, Medicinal plants, Traditional knowledge, Use Value, Relative Frequency of Citation, Relative Importance, District Bajaur, Pakistan.

Background

The district of Bajaur is situated in the north-east region at the latitude of 34°30' to 34°58' N and longitude 71°11' to 71°48' E with an area of about 1290 km² (Ali and Qaiser, 2009; Manan *et al.* 2025). The district is administratively divided into seven tehsils, namely Khar (142 km²), Salarzai (253 km²), Mamund (216 km²), Nawagai (150 km²), Chamarkand (9 km²), Uthman Khel (150 km²), and Barang (370 km²), respectively (Sajid *et al.* 2023). The Bajaur borders Kunar Province of Afghanistan (46.55 km), Jandool (Lower Dir, 56.75 km), Mohmand (68.19 km), and Malakand Agency (23.68 km) (Haq *et al.* 2022). According to the 2023 Population and Housing Census, Bajaur District has a population of 1,287,960 inhabitants (Pakistan Bureau of Statistics, 2023). The study area, Flora in Ghazi Baba, Arrang, Bajaur, Pakistan, is primarily inhabited by the Uthman Khel tribe and mainly the Shamozaï Tribe (Birjees *et al.* 2022; Haq *et al.* 2023b). Historically, the Uthman Khel have enjoyed close ties with both the Khakhi Khel and Yousafzai tribes and are part of the Karlani group of Pashtun tribes. These tribes worked together in several conflicts and travelled together throughout the regions (Haq *et al.* 2022). They originally lived near Kabul and then moved to Nangarhar, then Tank and Gomal Valley before moving to Peshawar (Sajid *et al.* 2023). Unfortunately, these conditions did not allow them to continue living their nomadic life, so they shifted their homes to Tirah and finally, after the battle of Katlang, they settled in the present locality of Ghazi Baba Arrang, where they have gradually spread out their settlements (Ahmad and Pieroni, 2016). The study area has about 60,000 people (Ullah *et al.* 2025c). The region is mostly arid and does not have enough fertile land as water is scarce, so many family members of families leave the region to other parts of Bajaur or elsewhere (Ullah *et al.*, 2025a; Haq *et al.* 2022). However, most of the population relies on agriculture and natural plant resources for their livelihood, either directly or indirectly (Dorje and Maurya, 2021). District Bajaur has an extreme climate with very hot summers and cold, moist winters (Aziz *et al.* 2020). June, July, and August are the hottest months of the year, with summer temperatures generally ranging from 23°C to 36°C, whereas December, January, and February are the coldest months, with winter temperatures generally ranging from 5°C to 16°C (Population Census Organization, 1998). The diverse flora composition in the region is attributed to the climatic conditions as well as the mountain topography (Aziz *et al.* 2020; Haq *et al.* 2023a).

Ethnobotany has been defined as a study of relationships and interactions between human beings and plants in time and space (Alexiades, 1996; Espin *et al.* 2007). It involves every facet of human–plant association, such as cultural, medicinal, ecological, and economic (Bodeker and Kronenberg 2002; Murad *et al.*, 2013; Khan *et al.*, 2018). Plants have been used to provide human beings with food, shelter, and medicines since time immemorial. Indigenous peoples have a vast knowledge of plant resources that is passed on from one generation to the next and is very important in maintaining primary health care systems, especially in remote communities where modern health systems are not available (Pieroni *et al.* 2005; Shakir *et al.* 2025). Plants serve subsistence purposes, but also play an important role in cultural identity, social organization, and ecological sustainability (Campbell, 1987). Their relationship with humans has influenced traditional knowledge systems, which are now considered valuable tools for discovering new drugs, conserving biodiversity, and sustainable development (Pieroni *et al.* 2007; Ullah *et al.* 2025b). This knowledge is continuously passed down from one generation to the next by local communities (Pieroni *et al.* 2007). This important indigenous knowledge is, however, being slowly lost due to rapid socio-economic changes, urbanization, and modernization (Pieroni *et al.* 2007). Ethnobotanical research has been growing in the mid-twentieth century in Pakistan, with the establishment of the “Botanical Survey of Medicinal Plants”, initiated by the Ministry of Food and Agriculture in 1951 (Haq *et al.* 2023a). Since then, many studies have been carried out in various regions, documenting thousands of species of plants and traditional uses (Laldingliani *et al.* 2022). Although such endeavors have been made, ethnobotany in Pakistan has still been deemed to be in its infancy, and numerous ecologically and culturally diverse areas have yet to be explored (Espin *et al.* 2007). Several ethnobotanical studies have been conducted in the various regions of Khyber Pakhtunkhwa province, but more detailed documentation and quantitative assessment of the uses of these

plants in Ghazi Baba Arrang, District Bajaur, is limited (Hussain *et al.* 2018). Rare studies that combine traditional knowledge with quantitative indices like Use Value (UV), Relative Frequency of Citation (RFC), and Importance Value (IV) exist, in particular (Pieroni *et al.* 2017; Haq *et al.* 2022). Furthermore, the information regarding life forms, plant parts used, and use categories specific to this region is still poorly documented in the current literature (Haq *et al.* 2023b). Thus, the present study is of great significance because of the systematic and quantitative evaluation of ethnobotanical knowledge in an unexplored region. Gaining insights into this knowledge is not only crucial for the conservation of cultural heritage but also for species identification with possible pharmacological and economic uses. Moreover, the studies are expected to help conserve biodiversity and sustainable use of plant resources, especially in ecologically sensitive mountainous regions. The results obtained in this study will be used as a reference for future research that is directed towards phytochemical, pharmacological, and conservation aspects. The aims of the present study are to: (1) investigate the medicinal plant diversity of the study area, (2) determine the biodiversity of angiosperms in the study area, and (3) document ethnobotanical uses of plants in the study area.

Materials and Methods

Study area

Geographical and ecological characteristics

The present study was carried out in Ghazi Baba, Tehsil Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan (Ullah *et al.* 2025b). The District Bajaur lies in the northern part of Pakistan and is situated on the border of Pakistan and Afghanistan and is considered as a part of the Hindu Kush Mountain system (Hussain *et al.* 2009). It is surrounded by District Dir in the north and north-east, District Malakand in the south-east, District Mohmand in the south, and Kunar Province of Afghanistan in the West and north-west (Sajid *et al.* 2023). Formerly, Bajaur was in the Federally Administered Tribal Areas and was united with Khyber Pakhtunkhwa Province in 2018. Ghazi Baba Arrang is located in the South-Eastern part of District Bajaur, close to the border with District Malakand (Hosseini *et al.* 2017). It has a central point at approximately 34.7329° N latitude and 71.6865° E longitude, and the elevations are between 762 m and over 1829 m above sea level (Naz *et al.* 2026). The topography is largely mountainous, and the topography is characterized by steep slopes, narrow valleys, rocky outcrops, agricultural fields, scrublands and small woodlands (Hosseini *et al.* 2017). South and southeast of the Arrang mountain ranges is the Panjkora River (Hussain *et al.* 2009; Sajid *et al.* 2023). The valley is drained by several small streams and seasonal water channels which feed some agriculture and natural vegetation on the slopes of the mountains (Ahmad *et al.* 2017). The Arrang stream is a tributary of the Panjkora River that starts from the upper mountainous part of Toheedabad, locally called Kharmotay, and runs through the Naranj region, where it is known as Naranj (Ahmad *et al.* 2017). The primary water sources for the community and agricultural activities are springs, seasonal streams, tube wells, and dug wells (Abbasi *et al.* 2013; Ullah *et al.* 2025c). The study area has a wide variety of habitats such as cropland, field margins and dry rock outcrops, moist stream banks, forest patches, scrub formations, roadsides, and around human settlements (Naz *et al.* 2026). This ecological diversity provides a diverse flora of wild, cultivated, and naturalized plants used for medicinal, nutritional, fodder, fuelwood, and other traditional purposes (Sajid *et al.* 2023). The geographical location of Ghazi Baba Arrang and major plant-collection sites is displayed in Figure 1.

Climate, soil, and vegetation

The climate of Ghazi Baba, Tehsil Arrang, District Bajaur, is generally continental, with considerable seasonal variation (Haq *et al.* 2023b). Winter typically extends from November to March and is characterized by cold conditions (Afzal *et al.* 2009). Mean winter temperatures generally range from 5 to 10 °C, although temperatures may fall below 0 °C at higher elevations (Ahmad *et al.*, 2016). December and January are the coldest months of the year (Haq *et al.* 2023a). Abbasi *et al.* (2010) reported that spring generally begins in mid-March and continues until the end of April (Manan *et al.* 2025). Rainfall is relatively low and occurs mainly during winter and spring, particularly from February to March, as well as during the summer monsoon from July to August, when conditions are generally warm to hot (Ullah *et al.* 2024a). The average annual rainfall is approximately 800 mm (Haq *et al.* 2023b). Vegetation distribution and density throughout the study area are closely associated with rainfall patterns, elevation, slope exposure, and water availability (Haq *et al.* 2022). Soils in Ghazi Baba, Arrang, are predominantly sandy loam, loam, and clay loam (Shinwari *et al.* 2009). Soil depth and moisture content vary among agricultural fields, stream banks, valley bottoms, and exposed mountain slopes (Ahmad *et al.* 2016). Soils in valleys, cultivated fields, and areas adjacent to streams are generally deeper and retain more moisture, whereas those on steep and rocky slopes are typically shallow, dry, and susceptible to erosion (Afzal *et al.* 2009). Soil characteristics, including pH, organic matter content, and nutrient availability, may also influence vegetation composition and distribution (Haq *et al.* 2022). The vegetation of the study area ranges from subtropical scrub to montane woodland (Hussain *et al.* 2018). Vegetation density is generally higher in areas receiving greater rainfall, on relatively moist slopes, and along streams (Mustafa *et al.* 2017). In

contrast, exposed and relatively dry slopes are characterized by open xerophytic scrub vegetation (Haq and Badshah, 2024). Common tree species in the study area include *Pinus roxburghii*, *Olea europaea* subsp. *cuspidata*, *Morus alba*, *Morus nigra*, *Ficus carica*, *Rhododendron arboreum*, *Ailanthus altissima*, and various species of *Quercus* (Abbasi et al. 2010). Shrub vegetation is commonly represented by *Dodonaea viscosa*, *Nannorrhops ritchieana*, *Indigofera heterantha*, *Myrtus communis*, *Monothea buxifolia*, *Sageretia thea*, *Periploca aphylla*, and other drought-tolerant species (Afzal et al. 2009). Annual and perennial herbs occur in cultivated fields, forest openings, grazing areas, stream banks, roadsides, and disturbed habitats (Abdullah et al. 2021a). Natural vegetation is affected by several anthropogenic and environmental pressures, including overgrazing, fuelwood collection, deforestation, soil erosion, and excessive harvesting of medicinal plants (Ahmad et al. 2016; Subhan et al. 2024). These disturbances may reduce the abundance and regeneration of medicinal plant species and pose long-term threats to their conservation in the region (Abbas et al. 2020).

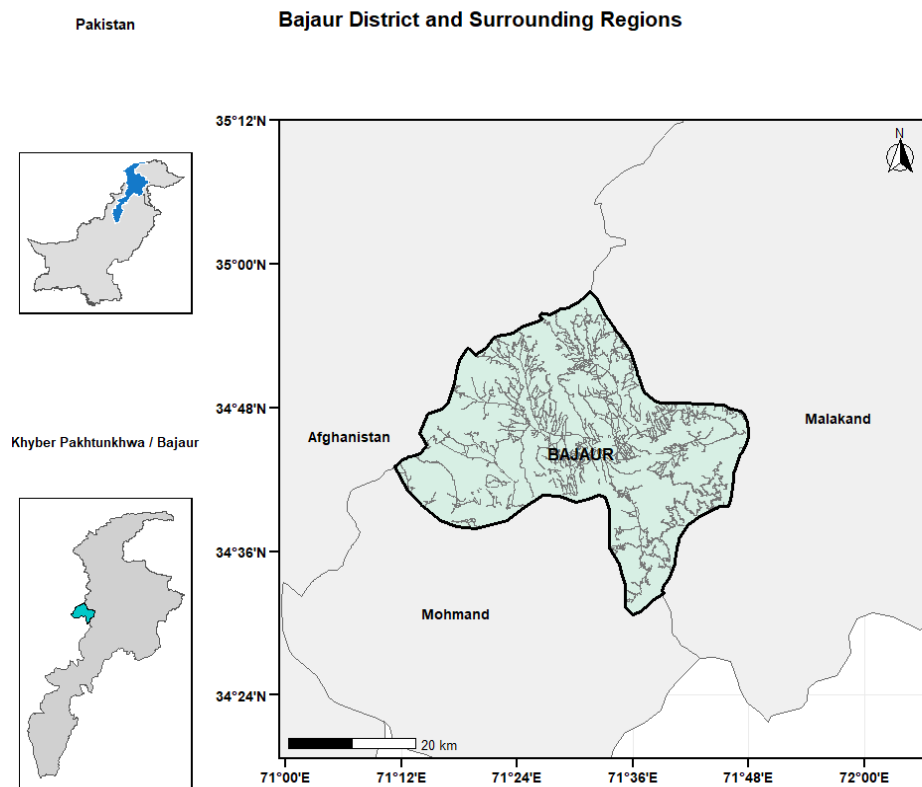


Figure 1. Location map of District Bajaur, Khyber Pakhtunkhwa, Pakistan, prepared in R using GADM administrative boundaries and OpenStreetMap drainage and road data, with a north arrow and scale bar.

Socioeconomic and ethnobotanical setting

Ghazi Baba Arrang is a community of the Pashtun (Utmankhel) ethnic group (Hussain et al. 2018). The livelihood of the local population is mostly agriculture, animal husbandry, picking of wild plants, petty trade, and daily wage labor (Abdullah et al. 2021b). Seasonal streams, springs, tube wells, and dug wells are utilized for agriculture, which is one of the most important economic activities in the area. In the region, the major cereal and pulse crops grown include wheat, maize, rice, barley, mustard, and lentils (Waheed et al., 2023). Other vegetables like tomato, chili, brinjal, garlic, onion, cauliflower, radish, and turnip are also popular crops. Livestock, such as cattle, goats, sheep, and poultry, play an important role in household income, food security, and subsistence (Amjad et al., 2020). Traditional knowledge on medicinal plants is more frequently found among elderly community members, traditional healers, farmers, owners of livestock, and other experienced community members (Ahmad et al., 2016). Medicinal plants are harvested from forests, scrublands, mountains, agricultural lands, river banks, and around the settlements by the local people (Haq et al. 2022; Ullah et al. 2024a). The plants are employed for medicinal purposes for humans and livestock, as well as for nutritional, fodder, fuelwood, building, spices, and home medicine purposes (Hussain et al. 2018). Traditional medicinal knowledge is mainly transmitted orally from older to younger generations. But, with the changing times, modernization, relocations, lack of interest in the knowledge among younger people, and reliance on modern health care may be responsible for its gradual decay (Amjad et al., 2020). Moreover, over-collection or harvesting of medicinal plants, namely roots, bark, and whole plants, can also have negative impacts on the regeneration and survival of locally important species (Ali et al. 2025). Some of the rural mountainous settlements where

access to modern health facilities is limited and not available, make the communities to continue the use of traditional remedies from plants (Amjad *et al.*, 2020). Hence, recording the medicinal flora and traditional knowledge of Ghazi Baba Arrang is crucial, not only for the conservation of cultural heritage, but also to identify the species that have medicinal properties, and to design effective strategies for the sustainable use and conservation of local plant resources (Murad *et al.* 2013; Ullah *et al.* 2024b).

Data collection and field survey

Ethnobotanical information was collected from Ghazi Baba, Tehsil Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan, over 12 months from April 2023 to March 2024. In all, eight field visits were made in various seasons to record their occurrence, availability, collection, and traditional uses of medicinal and other economically valuable plants (Musa *et al.* 2022). The surveys encompassed various habitats such as agricultural fields, forest patches, mountainous slopes, scrublands, stream banks, roadsides, and human settlements (Ullah *et al.* 2024c). Informants were selected by purposive sampling, as the selection of informants was for acquiring information from people who have good knowledge of local plants and traditional healthcare (Ibrar *et al.* 2007). The inclusion criteria were permanent residence in the study area, familiarity with the local flora, experience in collecting or using medicinal plants, and willingness to participate in the survey. Particular attention was given to elderly community members because traditional ethnobotanical knowledge is mainly retained by older generations (Jan *et al.* 2021). Traditional healers, farmers, livestock owners, plant collectors, and other knowledgeable members of the indigenous community were included in the survey (Younis *et al.* 2018).

A total of 36 informants participated in the study. Information regarding their age, gender, occupation, educational status, and experience with medicinal plants was recorded. The gender distribution of the participants reflected the sociocultural conditions of the study area, where access to female respondents was comparatively limited (Rahman *et al.* 2023). This gender imbalance and its possible influence on the documented ethnobotanical knowledge are acknowledged as limitations of the study (Ullah *et al.* 2023a). Ethnobotanical information was collected through semi-structured interviews using a modified questionnaire (Haq *et al.* 2023b). The interviews were conducted in Pashto, the local language of the study area, to facilitate communication and ensure the accurate documentation of indigenous knowledge (Ali *et al.* 2023). The questionnaire included questions concerning local plant names, plant parts used, preparation methods, routes of administration, medicinal applications, treated ailments, collection seasons, and other economic or cultural uses (Gul *et al.* 2025). Group discussions and informal conversations were also conducted where appropriate. Information obtained from individual participants was cross-checked with other informants and verified during repeated field visits to improve the reliability and consistency of the recorded data (Ali *et al.* 2023; Gul *et al.* 2025).

Before each interview, the objectives and procedures of the study were clearly explained to the participants (Ullah *et al.* 2023b). Written or verbal informed consent was obtained according to each participant's literacy level and preference before ethnobotanical information was collected and used for publication (Awan and Murtaza, 2013). Participation was voluntary, and the identities and personal information of the respondents were kept confidential (Jan *et al.* 2021). The study protocol was reviewed and approved by Ghazi Umara Khan Degree College under approval number GKDC-2023-217. Plant specimens were collected from different habitats, preferably in the presence of knowledgeable local informants. Field information, including the collection locality, habitat, collection date, local name, growth habit, and traditional uses of each plant, was recorded at the time of collection. Photographs were also taken to assist in field identification and documentation. Voucher numbers were generated as 'GKDC-2024', where 'GKDC' stands for Ghazi Umara Khan Degree College, '2024' is the year of the voucher preparation and deposition, and the remaining three digits represent the individual specimen. The voucher numbers ranged from GKDC-2024-001 to GKDC-2024-144, representing the 143 plant species reported in the study.

The collected specimens were pressed, dried, protected against insect damage, and mounted on herbarium sheets following standard herbarium procedures (Haq *et al.* 2022). Naphthalene and moth-repellent materials were used during storage to minimize damage caused by insects. Taxonomic identification was conducted using the Flora of Pakistan, available through eFloras (<http://www.efloras.org>) (Ali and Qaiser, 1993–2022), original species descriptions or protologues, regional floristic works, and other relevant taxonomic literature (Ali and Qaiser, 1993). Currently accepted scientific names, author citations, family assignments, and taxonomic synonyms were verified using Plants of the World Online (POWO, 2025; <https://powo.science.kew.org/>) and World Flora Online (WFO, 2025; <https://www.worldfloraonline.org/>). Both databases were accessed on 8 June 2025. Priority was given to the currently accepted nomenclature reported by POWO and WFO. Outdated scientific names appearing on herbarium labels or in earlier taxonomic and ethnobotanical literature were updated to their currently accepted equivalents where necessary (Bridson and Forman, 1998; Ali, 2011). The authenticated voucher specimens were deposited in the Herbarium of Ghazi Umara Khan Degree College, Samarbagh, District Lower Dir, Khyber

Pakhtunkhwa, Pakistan (Ali and Qaiser, 1993-2023). The herbarium does not currently have a registered digital or international acronym (Sajid *et al.* 2023). Every specimen deposited is kept in the collection and can be used in the future for taxonomic verification and reference.

Data analysis and classification

Data gathered from ethnobotanical field surveys and interviews were recorded in MS Excel and then systematically and thoroughly reviewed for completeness, consistency, and potential duplication. The recorded plant species were classified according to life form, taxonomic group, plant part used, traditional use category, and family-level representation. Life forms were categorized as herbs, shrubs, and trees. Taxonomic composition was assessed at the family, genus, and species levels and was further summarized into major groups, including dicotyledons, monocotyledons, angiosperms, and gymnosperms (Mir *et al.* 2022). Plant parts used were grouped into leaves, whole plants, fruits, seeds, bark, roots or rhizomes, flowers, stems or wood, and other parts. Traditional applications were classified into medicinal, fodder, fuelwood, food, timber or wood, ornamental, and other household or cultural uses (Haq *et al.* 2023a). Family-wise species richness was calculated to identify the dominant, moderately represented, and less frequently represented plant families in the study area. Frequencies and percentages were used to summarize life forms, plant parts used, use categories, taxonomic groups, and informant demographic characteristics (Haq *et al.* 2022; Ullah *et al.* 2021a).

Quantitative ethnobotanical analysis

Three quantitative ethnobotanical indices were calculated for the recorded plant species: Relative Importance, Relative Frequency of Citation, and Use Value. These indices were selected to evaluate the versatility, citation frequency, and local significance of each documented species (Haq *et al.* 2022).

Relative Importance

Relative Importance was used to assess the versatility of each plant species based on the number of use categories and the total number of use reports associated with that species. It was calculated following the modified approach described by Vitalini *et al.* 2013:

$$'RI = NUC + NT', 'NUC = NUCS/NUCVS', 'NT = NTS/NTS_{max}'$$

Where: NUC (Number of Use Categories) = NUCS / NUCVS

NT (Number of Use Reports) = NTS / NTS {max}

Here, NUCS represents the number of use categories reported for a given species, while NUCVS is the maximum number of use categories recorded for the most versatile species. NTS represents the total number of use reports for a species, and NTS {max} is the highest number of use reports among all species (Haq *et al.* 2022).

Relative Frequency of Citation

Relative Frequency of Citation was calculated to determine the proportion of informants who mentioned each plant species, following (Haq *et al.* 2022): Relative Frequency of Citation (RFC) was calculated using the formula:

$$Rfc = FC/N$$

Where: FC = number of informants mentioning a species

N = total number of informants

The RFC value ranges from 0 to 1, where 0 indicates no citation, and 1 indicates maximum citation by all informants.

Use Value

Use Value (UV) was calculated to estimate the relative cultural and practical importance of each plant species based on the number of uses reported by the informants, following Haq *et al.* (2022). The values were obtained using the following formula.

$$UV = \sum U_i / N.$$

where U_i represents the number of uses mentioned by each informant for a given plant species, $\sum U_i$ represents the total number of uses reported for that species by all informants, and N represents the total number of informants interviewed (N = 36). A high UV indicates that a species had numerous reported uses or was commonly used by the local community, whereas a low UV indicates that relatively few uses were reported for that species (Haq *et al.* 2022).

Data validation and statistical analysis

The collected data were validated through repeated field visits and cross-verification of information provided by different informants. Before the final analysis, the dataset was checked for incomplete records, duplicate entries, missing quantitative data, inconsistent local names, and outdated scientific names. Microsoft Excel was used for data organization, calculation of ethnobotanical indices, and descriptive statistical summaries. Statistical analyses and graphical representations were performed using R statistical software, version 4.6.1 (R Core Team, 2026). Bar charts, pie charts, and chord diagrams were generated to illustrate plant diversity, family composition, plant life forms, plant parts used, plant use categories, and the demographic characteristics of informants. Spearman's rank correlation coefficient was used to examine the relationships among Relative Importance (RI), Relative Frequency of Citation (RFC), and Use Value (UV), because the ethnobotanical index values were not normally distributed. The relationships between RI and UV ($p = -0.030$, $P = 0.72$) and between RI and RFC ($p = -0.138$, $P = 0.10$) were weak, negative, and statistically non-significant. The RFC–UV correlation was also evaluated and is presented in Figure 9. Correlation coefficients, sample sizes (n), and corresponding P-values were reported, with $P < 0.05$ considered statistically significant. The RFC–UV correlation coefficient and its P-value are provided in the caption of Figure 9.

Results**Demographic characteristics of the informants**

Thirty-six respondents were involved in the ethnobotanical survey. The majority of the respondents were male (63.89%), while females (36.11%) made up the minority. The traditional healers were the most frequent informants (52.78%), followed by indigenous community members (30.56%), pregnant women (11.11%), and midwives (5.56%). The largest proportion of respondents belonged to the 46–55-year age group (44.44%), followed by those aged 35–45 years (22.22%), 56–65 years (19.44%), and 66 years or older (13.89%). The results from the questionnaire show that the majority of ethnobotanical data were collected from middle-aged and elderly age groups. As far as education is concerned, over half of the people (52.78%) were illiterate. Respondents with matriculation-level education represented 22.22%, followed by those with primary education (16.67%) and secondary education (8.33%). Farmers constituted the largest occupational group (38.89%), followed by traditional practitioners or Hakeems (36.11%), housewives (19.44%), and salaried employees (5.56%). Most respondents were Muslim (97.22%), while one respondent was Sikh (2.78%). Among respondents involved in livestock grazing, 58.33% were primarily associated with cattle grazing, whereas 41.67% were associated with goat grazing. The complete demographic characteristics of the respondents are presented in Table 1 and Fig. 2.

Table 1. Demographic characteristics of the respondents interviewed in Ghazi Baba Arrang, District Bajaur, Pakistan.

Category	Sub-category	Total	Percentage
Gender	Men	23	63.89%
	Women	13	36.11%
Informant categories	Traditional healers	19	52.78%
	Indigenous people	11	30.56%
	Pregnant women	4	11.11%
	Midwives	2	5.56%
Age groups (years)	35–45	8	22.22%
	46–55	16	44.44%
	56–65	7	19.44%
	≥66	5	13.89%
Educational qualification	Illiterate	19	52.78%
	Primary	6	16.67%
	Matric	8	22.22%
	Secondary	3	8.33%
Occupation	Hakeems	13	36.11%
	Farmers	14	38.89%
	Housewives	7	19.44%
	Job holders	2	5.56%
Religion	Muslim	35	97.22%
	Sikh	1	2.78%
Livestock grazing	Cattle grazing	21	58.33%
	Goat grazing	15	41.67%

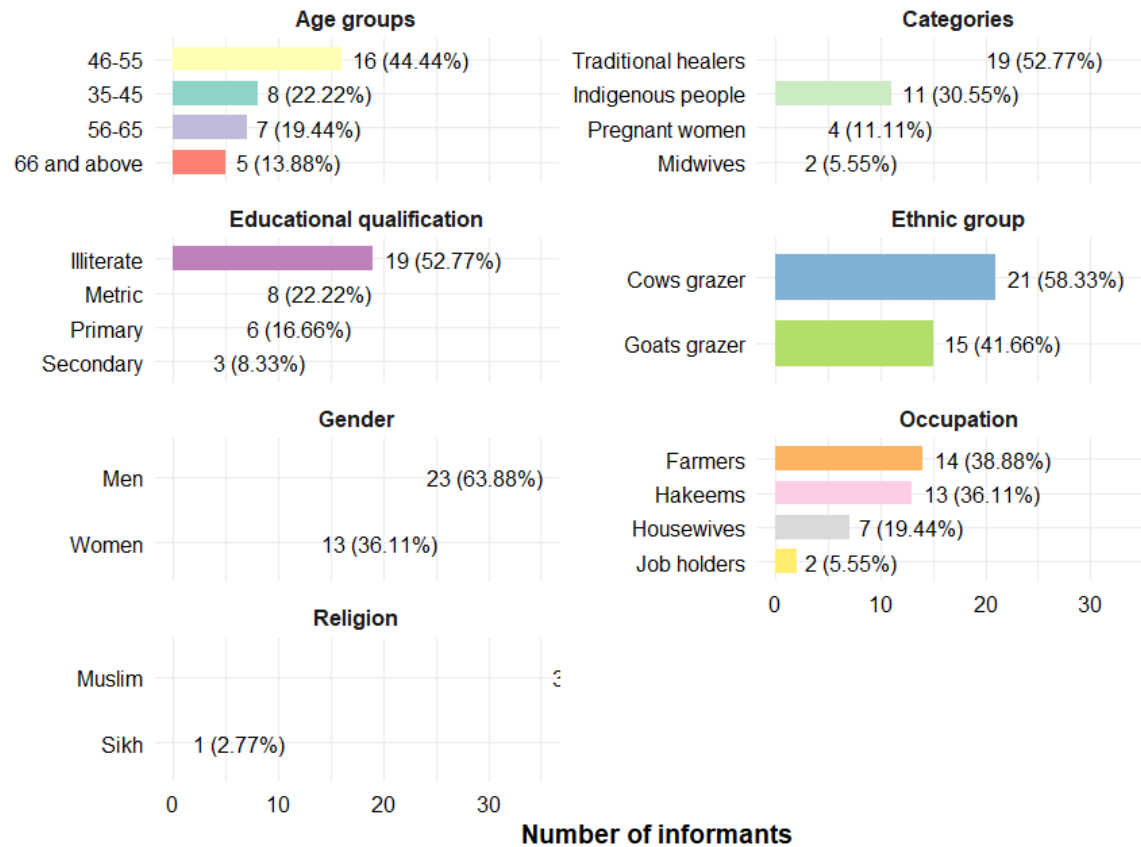


Figure 2. Demographic characteristics of the 36 informants interviewed in Ghazi Baba Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan

Quantitative ethnobotanical analysis

The quantitative ethnobotanical indices showed considerable variation in the cultural importance, citation frequency, and utilization of the 144 recorded plant species. Use Value (UV), Relative Frequency of Citation (RFC), and Relative Importance (RI) were used to assess the local significance of each species. The complete values of these indices are presented in Table 2.

Species importance based on use value

The ranking of species based on Use Value (UV) showed that a limited number of species had particularly high ethnobotanical importance (Fig. 3). Of these, the two plants with a higher value of the UV, as they are more used in local traditional practices, were *Portulaca umbraticola* Kunth and *Fumaria parviflora* Lam. Other species with relatively high UV values included *Coriandrum sativum* L., *Tagetes erecta* L., *Prunus armeniaca* L., *Foeniculum vulgare* Mill., and *Broussonetia papyrifera* (L.) L'Hér. ex Vent.

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Table 2. Ethnobotanical inventory of plants recorded in Ghazi Baba, Tehsil Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan, including their scientific names, local names, families, uses, and quantitative ethnobotanical indices.

Plant name	Family	Local name	Ethnobotanical uses	RI	RFC	UV
<i>Abelmoschus esculentus</i> (L.) Moench	Malvaceae	Bhindi	Used as a food and medicinal plant	0.83	0.5	0.6
<i>Achillea millefolium</i> L.	Asteraceae	Karkara	Used for toothache and medicinal purposes	1.41	0.8	1.6
<i>Ailanthus altissima</i> (Mill.) Swingle	Simaroubaceae	Bakanra	Used for fever, asthma, and circulation issues	0.41	0.5	0.6
<i>Ajuga bracteosa</i> Wall. ex Benth.	Lamiaceae	Gooti	Used for dysentery and diarrhea	0.75	0.9	1.1
<i>Ajuga parviflora</i> Benth.	Lamiaceae	Gooti	Used for dysentery and diarrhea	0.41	0.5	0.9
<i>Allium cepa</i> L.	Amaryllidaceae	Piyaz	Used for asthma, bronchitis, and food	0.58	0.4	0.9
<i>Allium griffithianum</i> Boiss.	Amaryllidaceae	Ogakai	Used for hypertension and cardiovascular issues	0.83	0.6	0.7
<i>Allium sativum</i> L.	Amaryllidaceae	Aooga	Used for cardiac problems and blood pressure	1.58	0.6	1.1
<i>Alnus nitida</i> (Spach) Endl.	Betulaceae	Geeray	Used for tanning and dyeing	0.58	0.6	0.7
<i>Alternanthera pungens</i> Kunth	Amaranthaceae	Insut	Used as fodder	1.33	0.7	1.4
<i>Amaranthus viridis</i> L.	Amaranthaceae	Charlie	Leaves used as a vegetable	0.83	0.8	0.7
<i>Argemone mexicana</i> L.	Papaveraceae	Redi Gul	Used as a diuretic, painkiller, and anti-inflammatory	0.75	0.9	1.4
<i>Artemisia absinthium</i> L.	Asteraceae	Tarkha	Fuel and traditional uses	0.58	0.7	1
<i>Artemisia vulgaris</i> L.	Asteraceae	Tarkha	Used for gastric disorders and epilepsy	0.58	0.7	0.6
<i>Astragalus graveolens</i> Benth.	Fabaceae	Azghay	Used for diabetes and immune support	0.41	0.8	1.8
<i>Avena fatua</i> L.	Poaceae	Jawdar	Used to increase milk production in animals	0.83	0.7	1
<i>Avena sativa</i> L.	Poaceae	Jawder	Used as fodder and fuel	0.58	0.9	0.9
<i>Berberis vulgaris</i> L.	Berberidaceae	Kwaray	Used for cough, fever and metabolic disorders	1.41	0.6	0.7
<i>Brassica rapa</i> L.	Brassicaceae	Turpak	Used as fodder and edible oil plant	0.83	0.5	0.9
<i>Broussonetia papyrifera</i> (L.) L'Hér. ex Vent.	Moraceae	Gul toot	Used as fodder and medicinal plant	0.83	0.4	2
<i>Calotropis procera</i> (Aiton) Dryand.	Apocynaceae	Spalamai	Used for external parasites in livestock	0.41	0.8	1.8
<i>Cannabis sativa</i> L.	Cannabaceae	Bhung	Narcotic and pain relief	0.58	0.7	0.7
<i>Capsicum annuum</i> L.	Solanaceae	Marchakay	Used for toothache, headache, and as spice	0.58	0.8	0.6
<i>Carthamus oxyacantha</i> M. Bieb.	Asteraceae	Kareza	Used to treat bilious disorders	2	0.6	1.1
<i>Caudanthera edulis</i> (Edgew.) Meve & Liede	Apocynaceae	Pamankay	Used as a vegetable and medicine	0.83	0.5	0.7
<i>Cedrus deodara</i> (Roxb. ex D. Don) G. Don	Pinaceae	Diyar Ranzra	Used medicinally and for timber/fuel	1.41	0.6	1.3
<i>Cestrum nocturnum</i> L.	Solanaceae	Rat ki Rani	Leaves used as vegetable; fruit for inflammation and liver issues	0.83	0.6	0.6
<i>Chenopodium album</i> L.	Amaranthaceae	Sarmay	Used as a vegetable	0.83	0.7	0.6

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<i>Citrus × limon</i> (L.) Osbeck	Rutaceae	Nembo	Used for vomiting and medicinal purposes	1.58	0.5	0.5
<i>Citrus × sinensis</i> (L.) Osbeck	Rutaceae	Malta	Medicinal, fuel and fruit	0.58	0.9	1.6
<i>Coriandrum sativum</i> L.	Apiaceae	Dhaniya	Used for digestion and gastrointestinal disorders	1.33	0.6	2.1
<i>Cucumis sativus</i> L.	Cucurbitaceae	Badrang	Fruits edible	1.33	0.7	0.8
<i>Cucurbita maxima</i> Duchesne	Cucurbitaceae	Kadoo	Used as a vegetable	0.41	0.8	0.9
<i>Cupressus sempervirens</i> L.	Cupressaceae	Sarwa	Used as an anthelmintic and astringent	1.58	0.8	0.7
<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Kabal	Fodder and lawn grass	0.75	0.7	1
<i>Cyperus rotundus</i> L.	Cyperaceae	Della	Used for digestive and metabolic disorders	0.41	0.6	1.4
<i>Dalbergia sissoo</i> Roxb. ex DC.	Fabaceae	Shawa	Used for furniture and fuel	0.83	0.6	1.5
<i>Datura stramonium</i> L.	Solanaceae	Batoora	Used for toothache, headache and epilepsy	0.41	0.8	0.5
<i>Desmostachya bipinnata</i> (L.) Stapf	Poaceae	Drab	Fuel and packing	1.41	0.9	0.6
<i>Dichanthium annulatum</i> (Forssk.) Stapf	Poaceae	Shamogha	Used as fodder	0.83	0.6	1
<i>Digera muricata</i> (L.) Mart.	Amaranthaceae	Surgulay	Used as vegetable and fodder	0.83	0.6	0.8
<i>Diospyros lotus</i> L.	Ebenaceae	Tore Amlook	Used as an antidiabetic and medicinal plant	0.83	0.7	0.5
<i>Dodonaea viscosa</i> (L.) Jacq.	Sapindaceae	Ghoraskai	Food and fuel	0.83	0.8	0.9
<i>Equisetum arvense</i> L.	Equisetaceae	Bandakay	Kidney stones and fodder	0.75	0.9	1
<i>Eriobotrya japonica</i> (Thunb.) Lindl.	Rosaceae	Loquat	Timber and medicinal	0.75	0.9	0.6
<i>Eucalyptus globulus</i> Labill.	Myrtaceae	Lachi	Used as fuel wood	1.33	0.6	0.8
<i>Euphorbia helioscopia</i> L.	Euphorbiaceae	Mandaroo	Used for bronchitis and respiratory disorders	0.58	0.8	0.5
<i>Ficus carica</i> L.	Moraceae	Inzar	Fuel and constipation remedy	0.58	0.7	0.6
<i>Foeniculum vulgare</i> Mill.	Apiaceae	Kagelanay	Digestive, carminative and respiratory uses	0.83	0.5	2
<i>Fumaria parviflora</i> Lam.	Papaveraceae	Shatara	Used as fodder and medicinal plant	0.75	0.7	2.7
<i>Gymnosporia royleana</i> Wall. ex M.A. Lawson	Celastraceae	Spin Azghay	Medicinal, fuel, vegetable	0.83	0.9	0.9
<i>Hedera nepalensis</i> K. Koch	Araliaceae	Parwatai	Used for diabetes and fodder	0.75	0.7	0.8
<i>Helianthus annuus</i> L.	Asteraceae	Anwer farasat	Used for oil production	2	0.7	0.7
<i>Hordeum vulgare</i> L.	Poaceae	Wabashay	Used as food, fodder and beverage	0.58	0.9	0.8
<i>Indigofera amblyantha</i> Craib	Fabaceae	Ghoreja	Basket making	1.91	0.9	1
<i>Iris germanica</i> L.	Iridaceae	Qabar Gulay	Used in medicine and perfumery	0.58	0.8	1
<i>Juglans regia</i> L.	Juglandaceae	Ghooz	Used for furniture and edible nuts	0.83	0.6	0.6
<i>Lathyrus aphaca</i> L.	Fabaceae	Koorkaman	Used for food and wound treatment	1.41	0.9	1.6
<i>Luffa aegyptiaca</i> Mill.	Cucurbitaceae	Toorai	Latex causes skin irritation; medicinal uses	0.41	0.9	0.6
<i>Malus domestica</i> (Suckow) Borkh.	Rosaceae	Manra	Used for digestive disorders and anemia	0.83	0.8	1.9
<i>Malva neglecta</i> Wallr.	Malvaceae	Panderak	Used as a medicinal plant	0.83	0.6	1.4

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<i>Melia azedarach</i> L.	Meliaceae	Hindustani Shandai	Used for timber and medicinal purposes	0.41	0.4	1.2
<i>Mentha arvensis</i> L.	Lamiaceae	Podina	Used for stomach problems and salads	1	0.6	0.7
<i>Mentha longifolia</i> (L.) L.	Lamiaceae	Enaly	Used for vomiting and dysentery	0.41	0.8	0.9
<i>Mirabilis jalapa</i> L.	Nyctaginaceae	Gulabasi	Used for wound healing and ornamental	0.58	0.5	0.9
<i>Momordica charantia</i> L.	Cucurbitaceae	Karila	Used for diabetes and infections	0.83	0.7	0.5
<i>Monothea buxifolia</i> (Falc.) A.DC.	Sapotaceae	Gorgowara	Medicinal, food, fuel and fruit	0.58	0.8	1.8
<i>Moraea sisyrinchium</i> (L.) Ker Gawl.	Iridaceae	Gandechar	Ornamental and medicinal uses	1.58	0.6	0.7
<i>Morus alba</i> L.	Moraceae	Thooth	Used as fodder	2	0.6	0.7
<i>Morus nigra</i> L.	Moraceae	Tor thooth	Used for wood and fodder	0.41	0.9	0.8
<i>Myrtus communis</i> L.	Myrtaceae	Manrho	Used for cold and stomach disorders	0.75	0.8	1.8
<i>Nannorrhops ritchieana</i> (Griff.) Aitch.	Arecaceae	Maizaray	Rope and food	0.41	0.9	0.5
<i>Narcissus tazetta</i> L.	Amaryllidaceae	Guli Gangas	Used for cardiovascular and respiratory disorders	0.41	0.6	1.8
<i>Nasturtium microphyllum</i> (Boenn.) Rchb.	Brassicaceae	Tarmeera	Food, fodder and medicinal uses	1.58	0.7	1
<i>Nasturtium officinale</i> W.T. Aiton	Brassicaceae	Tarmeera	Used as a vegetable and medicinal plant	1	0.6	0.7
<i>Nerium oleander</i> L.	Apocynaceae	Ganderay	Used for asthma, epilepsy and skin diseases	1	0.8	0.5
<i>Ocimum basilicum</i> L.	Lamiaceae	Kachmachu	Wounds and expectorant	0.58	0.7	0.7
<i>Olea europaea</i> subsp. <i>cuspidata</i> (Wall. ex G. Don) Cif.	Oleaceae	Khona	Constipation treatment	0.83	0.7	0.6
<i>Opuntia dillenii</i> (Ker Gawl.) Haw.	Cactaceae	Zaqoom	Diabetes and ornamental	0.83	0.9	1
<i>Origanum vulgare</i> L.	Lamiaceae	Ghar Kashmaly	Used as food and medicinal herb	2	0.7	0.8
<i>Papaver pavoninum</i> Schrenk	Papaveraceae	Raiday	Used for diarrhea and inflammation	0.83	0.9	0.8
<i>Papaver somniferum</i> L.	Papaveraceae	Koknar	Used for headache and dysentery	0.83	0.5	1.3
<i>Periploca aphylla</i> Decne.	Apocynaceae	Barara	Used as an ornamental plant	2	0.8	0.7
<i>Persicaria barbata</i> (L.) H. Hara	Polygonaceae	Palpulak	Used for fever and as a diuretic	0.75	0.9	0.9
<i>Pinus roxburghii</i> Sarg.	Pinaceae	Nakhtar	Fuel, timber, medicinal	1.16	0.7	0.7
<i>Plantago lanceolata</i> L.	Plantaginaceae	Ghawajabai	Used for dysentery and constipation	0.41	0.9	1.7
<i>Platanus orientalis</i> L.	Platanaceae	Chinar	Furniture and fuel	1.16	0.9	0.7
<i>Populus alba</i> L.	Salicaceae	Watani Sperdar	Medicinal, fuel and fencing	0.58	0.9	0.7
<i>Populus nigra</i> L.	Salicaceae	Sufaidad	Furniture and timber	0.83	0.9	0.9
<i>Portulaca umbraticola</i> Kunth	Portulacaceae	Warkharay	Used as antiseptic, anti-inflammatory, and wound healing	1.58	0.8	2.7
<i>Prunus amygdalus</i> Batsch	Rosaceae	Badam	Used for memory enhancement and food	0.83	0.7	1.9
<i>Prunus armeniaca</i> L.	Rosaceae	Khoobanai	Food, medicinal and timber	0.83	0.9	2
<i>Prunus domestica</i> L.	Rosaceae	Aloocha	Food, medicinal and timber	0.58	0.7	0.7

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<i>Prunus persica</i> (L.) Batsch	Rosaceae	Shaftaloo	Food, medicinal and timber	0.41	0.9	0.8
<i>Punica granatum</i> L.	Lythraceae	Anar	Medicinal, fuel and agricultural uses	0.41	0.9	1.2
<i>Pyrus communis</i> L.	Rosaceae	Nashfati	Food, medicinal and timber	0.41	0.9	1
<i>Quercus baloot</i> Griff.	Fagaceae	Sirai	Used for cough, fever and bronchitis	0.75	0.9	0.7
<i>Quercus leucotrichophora</i> A. Camus	Fagaceae	Sirai	Fodder, medicinal, fuel, fruit	0.75	0.9	0.5
<i>Ranunculus muricatus</i> L.	Ranunculaceae	Zergulay	Fodder and diaphoretic	0.83	0.3	0.7
<i>Ranunculus sceleratus</i> L.	Ranunculaceae	Jashagay	Fruit, medicinal and fuel	0.58	0.7	1.1
<i>Ricinus communis</i> L.	Euphorbiaceae	Randa	Used as fuel and medicinal plant	0.83	0.7	1.6
<i>Rosa chinensis</i> Jacq.	Rosaceae	Soor Gulab	Fragrance and agricultural uses	0.83	0.7	1.8
<i>Rosa moschata</i> Herrm.	Rosaceae	Zangli Gulab	Used for dysentery and reproductive health	1	0.5	1.8
<i>Rosa webbiana</i> Wall. ex Royle	Rosaceae	Jangli Gulab	Used as food and for stomach disorders	1.33	0.8	0.6
<i>Rubus ulmifolius</i> Schott	Rosaceae	Karwara	Food and agricultural uses	0.58	0.7	0.8
<i>Rumex dentatus</i> L.	Polygonaceae	Shalkhay	Used for skin diseases and digestive issues	0.58	0.9	0.7
<i>Rumex hastatus</i> D. Don	Polygonaceae	Taro okay	Used as fuel	0.83	0.5	0.8
<i>Saccharum spontaneum</i> L.	Poaceae	Mandaruy	Baskets and brooms	0.41	0.9	1.1
<i>Salix babylonica</i> L.	Salicaceae	Asleewala	Furniture and timber	0.41	0.9	0.8
<i>Salix tetrasperma</i> Roxb.	Salicaceae	Wala	Furniture and timber	0.41	0.3	0.7
<i>Salvia moorcroftiana</i> Wall. ex Benth.	Lamiaceae	Khurdug	Used for internal injuries in cattle	0.41	0.6	1.8
<i>Senegalia modesta</i> (Wall.) P.J.H. Hurter	Fabaceae	Palosa	Fuel, medicinal (backache, dysentery)	0.83	0.7	1
<i>Sisymbrium irio</i> L.	Brassicaceae	Ginger	Used as fuel	0.83	0.8	0.7
<i>Solanum lycopersicum</i> L.	Solanaceae	Tamater	Used as food	1.33	0.8	0.5
<i>Solanum nigrum</i> L.	Solanaceae	Kacmachoo	Used as a vegetable and medicinal plant	0.41	0.6	0.7
<i>Solanum virginianum</i> L.	Solanaceae	Maraghoonay	Used for digestive disorders and infections	0.83	0.7	0.8
<i>Sonchus asper</i> (L.) Hill	Asteraceae	Shodapii	Used for skin diseases	0.58	0.7	1.3
<i>Sorghum halepense</i> (L.) Pers.	Poaceae	Dadam	Used as fodder	0.83	0.5	1.3
<i>Spinacia oleracea</i> L.	Amaranthaceae	Palak	Used as vegetable	0.75	0.6	1.1
<i>Swertia chirayita</i> (Roxb.) H. Karst.	Gentianaceae	Chirayita	Used for malaria, liver disorders and diabetes	2	0.8	1
<i>Tagetes erecta</i> L.	Asteraceae	Dambergulay	Used as an ornamental plant	1.41	0.8	2
<i>Teucrium leucocladum</i> Boiss.	Lamiaceae	Yakandaaz	Fever, hepatitis, stomach disorders	0.41	0.7	0.5
<i>Teucrium stocksianum</i> Boiss.	Lamiaceae	Yakhandaz	Used as an ornamental plant	0.83	0.9	0.9
<i>Toona sinensis</i> (A. Juss.) M. Roem.	Meliaceae	Shenai	Used for antimicrobial purposes	0.58	0.7	1.7
<i>Tribulus terrestris</i> L.	Zygophyllaceae	Markondai	Used for urinary disorders and libido enhancement	0.41	0.7	1.2
<i>Triticum aestivum</i> L.	Poaceae	Ghanam	Used as food and fodder	0.58	0.7	0.6

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<i>Tulipa clusiana</i> DC.	Liliaceae	Ghantol	Used as fuel and ornamental plant	0.83	0.6	1.5
<i>Tulipa orphanidea</i> Boiss. ex Heldr.	Liliaceae	Ghantol	Medicinal	0.41	0.9	0.9
<i>Urtica dioica</i> L.	Urticaceae	Seezonkay	Used for arthritis and back pain	1.33	0.5	1.4
<i>Vachellia nilotica</i> (L.) P.J.H. Hurter & Mabb.	Fabaceae	Kikar	Used for construction, tools and fuel	0.83	0.8	0.8
<i>Verbascum thapsus</i> L.	Scrophulariaceae	Har ghwag	Used for respiratory disorders and wounds	0.75	0.7	0.8
<i>Verbena officinalis</i> L.	Verbenaceae	Shoomakay	Used for digestive and nervous disorders	0.58	0.8	0.6
<i>Veronica cinerea</i> Boiss. & Balansa	Plantaginaceae	Shumakay	Used for fever and acne	1	0.6	1
<i>Viola canescens</i> Wall.	Violaceae	Guli Binafsha	Used for flu, fever and cough	0.83	0.8	1
<i>Visnaga dauroides</i> Gaertn.	Apiaceae	Speerkai	Used for angina, asthma and diabetes	0.83	0.9	0.7
<i>Vitis vinifera</i> L.	Vitaceae	Kwar	Used for joint pain	1.41	0.7	0.6
<i>Withania somnifera</i> (L.) Dunal	Solanaceae	Kotilal	Used for fertility and general health	0.58	0.9	0.7
<i>Xanthium strumarium</i> L.	Asteraceae	Geeshkay	Used for respiratory allergies	0.41	0.7	0.9
<i>Zanthoxylum armatum</i> DC.	Rutaceae	Dambara	Medicinal and vegetable	1.58	0.9	0.6
<i>Zea mays</i> L.	Poaceae	Jawar	Used as fodder	0.41	0.7	0.7
<i>Phragmites karka</i> (Retz.) Trin. ex Steud.	Poaceae	Karkanda	Used as fodder	0.41	0.6	1.7
<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	Markhani	Food, medicinal and agricultural uses	0.58	0.7	0.9
<i>Ziziphus oxyphylla</i> Edgew.	Rhamnaceae	Elani	Used as an antibiotic	0.41	0.5	1.4

Note: RI, Relative Importance; RFC, Relative Frequency of Citation; UV, Use Value

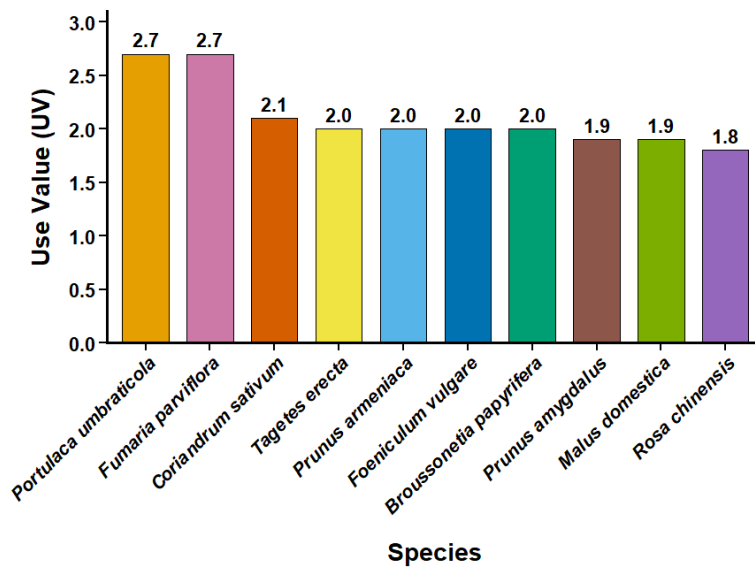


Figure 3. Ethnobotanical importance of plant species based on the top 10 Use Values (UV) in Ghazi Baba, Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan. Higher UV values indicate more uses reported by the informants.

Family-wise variation in mean use value

The mean values of the Use Value (UV) of the plant species differed widely by family (Fig. 4). The mean UV was highest in Portulacaceae (2.70), followed by Sapotaceae (1.80), Plantaginaceae (1.70) and Apiaceae (1.60). It was also found that Papaveraceae (1.55), Meliaceae (1.45), Cyperaceae (1.40), Urticaceae (1.40), Myrtaceae (1.30), and Fabaceae (1.28) have relatively high mean UV values. Solanaceae had the highest mean UV (0.63), Oleaceae and Fagaceae (0.60 each), Juglandaceae, Simaroubaceae and Vitaceae (0.60 each), while Ebenaceae and Arecaceae both had the lowest mean UV (0.50 each). Overall, the results demonstrate considerable variation in the average reported use of species among plant families.

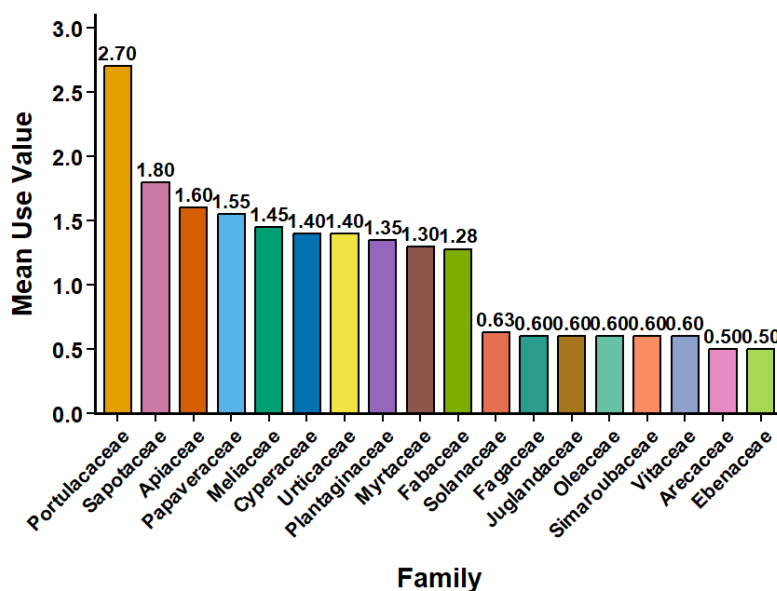


Figure 4. Mean Use Value (UV) of plants recorded from Ghazi Baba Arrang in the District of Bajaur showed the family-level variation.

Life-form and taxonomic composition

A total of 143 plant species belonging to 118 genera and 55 families were recorded in Ghazi Baba, Tehsil Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan. Herbs were the most abundant life-form category (72 species, 50.35%), followed by trees (39 species, 27.27%) and shrubs (32 species, 22.38%) (Fig. 5). At the species level, eudicots were the most represented

group, comprising 118 species (82.52%), followed by monocots with 21 species (14.69%) and gymnosperms with three species (2.10%). A single pteridophyte species, *Equisetum arvense* L., was recorded (0.70%). The 143 species belonged to 118 genera. Eudicots accounted for the highest number of genera (97, 82.20%), followed by monocots (17, 14.41%), gymnosperms (3, 2.54%), and pteridophytes (1, 0.85%). At the family level, the recorded flora comprised 55 families, including 46 eudicot families (83.64%), six monocot families (10.91%), two gymnosperm families (3.64%), and one pteridophyte family (1.82%). Angiosperms constituted the dominant major plant group, comprising 139 species (97.20%), whereas gymnosperms accounted for three species (2.10%) and pteridophytes for one species (0.70%). Table 3 summarizes the life-form and taxonomic composition of the recorded flora.

Table 3. Medicinal Plant Species Inventory of Life-form and Taxonomic Composition of Ghazi Baba Arrang, District Bajaur, KP, Pakistan.

Analytical level	Group/category	Number	Percentage (%)
Life form	Herbs	72	50.00
	Shrubs	32	22.22
	Trees	40	27.78
	Total	144	100.00
Major taxonomic group species level	Eudicots	118	81.94
	Monocots	21	14.58
	Gymnosperms	4	2.78
	Pteridophytes	1	0.69
	Total	144	100.00
Generic level	Eudicots	97	82.20
	Monocots	17	14.41
	Gymnosperms	3	2.54
	Pteridophytes	1	0.85
	Total	118	100.00
Family level	Eudicots	46	83.64
	Monocots	6	10.91
	Gymnosperms	2	3.64
	Pteridophytes	1	1.82
	Total	55	100.00
Broad plant group species level	Angiosperms	139	96.53
	Gymnosperms	4	2.78
	Pteridophytes	1	0.69
	Total	144	100.00

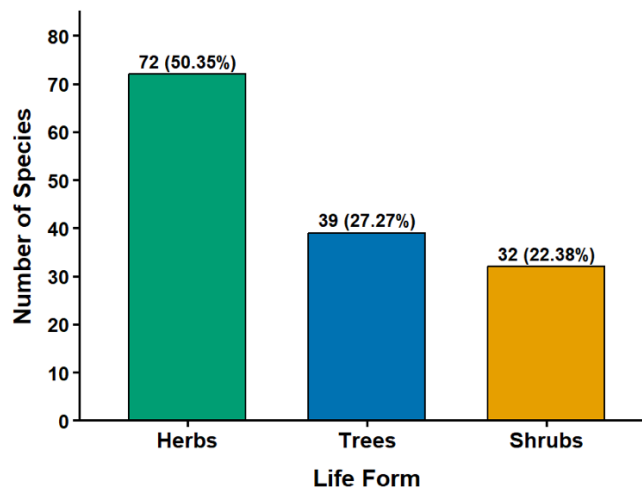


Figure 5. Plant Life Form Distribution of 144 recorded species of plants for three life forms: herbs, shrubs, and trees in Ghazi Baba Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan.

Use-category analysis

The ethnobotanical applications recorded were grouped into seven broad categories (Fig. 6). Medicinal uses were the highest, representing approximately 55% of all recorded uses. The second largest category was fodder (15%), followed by fuelwood (10%), food (8%), and timber and wood-related uses (5%). Other uses, including fiber, dyes, and agricultural applications, accounted for 4%, followed by ornamental uses (3%). Overall, medicinal uses represented the largest category, whereas other uses and ornamental uses accounted for relatively small proportions.

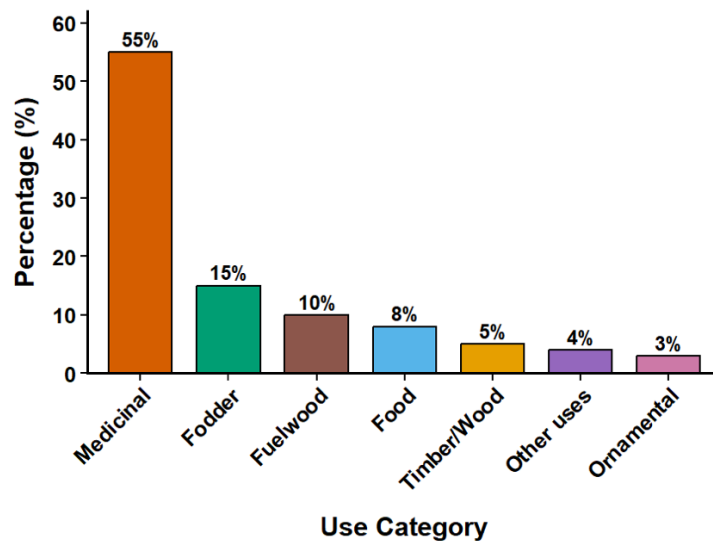


Figure 6. Ethnobotanical uses recorded among the use categories in Ghazi Baba Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan. The major use was for medicinal purposes, followed by fodder, fuelwood, food, timber or wood, ornamental, and others.

Plant parts used

To examine plant parts used, it was concluded that leaves were the most frequently used plant part, with 60 species (41.67%). Whole plants were used from 28 species (19.44%), followed by fruits from 18 species (12.50%) and seeds from 12 species (8.33%). Eight species (5.56%) had their bark harvested, and seven (4.86%) had their roots or rhizomes harvested. The flower parts were used from 6 species (4.17%), and stems or wood were the least used (5 species, 3.47%). The distribution of the plant parts used is given in Fig. 7.

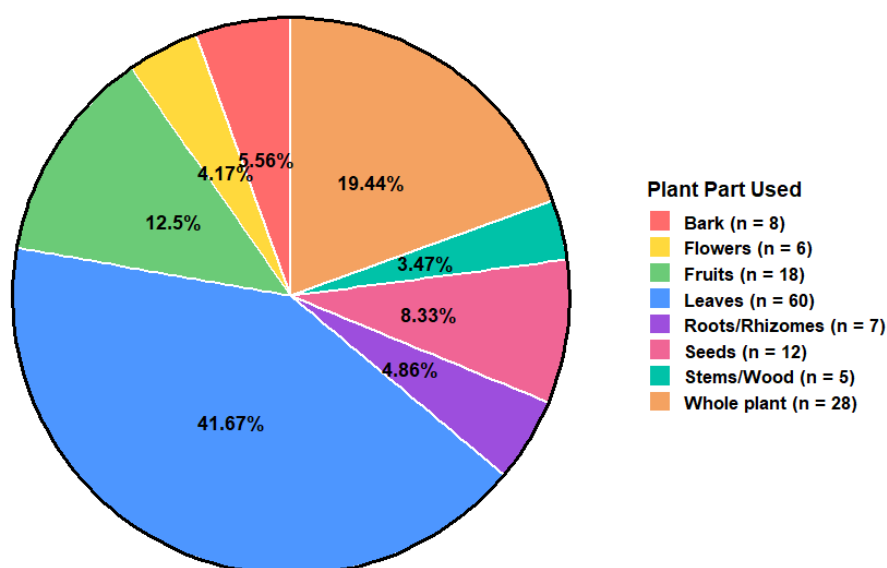


Figure 7. Ethnobotanical uses of plant parts in the distribution of Ghazi Baba, Arrang, District Bajaur, KP, Pakistan. The most common part of the plants used was leaves, followed by whole plants, fruits, seeds, bark, roots/rhizomes, flowers, and stems/wood.

Family-wise species representation

A total of 143 plant species belonging to 55 families were recorded, with considerable variation in species representation among families (Table 2; Fig. 8). Poaceae and Rosaceae were the most represented families, with 11 species each, followed by Lamiaceae with nine species, Asteraceae with eight species, Solanaceae with seven species, and Fabaceae with six species. Brassicaceae, Amaryllidaceae, and Papaveraceae were represented by four species each, while Rutaceae comprised three species. Several other families were represented by fewer species, and many families contained only a single recorded species. Overall, a relatively small number of families accounted for a substantial proportion of the recorded species, whereas most families exhibited comparatively low species richness. The family-wise distribution of species is illustrated in the chord diagram in Fig. 8.

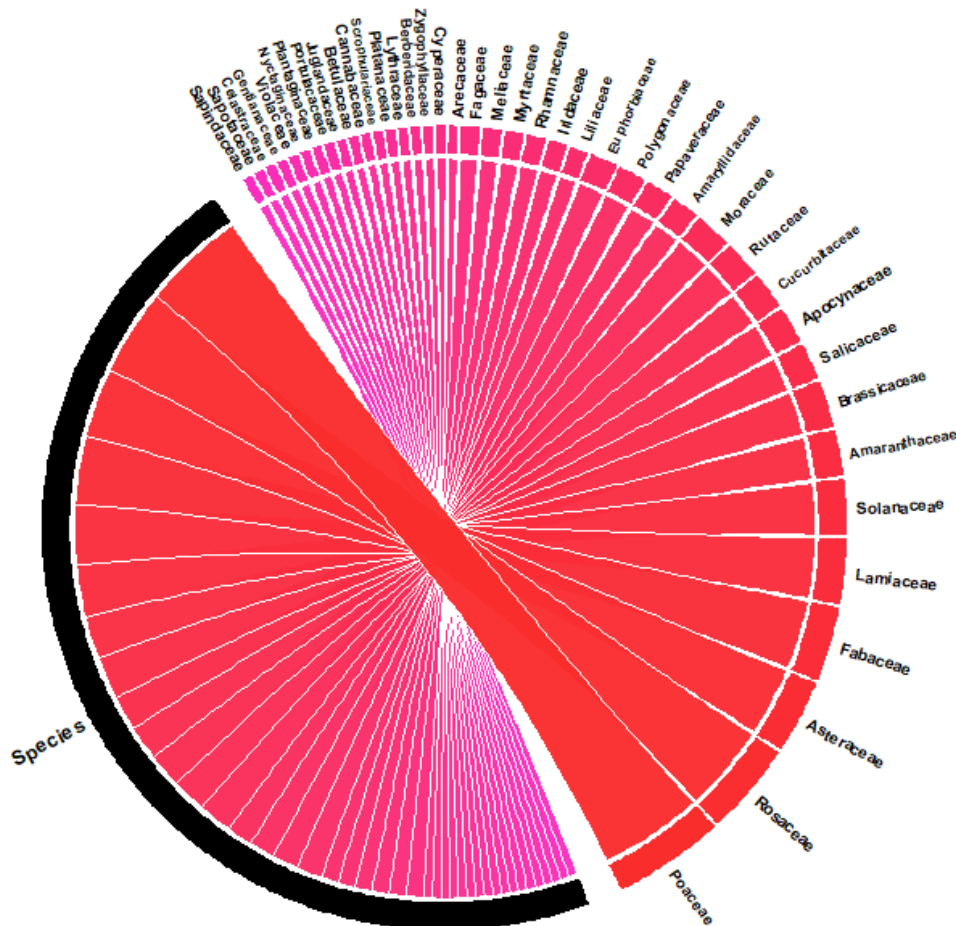


Figure 8. Chord diagram displaying species-wise family representation of plants collected from Ghazi Baba Arrang of District Bajaur.

Overall pattern of ethnobotanical indices

Use Value (UV) was positively skewed, with most species exhibiting low to moderate values and a few species showing comparatively high values. UV ranged from 0.50 to 2.70, with a mean of 1.02 and a median of 0.90. This pattern suggests that a relatively small number of species had numerous reported uses. Spearman's rank correlation analysis revealed a weak, negative, and statistically non-significant relationship between Relative Frequency of Citation (RFC) and UV ($p = -0.111$, $n = 142$, $P = 0.187$; Fig. 9). This indicates that species cited by a greater proportion of informants did not necessarily have a higher number of reported uses.

Discussion

In the present study, a total of 143 ethnobotanically important plant species were documented, highlighting the continued dependence of local communities in Ghazi Baba, Tehsil Arrang, District Bajaur, on plant resources for healthcare, food, fodder, fuelwood, ornamental purposes, and other domestic requirements (Haq and Badshah, 2021). The persistence of traditional plant-based practices may be associated with limited access to modern healthcare facilities, economic constraints, and the preservation of indigenous knowledge within families and local communities. Similar dependence on traditional plant-based healthcare has been reported from other mountainous and rural regions of Pakistan, particularly Khyber

Pakhtunkhwa, where medicinal plants continue to contribute to primary healthcare and local livelihoods (Bhat *et al.* 2021; Haq and Badshah, 2021).

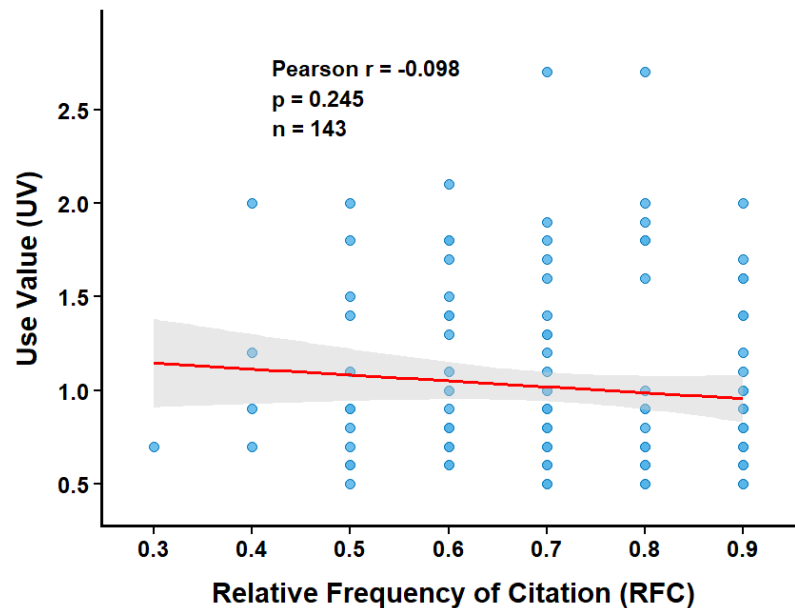


Figure 9. The relationships among the Relative Frequency of Citation (RFC) and Use Value (UV) of plant species recorded from Ghazi Baba Arrang, District Bajaur. The solid line is the best-fit linear model and the shaded region is the 95% confidence interval.

The demographic characteristics of the respondents indicated that middle-aged and older individuals constituted the majority of the surveyed population. Of the 36 informants, 77.78% were aged 46 years or older, with the highest proportion belonging to the 46–55-year age group. Previous ethnobotanical studies have suggested that older individuals often possess extensive knowledge of medicinal plants because of their longer experience with local flora, repeated exposure to traditional practices, and involvement in medicinal plant collection and preparation (Ahmad *et al.* 2017). Traditional ethnobotanical knowledge is frequently transmitted between generations through informal learning, observation, and practical experience rather than formal education (Kayani *et al.* 2014). In the present study, more than half of the respondents had received no formal education. However, because individuals younger than 35 years were not included, the study could not directly assess knowledge loss among younger generations. Future investigations should therefore include younger participants to evaluate intergenerational knowledge transmission more comprehensively. Men accounted for 63.89% of the respondents, whereas women represented 36.11%. This difference in participation may reflect sociocultural barriers to interviewing women rather than differences in their ethnobotanical knowledge. Women may possess specialized knowledge concerning food plants, maternal healthcare, childcare, and household remedies; however, fewer women may participate in ethnobotanical surveys, potentially resulting in the underrepresentation of their knowledge (Bhat *et al.* 2021; Ullah *et al.* 2021b). Similar challenges have been reported in ethnobotanical investigations conducted in culturally conservative communities. Greater involvement of female researchers and female informants in future studies could improve the representation of community knowledge (Bhat *et al.* 2021).

Herbs constituted the largest life-form category, accounting for 72 species (50.35%) of the recorded flora, followed by trees with 39 species (27.27%) and shrubs with 32 species (22.38%). The predominance of herbaceous species is comparable to findings from ethnobotanical investigations conducted in mountainous regions (Jalali *et al.* 2024). Herbaceous plants commonly occur in forest openings, disturbed habitats, roadsides, streambanks, and cultivated fields (Mohini *et al.* 2022). Their accessibility, seasonal availability, rapid growth, and ease of collection may contribute to their frequent utilization in traditional plant-use systems. Trees and shrubs collectively accounted for 49.65% of the recorded flora and included species valued for medicinal purposes, fruits, fodder, fuelwood, timber, and construction materials (Haq and Badshah, 2023). Eudicots were the most represented major taxonomic group, comprising 118 species, 97 genera, and 46 families. The importance of accurately documenting taxonomic diversity and traditional plant uses has been emphasized in earlier ethnobotanical research (Martin, 1995). The prominence of eudicots in the present study reflects their substantial contribution to the recorded regional flora and their diverse ecological and ethnobotanical roles. Angiosperms accounted

for 139 species (97.20%), whereas gymnosperms were represented by three species (2.10%) and pteridophytes by one species (0.70%). Previous research has also highlighted the medicinal significance of angiosperm taxa (Abate *et al.* 2022). The broad representation and utilization of flowering plants have been discussed in other floristic and ethnobotanical investigations (Mohini *et al.* 2022).

Poaceae and Rosaceae were the most species-rich families, with 11 species each, followed by Lamiaceae (nine species), Asteraceae (eight species), Solanaceae (seven species), and Fabaceae (six species). Family-level species richness in the present study reflects the floristic composition of the surveyed area. Studies examining vegetation composition and ecological changes in agroforestry landscapes provide additional context for understanding the relationship between plant diversity and land use (Abate *et al.* 2022). The prominence of Poaceae may be associated with the occurrence of grasses and cereal crops in agricultural fields, grasslands, roadsides, and disturbed habitats. Members of this family are commonly used for forage, food, thatching materials, and soil stabilization (Selehi *et al.* 2020). Rosaceae included several wild and cultivated fruit-bearing plants, whereas Fabaceae comprised species used for medicinal purposes, fodder, and other domestic applications. Asteraceae and Lamiaceae also contributed substantially to the recorded flora. Research on medicinal plants has highlighted the importance of investigating the biological properties and traditional applications of different plant taxa (Wali *et al.* 2019). Several aromatic and medicinal species belonging to Asteraceae and Lamiaceae are traditionally used to address digestive, inflammatory, respiratory, and infectious conditions (Rahman *et al.* 2022). Solanaceae includes medicinal, vegetable, and cultivated species. Although species richness varied considerably among families, greater family-level richness does not necessarily indicate greater ethnobotanical importance, because cultural significance also depends on the frequency and diversity of reported plant uses. A species-poor family may exhibit a high mean Use Value (UV) when one or more constituent species have numerous reported uses, whereas a species-rich family may have a comparatively lower mean UV (Ghanimi *et al.* 2022).

Medicinal uses represented the largest ethnobotanical category, accounting for approximately 55% of all recorded uses. This finding highlights the continued importance of traditional herbal remedies in local healthcare practices and is consistent with ethnobotanical studies conducted in Malakand, Swat, and other parts of Khyber Pakhtunkhwa, where medicinal plants contribute substantially to primary healthcare (Ali *et al.* 2026). Important medicinal species recorded in the present study included *Mentha longifolia*, *Senegalia modesta*, *Ajuga bracteosa*, *Prunus domestica*, *Foeniculum vulgare*, *Calotropis procera*, *Periploca aphylla*, *Withania somnifera*, and *Punica granatum*. The medicinal applications of several of these species have previously been documented in Pakistan, suggesting similarities in traditional plant-use practices across different regions (Ahmad *et al.* 2017; Wali *et al.* 2019). Fodder was the second-largest use category, representing 15% of the recorded uses. This finding highlights the importance of livestock husbandry in the local economy and the reliance on wild and cultivated vegetation as feed for domestic animals (Bhatt *et al.* 2021). Fuelwood accounted for 10% of the recorded uses, reflecting the contribution of local plant resources to household energy requirements. Food uses represented 8% and included fruits, vegetables, cereals, and spices (Martin, 1995; Cotton, 1996; Mir *et al.* 2022). Timber and other wood-related uses accounted for 5%, followed by miscellaneous uses (4%) and ornamental purposes (3%). Similar multipurpose utilization of plants for medicine, nutrition, fodder, fuel, and construction has been documented in rural communities of Khyber Pakhtunkhwa and surrounding regions (Majeed *et al.* 2021; Arshad *et al.* 2022; Haq *et al.* 2022; Mir *et al.* 2022; Mustafa *et al.* 2023; Ali *et al.* 2025; Gul *et al.* 2025).

Leaves were the most frequently recorded plant part, being used in 60 species. Their widespread utilization may be associated with their accessibility, ease of collection, and suitability for preparing decoctions, infusions, powders, and pastes (Abdin *et al.* 2022). Leaf harvesting may be less destructive than removing roots, bark, or entire plants, although excessive defoliation can also reduce plant growth and survival. Other plant parts used included fruits, seeds, bark, roots or rhizomes, flowers, and stems or wood, while whole-plant harvesting was also recorded (Haq and Badshah, 2024). The collection of entire plants may have important conservation implications, particularly for annual herbs and species with limited local populations, because it can prevent reproduction and natural regeneration (Ahmad *et al.* 2017). Similarly, intensive harvesting of roots, rhizomes, and bark can adversely affect plant survival (Tardío and Pardo-de-Santayana, 2008). Although fruits and seeds provide important nutritional and medicinal resources, excessive removal of reproductive structures may reduce natural recruitment (Hussain *et al.* 2025). Sustainable harvesting strategies should therefore consider the plant parts collected, harvesting intensity, reproductive season, and local species abundance (Mohini *et al.* 2022; Haq *et al.* 2022). The quantitative ethnobotanical indices revealed considerable variation in the reported uses and relative importance of the documented species (Hamilton, 2004). *Fumaria parviflora* and *Portulaca umbraticola* exhibited the highest Use Values (UV = 2.70 each), followed by *Coriandrum sativum*, *Broussonetia papyrifera*, *Foeniculum vulgare*, *Prunus armeniaca*, and *Tagetes erecta*. Higher UV values indicate a greater number of uses reported per informant for a particular species, rather than

necessarily demonstrating greater medicinal effectiveness (Tardío and Pardo-de-Santayana, 2008). High ethnobotanical values should therefore not be interpreted as direct evidence of pharmacological efficacy or safety. Instead, species with high UV values may be considered candidates for further phytochemical, pharmacological, and toxicological investigations (Ahmad *et al.* 2017; Mohini *et al.* 2022). The weak, negative, and statistically non-significant relationship between Relative Frequency of Citation (RFC) and UV suggests that citation frequency and the number of reported uses represent different aspects of ethnobotanical importance. Species mentioned by a larger proportion of respondents did not necessarily have higher UV values (Kayani *et al.* 2014; Khan *et al.* 2018; Mustafa *et al.* 2023). Conversely, some species with multiple reported applications may have been known primarily to traditional healers or experienced informants. These findings highlight the value of considering multiple quantitative indices, including Relative Importance (RI), RFC, and UV, when evaluating the ethnobotanical significance of plant species. Several medicinal applications documented in Ghazi Baba, Tehsil Arrang, resemble traditional uses reported elsewhere in Pakistan, suggesting similarities in regional ethnomedicinal knowledge (Hamilton, 2004; Shinwari, 2010). However, claims of previously unreported medicinal uses require systematic comparison of individual species–ailment associations with regional and international ethnobotanical literature (Kayani *et al.* 2014; Umair *et al.* 2019). Potentially novel uses should be documented carefully and investigated through appropriate experimental studies. Species exhibiting high UV or RI values may be prioritized for phytochemical screening, antimicrobial and anti-inflammatory assays, toxicity assessment, dosage standardization, and suitable *in vivo* investigations (Heinrich *et al.* 1998; Hamilton, 2004). The recorded medicinal and multipurpose uses of *Periploca aphylla*, *Calotropis procera*, *Foeniculum vulgare*, *Visnaga daucooides*, *Ziziphus mauritiana*, and *Withania somnifera* highlight the importance of considering sustainable harvesting and conservation measures. However, the present study did not quantify population trends or systematically assess local perceptions of species decline; therefore, these species cannot be classified as declining or threatened based on the ethnobotanical records alone. Reliable assessments of conservation status require additional information on population size, distribution, regeneration, harvesting pressure, and, where available, formal conservation assessments (Mohini *et al.* 2022). Potential conservation strategies include regulated harvesting, rotational collection, cultivation in home gardens, establishment of community nurseries, protection of natural habitats, seed banking, and awareness programmes for collectors and traditional healers (Hamilton, 2004; Shinwari, 2010).

Future perspectives and limitations of the study

The present study serves as baseline data on ethnobotanical knowledge and ethnobotanical diversity in terms of useful plants of Ghazi Baba Arrang, District Bajaur. Phytochemical, pharmacological, and toxicological studies of species with high UV, RFC, and RI values should be focused on in future work to validate the traditional use, to determine active compounds, and to evaluate the safety of these species. Comparative studies using more villages, more diverse and balanced informant samples, and different seasons would help to shed more light on regional differences in plant use and plant knowledge transfer. Ethnobotanical information, combined with GIS, ecological surveys, and sophisticated statistical modeling, may also contribute to the delineation of significant habitats, areas for harvesting, and species under local pressure.

The present study gives some baseline data on ethnobotanical knowledge and medicinal flora of Ghazi Baba Arrang, but the results of this study are limited to that particular locality and group of informants. A purposive selection of 36 knowledgeable respondents allowed detailed traditional information to be gathered; however, additional surveys with other villages, younger respondents, and female informants would help to increase the representativeness of the information. The study was limited to the indices of RI, RFC, and UV; further scientific studies involving other indices, experimental testing, and population-level conservation studies would give a more comprehensive description of the recorded plant resources. Hence, the present study provides a sound basis for further ethnobotanical, medicinal, and conservation studies in District Bajaur.

Conclusion

The present study documented 143 ethnobotanically important plant species belonging to 118 genera and 55 families in Ghazi Baba, Tehsil Arrang, District Bajaur, Khyber Pakhtunkhwa, Pakistan, highlighting the continued dependence of local communities on plant resources for medicinal, food, fodder, fuelwood, timber, and other domestic purposes. Herbs constituted the dominant life-form category, while Poaceae and Rosaceae were the most species-rich families, followed by Lamiaceae, Asteraceae, Solanaceae, and Fabaceae. Medicinal uses represented the largest use category (55%), and leaves were the most frequently utilized plant part. Quantitative ethnobotanical indices, including Use Value (UV), Relative Frequency of Citation (RFC), and Relative Importance (RI), revealed differences in the reported utilization and cultural significance of the documented species. The predominance of middle-aged and older informants highlights the importance of documenting traditional knowledge and investigating its transmission to younger generations. Although harvesting practices and habitat pressures may present conservation challenges, further field-based assessments are required to determine their effects on local plant populations. The findings emphasize the need for sustainable harvesting, cultivation

of frequently used species, community-based conservation initiatives, and further phytochemical, pharmacological, and toxicological investigations of medicinal plants with high ethnobotanical values. Overall, this study provides baseline information for preserving indigenous ethnobotanical knowledge and promoting the sustainable utilization of plant resources in District Bajaur.

Conservation status and conservation priorities

The priority of local conservation was determined by harvesting intensity, plant parts harvested, disturbance of the habitat, and abundance reported. Considered to be most vulnerable were species harvested for their roots, bark, whole plants, timber, or for fuelwood. *Swertia chirayita*, *Periploca aphylla*, *Withania somnifera*, *Nannorrhops ritchieana*, *Ziziphus oxyphylla*, *Olea europaea* subsp. *cuspidata* and local *Quercus* species were found to be of conservation priority. Suggested strategies are controlled harvesting, home garden cultivation and community nurseries, habitat protection, seed gathering, and community awareness programmes.

Declarations

List of Abbreviations: RFC – Relative Frequency of Citation, RI – Relative Importance, UV – Use Value

Ethical Approval and Consent to Participate: The study protocol was reviewed and approved by Ghazi Umara Khan Degree College, Samarbagh, District Lower Dir, Khyber Pakhtunkhwa, Pakistan, with the approval number GKDC-2023-217. Before each interview, the objectives and procedures of the study were explained to the participants. Written or verbal informed consent was obtained from all participants according to their literacy level and preference. Participation was voluntary, and the confidentiality of the respondents' personal information was maintained throughout the study.

Consent for Publication: Not applicable.

Availability of Data and Materials: The datasets generated and analyzed during the present study are available from the corresponding author upon reasonable request.

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Conflict of Interest: The authors declare that they have no competing interests.

Author Contributions: Shakir Ullah and Mohammad Sohail conceived and designed the study, conducted the field surveys, analyzed the data, and prepared the original manuscript. Lubna Shakir contributed to data collection, the literature review, and manuscript editing. Naveen Dilawar contributed to data analysis and interpretation of the findings. Lubna Shakir and Naveen Dilawar critically revised the manuscript for important intellectual content. Ghani Subhan contributed to the field surveys and taxonomic identification of plant species. All authors read and approved the final version of the manuscript.

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