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Muhammad Zamin, Muhammad Adnan, Mohammad Hamid Hamdard, Waheed Murad & Shaheen Begum

Tribal Traditions and Conservation Perspectives of Wild Plants in Orakzai District, Pakistan

Muhammad Zamin[1*], Muhammad Adnan[1], Mohammad Hamid Hamdard[2*], Waheed Murad[3] and Shaheen Begum[4]

[1] Department of Botany, Kohat University of Science and Technology, Kohat-26000, Khyber Pakhtunkhwa, Pakistan.

[2] Department of Botany, Faculty of Biology, Kabul University, Kabul-1002, Kabul, Afghanistan.

[3] Department of Botany, Abdul Wali Khan University, Mardan-23200, Khyber Pakhtunkhwa, Pakistan

[4] Department of Environmental Sciences, Fatima Jinnah Women University, Mall, Rawalpindi-46000, Pakistan

*Corresponding authors: M. Hamid Hamdard hamid.kabuluniversity@gmail.com
Muhammad Zamin samana5410@outlook.com

Abstract

The present study deals with the traditional knowledge and conservation status of wild plant species in the tribal Orakzai district, an ecologically transitional zone between subtropical and temperate, which is still largely underexplored in quantitative and conservation ethnobotany. Semi-structured questionnaires and participatory observations were employed to interview local participants and plant specimens were collected in the study area. In total, 123 species belonging to 60 families and 112 genera were reported with multiple tribal applications. Trends in tribal practices and cultural outcomes of the reported taxa were assessed using quantitative indices including cultural importance index (CI), use diversity index (UDI), direct matrix ranking (DMR), informant consensus factor (I_{CF}), and Pearson correlation coefficient (PCC). Traditionally important medicinal plants, including *Daphne papyracea, Olea europaea* subsp. *cuspidata, Salix babylonica, Berberis lycium, Hedera helix,* and *Pyrola chlorantha* were identified in the surveys. Herbaceous species are the most common. Leaves, twigs and rhizomes were the main parts of the plants. The vulnerability status was determined by using a cross-referencing protocol based on a combination of community perceptions, field observations, IUCN categories and Kew's predicted extinction risks. With this integrated protocol, 37% of species were classified as highly vulnerable, 19% as moderately threatened and 43% as least vulnerable. The study concludes that there is a dire need for plant conservation and preservation of tribal ecological knowledge.

Keywords: Flora of Orakzai, subtropical to temperate regions, tribal ecological knowledge, wild medicinal plants, conservation concerns, Pakistan

1. Introduction

Ethnobotanical studies are important to understand the relationship between people and plants, especially in tribal communities, which are rural and resource-limited, where wild plants are the main source of healthcare, food security and livelihood. In this context, ethnobotanical knowledge has been crucial in preserving tribal traditions and discovering modern use of plant-based resources. The key to conserve biodiversity and sustainable use of plant resources is the recognition of long-term interactions between people and their natural environment [1]. Research in ecologically comparable region has highlighted the role of wild plant resources for traditional food systems, household nutritional status, and livelihood resilience of tribal communities [2]. However, rapid socio-economical changes and ecological pressures are eroding traditional knowledge systems; thus, systematic documentation and analysis with respect to these systems is required.

Pakistan has a vast diversity of plants and long history of utilization of medicinal plants t hat has contributed to our health care systems as well as to our national economy [3–5]. The country harbors more than 6,000 species of vascular plants, approximately 10–15% of which are used for medicinal purposes [6]. Exports of medicinal plants from Pakistan are worth money, but much of the knowledge is regionally specific and unevenly documented. Despite systematic documentation, quantitative evaluation, and conservation planning, most of these plant species are still used in traditional healthcare systems [7, 8]. Previous studies have also suggested that continued dependence on traditional ecological knowledge in tribal communities is often associated with limited livelihood alternatives and restricted access to modern healthcare facilities [9].

The ethnobotanical history of Pakistan is rich, but there are significant gaps in the methods and places where ethnobotanical research is conducted, especially in the remote tribal regions of the northwestern parts of the country. Traditionally, ethnobotanical studies in Pakistan have focused on accessible and well-studied regions, leading to uneven geographic coverage [10–14]. On the other hand, remote and tribal areas, including Orakzai district, remain relatively underexplored as a result of logistical limitations and limited research access [15, 16]. Despite ethnobotanical investigations being conducted in adjacent tribal regions such as the Bajaur district [17], insufficient evidence of ethnobotanical diversity exists in the Orakzai district. Comparable ethnobotanical patterns have also been reported from other mountainous tribal communities of the Hindu Kush region along the Pakistan–Afghan border [18]. This uneven documentation has created significant gaps in the understanding of local plant use and traditional knowledge systems, underscoring the need for focused ethnobotanical investigations in such regions.

The Orakzai district of northern Pakistan remains poorly documented in ethnobotanical research despite its ecological diversity and the strong reliance of local communities on plant-based resources [19]. This lack of systematic and quantitative documentation of traditional ecological knowledge underscores a critical research gap. Therefore, the present study aims to document the ethnobotanical uses of wild plant species, analyze their cultural and medicinal significance, and assess associated conservation concerns in the Orakzai district.

This study applies an integrated approach of ethnobotanical documentation and quantitative indices to analyze plant use and associated knowledge in the Orakzai district. Participant perceptions together with international conservation assessments, including IUCN

Red List categories [20] and Kew extinction risk predictions [21], were used to determine the conservation status.

Accordingly, this analysis was designed and guided by the following focused research questions: (i) In the tribal region, which wild plants are consistently harvested? (ii) With respect to quantitative criteria, which plants are the most culturally important and useful in tribal practices? (iii) How do documented patterns of ethnobotanical use and knowledge compare with findings reported from other comparable regions of Pakistan? (iv) What is the risk of overcollection and extinction for important wild flora? Therefore, this assessment was guided by specific research questions to identify the cultural relevance, conservation priorities and sustainable management of wild plants in Orakzai district.

This study presents an ethnobotanical evaluation of the Orakzai district with special reference to traditional ecological knowledge of wild plants, their uses and conservation problems. This relatively under-studied area is tackled by a combination of field-based data collection and quantitative ethnobotanical indices to have a more systematic understanding of plant use patterns. These results provide an important framework for future research and further support efforts to conserve and manage local plant resources in a sustainable manner.

2. Methodology and Study Design

Study Area: This study was conducted in district Orakzai which is located northwest to Koh-e-Safaid mountain range, Khyber Pakhtunkhwa Pakistan. The tribal district is characterized by a varied topography consisting of subtropical valleys and cold temperate mountains. Geographically, the region spans latitudes from 33° 33′ to 33° 54′ N and longitudes from 70° 36′ to 71° 22′ E [22]. The district is bordered on the east by Dara Adam Khel, on the west by Kurram District, on the south by Hangu and Kohat districts and on the north by Khyber District (Figure 1).

The area varies substantially in altitude, ranging from 1,700 meters to 3,000 meters above sea level. Typically, the eastern highlands reach a height of 2,030 meters above sea level [23]. Several valleys are located in this region, including Khanki, Mastura, Khurmana, and Bara, which are characterized by the Khanki and Mastura rivers. Climates range from subtropical to temperate, with mild to hot summers (26°C to 39°C) and cold winters (4°C to 18°C). Annual precipitation varies between 250 and 500 millimeters [24].

Geographically the district is divided into two administrative subdivisions: the green and rocky highlands in the southwest are part of the upper subdivision, whereas the flat, warm, and dry landscapes located in the northeastern are categorized as lower subdivision [25]. Temperate to Mediterranean climates prevail in the upper subdivisions, while semiarid to subtropical humid climates characterize the lower subdivisions [26]. This altitudinal and climatic variation results in the district being a subtropical–temperate ecological transition zone. The vegetation in the area ranges from subtropical semi-deciduous thorn forests at lower elevations to evergreen oaks, dry, moist temperate forests at higher altitudes [19].

A majority of the population lives in rural areas, relying on agriculture, livestock, and plant resources for their livelihoods. There is a long tradition of using wild plants in primary healthcare and subsistence practices in the region as an integral part of traditional knowledge.

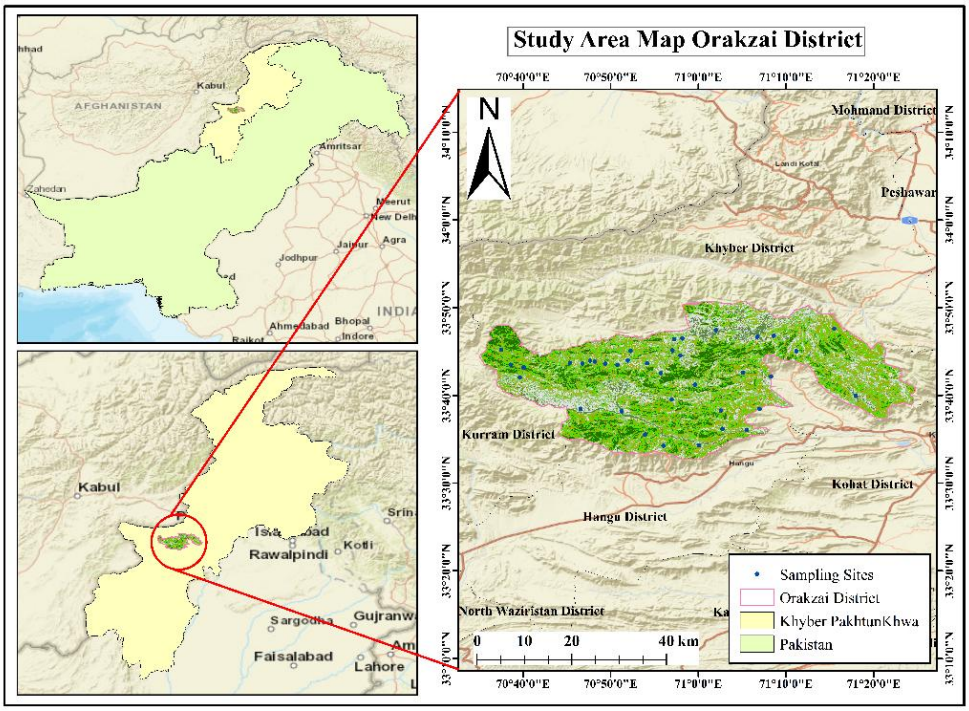

Figure 1. Study area map indicating the position of sampling sites

Fieldwork and Selection of Informants: An intensive field study and qualitative survey were conducted between March 2022 and October 2023, covering spring, summer, winter, and autumn. Field investigations required seasonally-based coverage because many wild plants differ considerably in their availability, collection, flowering and traditional use. The Orakzai district has approximately 52,104 households and a population of 387,561 individuals as of the 2023 census. In estimating the sample size for ethnobotanical surveys, Yamane's formula ($n = \frac{N}{1+N(e)^2}$) was applied to household data with a margin (e) of error of 5%. [27]. Based on this calculation, 3,862 households were surveyed across 38 study sites. A total of 400 informants were selected for detailed semi-structured interviews, including key informants and general informants.

In order to assess the knowledge of traditional plant uses among informants, two categories were created: key participants and general participants. The key informants were local healers, elders, and individuals with medical plant experience, while general informants were representative of the broader community. Participants were selected on the basis of their willingness to participate, their residency in the study area, and their comprehension of local plant usage practices.

The study protocol was approved by the Advanced Studies Research Board Committee under Reference No. KUST/BOT/25/283 in its 127th meeting. Informed consent was obtained from all subjects before data collection. Oral consent was deemed adequate given varying levels of literacy and cultural considerations where written documentation may not be the norm. Participants were informed of the purpose of the study and volunteered to participate. All the methods approved by the Advanced Studies Research Board Committee of Kohat

University of Science and Technology were performed in compliance with the corresponding guidelines and legislation.

collected using a semi-structured questionnaire, a household survey, a guided field trip, and open discussions with community members. The semi-structured questionnaire covered a number of important domains, such as informant demographics, plant identification and ecology, ethnobotanical uses, preparation techniques, dosage, and informants' perceptions of the sustainability of plants (Table S3). The interviews were conducted in the local language to facilitate communication and ensure seasonal coverage and maximize community involvement.

The specimens collected during the fieldwork were identified by Dr. Ghazala Nawaz, assistant professor at the department of botany, Kohat University of Science and Technology (KUST), Pakistan. The identification was further verified using standard floristic literature and online taxonomic databases. Online taxonomy databases and conventional floristic literature including, Flora of Pakistan, World Flora Online, and Plants of the World Online were used to confirm the identification and scientific names. Some commonly cultivated and naturalized species were included when reported by informants as wild-growing, locally gathered, or semi-naturalized ethnobotanical resources. Immediately after collection, samples were compressed between newspaper sheets, air-dried, and mounted on herbarium sheets. A total of 123 voucher specimens were deposited in the public Herbarium Room of the Department of Botany at KUST under accession numbers BOT-KHS-03 to BOT-KHS-223 (Table S2). Permission to collect the plants was obtained from the District Forest Department, Kohat Division, with permit number DFD-Kohat-1023.

Plant collection and fieldwork were conducted following the direction and approval of the Orakzai Forest Division and in compliance with all relevant international, national, and institutional guidelines. Specimen collection followed the IUCN Policy Statement on Research Involving Species at Risk of Extinction (IUCN, 1989), and only a minimum number of specimens were collected for scientific identification and documentation. This study did not collect, transport, and trade any plant species protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further, specimens were collected from areas with a sufficient density of species to minimize adverse effects on natural populations.

Quantitative ethnobotanical analysis: Using multiple ethnobotanical indices, participant reports of tribal uses were analyzed quantitatively to assess the significance, diversity, and agreement among informants regarding wild plants. Among these are the cultural importance index, the use diversity index, the direct matrix ranking, and the informant consensus factor. To examine the relationships between demographic variables and ethnobotanical knowledge, Pearson's correlation analysis was also performed.

1. Cultural importance index (CI): A plant species' relative importance was calculated following the standard ethnobotanical methodology based on its reported use categories. Cultural importance is calculated via the following formula:

$$CI = \sum \frac{UR}{N}$$

where UR represents the number of use reports per species, and N is the total number of informants participating in the study.

2. **Use Diversity Index (UDI)** was used to assess the diversity of use values assigned to each plant species, including medicine, fodder, fuel, food, and ritual purposes [28]. The Use Diversity Index (UDI) was calculated using Shannon's diversity index formula:

$$UDI = -\sum (pi \ln pi)$$

where *pi* represents the proportion of use reports belonging to a specific usage category relative to the total number of use reports for a given species, calculated as:

$$pi = \frac{URi}{\sum UR}$$

where, UR_i is the number of use-reports in a specific category, and $\sum UR$ is the total number of use-reports for that species. Use categories were defined based on major ethnobotanical functions, including medicinal, nutritional, veterinary, and non-medicinal uses. Higher UDI values indicate multipurpose plant species with diverse uses within the local community.

3. **Direct matrix ranking (DMR):** This index was employed to assess the relative anthropogenic pressure exerted on multipurpose wild plant species [29]. Selected plant species were assessed by key informants across various ethnobotanical use criteria, including medicinal, fuel, fodder, construction, and other local applications. The DMR score was calculated as:

$$DMR = \sum Sij$$

where S_{ij} represents the score assigned by informants to species i for use category j. The respondents assigned scores to selected plant species across multiple use categories via a five-point scoring scale (1 = negligible use, 2 = low use, 3 = moderate use, 4 = high use, 5 = very high use). Species were ranked according to their multipurpose importance based on the summed scores. The higher the DMR value, the greater the utilization pressure and the wider the ethnobotanical significance.

4. **Informant consensus factor (I_{CF})**: This index was used to assess the degree of agreement among participants for specific use categories [30]. The I_{CF} was calculated using the formula:

$$I_{CF} = \frac{(Nur - Nt)}{(Nur - 1)}$$

where N_{ur} is the total number of use reports recorded for a particular use category, and N_t is the number of plant species used for that category. Higher I_{CF} values indicate greater informant consensus and a more selective use of plant species. In this study, I_{CF} values were applied to identify key plant species used to treat 17 major disease categories.

5. **Conservation Status of plants:** An integrative qualitative approach was used to assess the conservation status of the plant species reported, incorporating (i) local community perceptions of species abundance, harvesting pressure, and population decline, (ii) repeated field observations made during ethnobotanical surveys, (iii) conservation information available from the IUCN Red List and Kew's extinction risk prediction. In place of formal IUCN threats, this framework provided a contextual, local-scale conservation assessment. In light of local harvesting pressure, observed population trends, field availability, and comparison with global conservation references, species were qualitatively divided into highly vulnerable, moderately threatened, and least concern categories.

6. **Statistical analysis:** The Pearson correlation coefficient was used to examine relationships between different informant categories, their professions, genders, levels of

expertise, and number of use reports. Using this analysis, we aimed to determine how ethnobotanical knowledge and informant characteristics are associated. The statistical analysis and graphical visualizations were performed with Microsoft Excel 365. A p value of 0.05 was used for statistical significance.

3. Results

Ethnographic Survey and Informant Selection: The sampling sites with the most participants were Khadizai, Kalaya, and Mishti Bazar, likely reflecting differences in population size, accessibility, or sampling coverage rather than actual variations in traditional knowledge preservation. However, fewer respondents were found in smaller communities, like Abi Shal and Tarangi, which have a limited population and a declining interest in traditional practices (Table 1). Specifically, general informants preserved routine household practices while key informants were more skilled at preserving medicinal, commercial, and folk practices.

Table 2. Households and participants distribution across sampling sites

Name of Community (Union Councils)	HHs	Is	Key Informants				General Informants		
			HPs	PCs	Fs	Es	MSs	Housewives	Male
ABISHAL & AKHUN KOT	180	19	3	3	3	2	3	5	14
AND KHEL & ANJANI	137	14	2	3	4	2	3	0	14
ARGHUNJA & BAGARA MISHTI	190	19	4	5	4	2	2	2	17
BAGHNAK & BAZID KHEL	220	23	3	5	3	7	3	2	21
MAMOZAI & FEROZ KHEL	148	16	2	5	3	2	3	1	15
DRAN SHEIKHAN	102	11	2	2	2	4	0	1	10
FARID MELA & GANDI TAAL	225	23	5	3	6	3	4	2	21
KHADIZAI & GHILJO	262	27	9	5	4	3	3	2	25
JALAKA MELA & KARGHAN	197	20	4	5	5	2	4	0	20
KALAYA & KARI TAAL	306	33	5	6	5	3	4	10	23
KASHA & GHOZ GHARH	200	20	4	4	3	5	3	1	19
KHAIR ALI KALAY KURAIZ	164	17	5	3	4	1	2	2	15
KUREZ & MANDATI	203	21	4	5	4	2	3	3	18
MISHTI BAZAR & PALOSI	218	23	5	3	8	3	3	1	22
QASIM KHEL & SAIFAL DARA	184	19	4	4	5	2	4	0	19
SAMA MAMOZAI & ZAKHTAN	230	24	4	4	7	4	2	3	21
SHAWI KILLAY & TARANGI	174	18	3	3	6	2	4	0	18
SPEEDAR & TAGHA SAM	210	21	4	3	6	3	4	1	20
TOOR SMAT & WAM PANRRA	101	11	3	3	3	2	1	0	11
ZANDA & ZERRA	211	21	5	5	4	2	2	3	18
GRAND TOTAL	**3662**	**400**	**80**	**79**	**89**	**56**	**57**	**39**	**361**

Notes: (HHs) Households, (Is) Informants, (HPs) Herbal Practitioners, (PCs) Plant Collectors, (Es) Elders, (Fs) Farmers, (MSs) Market Sellers

Species Diversity: The study reported 123 wild medicinal plants belonging to 60 families and 112 genera. Herbs dominated the plant categories with the most species, followed by shrubs, trees, and succulents/subshrubs (Table 3). In terms of diversity, the Asteraceae had the most species and genera, followed by the Fabaceae with 7 species and genera and the Rosaceae with six species and five genera. Similarly, the families Amaranthaceae, Apocynaceae, and Lamiaceae each include five species, whereas Poaceae includes five species and four genera (Figure 2). In order to simplify the visualization process, we grouped the remaining less-represented families into an 'Others' category. According to our findings,

herbaceous taxa are dominant in traditional medicinal systems, revealing the ecological heterogeneity of the Orakzai region.

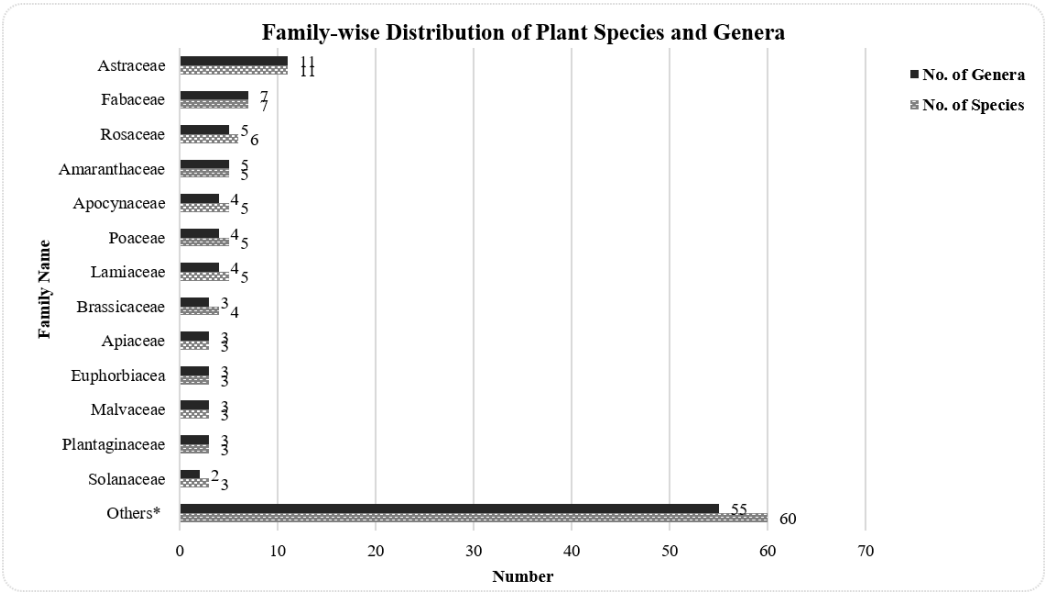

Figure 3. Family-level patterns of species and genus richness *Others represent plant families with fewer than three recorded species

Plant Parts Used: In tribal cultures, different plant parts were traditionally used for medicinal purposes. Leaves were the most frequently utilized plant part (33%), with roots and rhizomes (16.09%) and stems/barks and branches (15%). Fruits and pods (10.4%), flowers and buds (9%), and whole plants and seeds (7%) were comparatively less frequently used (Table 4). Rather than their therapeutic effectiveness, leaf use in a cultural setting is likely to reflect their relative availability and ease of harvesting.

Table 5. General characteristics of the reported wild flora in the Orakzai district.

ATTRIBUTES	Trees	Shrubs	Herbs	Subshrubs/ Succulents	Total Taxa	Percentage
HABIT	**23**	**37**	**58**	**5**	**123**	**100**
Annual, Biennial & Perennial	0	0	58	5	63	51.22
Woody	23	37		0	60	48.78
PART(S) USE						
Leaves					77	33.48
Roots and rhizomes					37	16.09
Stems, bark, and twigs					34	14.78
Fruits and pods					24	10.43
Flowers and buds					21	09.13
Whole plant					17	07.39
Seeds					16	06.96
Galls, Gums, Latex, and Resin					4	01.74
CONSERVATION STATUS						
Highly vulnerable	07	15	20	03	46	37.4
Moderately vulnerable	04	06	14	0	24	19.5
Least vulnerable	12	16	23	02	53	43.1

Preparation methods: Various traditional techniques for drug preparation have been used in the region (Table S2). The most frequently preferred preparatory practices were decoction (29%), concoction (22%), powder (16%), and paste (12%). Raw consumption (9.1%), boiling (7.4%), poultry (4.1%), latex extraction (2%), and fumigation (Table 3) were the least common methods of preparation. More than half of the documented wild plant species were reported with preparation methods that have not been previously documented in the Orakzai district, emphasizing the dynamic nature and novelty of the study.

The novelty analysis in plant uses and drug formulations was conducted through a comparative review of published ethnobotanical studies from comparable regions. Reported uses in the present study were cross-checked against existing literature to determine whether they had been previously documented. Novelty in this study, therefore, refers to uses that have not been reported in the available literature or have not been documented specifically for the Orakzai district.

Ailments Treated: The cited wild plant species were used against a wide range of health-related concerns, including respiratory ailments, contagious diseases, inflammatory conditions, urinary problems, metabolic disorders, and gastrointestinal disorders. Commonly reported health conditions, with plant-based remedies classified into therapeutic categories including antibacterial, antidiabetic, and anti-inflammatory uses. Some herbal remedies have been less commonly observed for neurological ailments, veterinary diseases, and cancer-related conditions.

Quantitative ethnobotanical analysis: A quantitative analysis of 123 species was conducted using information provided by 400 informants. The cultural importance index, use diversity index, direct matrix ranking, informant consensus factor, and Pearson correlation analysis were used.

Cultural Importance Index (CI): According to the cultural importance index, *Olea europaea* subsp. *cuspidata* (0.023), *Daphne papyracea* (0.020), and *Salix babylonica* (0.020) exhibited the highest values, reflecting their relatively greater importance and frequent use

among local communities in the study area. Based on the distribution of cultural importance values, species were categorized into four levels: highest (0.020–0.023), high (0.015–0.019), moderate (0.010–0.014), and low (0.005–0.009). A substantial proportion of species fell within the moderate category, while relatively fewer species were represented in the highest category. Species with CI values below 0.005 were infrequently cited, indicating comparatively lower levels of reported use among informants (Figure 3). Plant species were categorized according to the frequency of ethnobotanical citations recorded for each use-report category (UR).

Use Diversity Index: An index of use diversity was calculated to evaluate the different uses reported for each species of plant. A variety of ethnobotanical applications contributed to the variation of UDI values (0.12 to 1.00) among species. Based on the use diversity analysis, *Berberis lycium* (1.00), *Artemisia indica*, *Azadirachta indica*, and *Cannabis sativa* (0.88) exhibited relatively higher use diversity, reflecting their broader range of reported applications. In contrast, species, i.e., *Citrullus colocynthis*, *Hedera helix*, and *Pyrola chlorantha* with lower UDI values (0.12), were associated with more specific uses. There is a limited number of species that serve multiple ethnobotanical roles, while the majority are more specialized. There is a similar pattern with other quantitative indices, where only a few species exhibit broader usage profiles.

Table 3. Principal ethnobotanical data of wild plant species documented in the Orakzai district

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Abutilon grandifolium	Zerr Gollai	Malvaceae	Herb	Leaves	Throat infections (decoction)	Oral	Fodder
Achyranthes aspera	Buch Kanda	Amaranthaceae	Herb	Fruits, leaves	Gonorrhea, insect bites, gastrointestinal disorders (decoction, powder)	Oral and topical	Fuel, wild food
Aerva javanica	Buoi booty	Amaranthaceae	Herb	Leaves	Epilepsy, neurological disorders (powder)	Oral	Fuel, fodder
Aloe vera	Zahar Panrri	Asphodelaceae	Herb	Leaves, roots	Burns, skin irritation, reproductive disorders (paste)	Topical	Ornamental
Amaranthus viridis	Ranzaka (Saaba)	Amaranthaceae	Herb	Fruits, leaves, and stems	Gastrointestinal disorders, hypertension, inflammation (powder, raw)	Oral	Food
Apteranthes tuberculata	Gharani pawana	Apocynaceae	Subshrub	Stem	Anticancer, antidiabetic (decoction)	Oral	Food
Argemone mexicana	Zer Ghat Gul	Papaveraceae	Herb	Roots, latex, seeds	Antifungal, anthelmintic, wart removal (extract, tincture)	Topical	Fodder
Argyrolobium roseum	Bambal	Fabaceae	Herb	Leaves	Antidiabetic, rheumatism, antimalarial (tablet)	Oral	NA
Artemisia arborescens	Maturyana	Asteraceae	Herb	Whole plant	Tonic, neurological disorders, anthelmintic (liquid extract)	Oral	Insect, evil eye repellent
Asparagus officinalis	Lakhtukai	Asparagaceae	Herb	Aerial parts, bark, roots	Anticancer, antimicrobial, aphrodisiac (raw, powder, extract)	Oral	Food
Azadirachta indica	Daraka	Meliaceae	Tree	Stems, leaves	Antidiabetic, gastrointestinal disorders, tumors, boils (suspension, poultice)	Oral and topical	Ornamental
Bacopa monnieri	Werkharra	Plantaginaceae	Herb	Whole plant	Anemia, asthma, epilepsy, veterinary uses (powder)	Oral	Food, fodder, ornamental
Bauhinia variegata	Korryal	Fabaceae	Tree	Flowers, bark	Astringent, carminative, veterinary diarrhea (raw, bark)	Oral	Food, ornamental
Berberis lycium	Zark azghai	Berberidaceae	Shrub	Roots, bark, leaves	Antiseptic, splenic disorders, jaundice, tonic (poultice, decoction)	Oral	Food
Buxus wallichiana	Shamshad	Buxaceae	Shrub	Stem bark	Joint pain (decoction)	Oral	Food, furniture

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Calotropis gigantea	Madar	Apocynaceae	Shrub	Roots, leaves, and flowers	Tumors, chest pain, dysentery, skin disorders, gastrointestinal disorders (extract, poultice)	Oral and topical	Insect repellent
Calotropis procera	Then doraye	Apocynaceae	Shrub	Fruits	Blood purifier, antidiarrheal, tonic (decoction)	Oral	Fuel
Cannabis sativa	Bhang	Cannabaceae	Herb	Flower, seeds, leaves,	Appetizer, diuretic, stimulant (powder)	Oral	Various traditional uses
Capparis decidua	Kerarha	Capparaceae	Shrub	Stem	Anthelmintic, antimalarial, toothache (raw)	Oral	Fuel
Capsella bursa-pastoris	Bombasa	Brassicaceae	Herb	Leaves	Astringent, stimulant (decoction)	Oral	Fodder
Carpesium abrotanoides	Tabakha	Asteraceae	Subshrub	Whole plant	Inflammation, diarrhea (decoction, poultice)	Oral, topical	No other use
Carthamus oxyacanthus	Speen azghai	Asteraceae	Herb	Leaves	Skin infections, jaundice (decoction)	Oral	Oil
Celtis sinensis	Tagha	Cannabaceae	Tree	Bark	Animal gastrointestinal disorders (decoction)	Oral	Fuel and furniture
Cenchrus ciliaris	Gharani wakha	Poaceae	Herb	Leaves	Diarrhea, vomiting (decoction)	Oral	Fodder, crafts
Cenchrus setosus subsp. *setosus*	Babar wakha	Poaceae	Herb	Rhizome	Digestive stimulant, skin disorders (confection)	Oral	Fodder
Chrysojasminum humile	Ghojara	Oleaceae	Shrub	Flowers, leaves, roots	Indigestion, skin infections, anthelmintic (oil, paste)	Oral, topical	Ornamental
Citrullus colocynthis	Tarkha manrra	Cucurbitaceae	Herb	Fruits, seeds	Abortifacient, cathartic (filtrate)	Intravascular	No other use
Cleome brachycarpa	Kari wala	Cleomaceae	Subshrub	Fruits	Wound healing (fruit extract bath)	Topical	Fodder
Convolvulus arvensis	Parvata	Convolvulaceae	Herb	Flower, roots	Astringent, diuretic, gastrointestinal disorders, laxative (powder, tea)	Oral	No other use
Cornus alternifolia	Pagoda	Cornaceae	Tree	Bark, leaves, roots	Antipyretic, digestive, tonic, wound healing (decoction, infusion)	Oral	No other use
Crataegus marshallii	Ghwanza	Rosaceae	Shrub	Fruits, leaves, flowers	Antihypertensive, cardiotonic (decoction, infusion)	Oral	Food
Cuscuta reflexa	Akas bila	Convolvulaceae	Herb	Whole plant	Skin infections (decoction)	Topical	Hair removal
Cymbopogon citratus	Sharr	Poaceae	Herb	Roots	Analgesic, diarrhea (powder)	Oral	Handicrafts

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Cymbopogon flexuosus	Dadan	Poaceae	Herb	Flower	Hair loss (decoction)	Topical	Crafts, fodder
Cynodon dactylon	Birawa	Poaceae	Herb	Flowers	Skin disorders (powder)	Topical	Thatching purpose
Cynoglossum zeylanicum	Murgha khpa	Boraginaceae	Herb	Leaves, roots, seeds	Anthelmintic, infections, leukorrhea, veterinary uses (poultice, decoction)	Oral, topical	Traditional tea in ritual events
Cyperus rotundus	Nagar motha	Cyperaceae	Herb	Rhizome, aerial parts	Antipyretic, respiratory disorders (tea, fumigation)	Oral, nasal	Fodder, fuel
Dalbergia sissoo	Shawa	Fabaceae	Tree	Leaves, bark	Skin disorders, itching (extract)	Topical	Fuel, timber
Daphne papyracea	Laghoome	Thymelaeaceae	Shrub	Leaves, roots, bark	Abscesses, headache, skin disorders, swelling, toothache (paste, fumigation)	Nasal, topical	Bark fibers are used in crafts
Datura stramonium	Toorai	Solanaceae	Herb	Fruits, seeds, leaves	Sedative, earache, rheumatism (paste, fumigation)	Topical and nasal	No other use
Delphinium uncinatum	Tora jelma	Ranunculaceae	Herb	Twigs, leaves	Menstrual disorders (decoction)	Oral	Fodder
Descurainia pinnata	Sharshamai	Brassicaceae	Herb	Leaves, seeds, whole Plant	Expectorant, febrifuge, urinary disorders, stomachache (decoction, infusion)	Oral and topical	Food
Dianthus anatolicus	Karaka	Caryophyllaceae	Herb	Leaves	Respiratory disorders (steam decoction)	Oral, nasal	Fodder
Dianthus deltoides	Enatoli	Caryophyllaceae	Herb	Whole plant	Anthelmintic (powder)	Oral	Fuel, fodder
Digera muricata	Tandola	Amaranthaceae	Herb	Leaves, twigs	Antifungal, astringent, diuretic (decoction)	Oral	Fodder, food
Diospyros kaki	Soor Amlok	Ebenaceae	Tree	Fruits, leaves	Constipation, hypertension (raw, decoction)	Oral	Food
Diospyros lotus	Toor Amlok	Ebenaceae	Tree	Fruits	Digestive, cardiotonic, tonic (raw)	Oral	Food
Dodonaea viscosa	Zera Woonai	Sapindaceae	Shrub	Leaves, stems, fruits	Wound healing, toothache, laxative (smoke, poultice)	Oral, topical, nasal	Fuel, hair remover
Drosera rotundifolia	Kheroba	Droseraceae	Shrub	Leaves	Boils, itching, acne (paste)	Topical	Fodder
Echinops echinatus	Silaba	Asteraceae	Herb	Seeds	Renal disorders (powder)	Oral	Fuel
Erigeron bonariensis	Chonyza	Asteraceae	Herb	Leaves, whole plant	Analgesic, anti-inflammatory, diuretic, gastrointestinal disorders (decoction, infusion)	Oral, topical, inhalation	Fodder

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Eucalyptus camaldulensis	Lechai	Myrtaceae	Tree	Leaves	Antiseptic (poultice)	Oral	Thatching
Euphorbia hirta	Chapa tray	Euphorbiaceae	Herb	Leaves, roots, whole plant	Boils, gastrointestinal disorders, gynecological disorders, itching (extract, powder)	Oral and topical	Fodder
Euphorbia serrata	Doodak	Euphorbiaceae	Herb	Root, stem	Anthelmintic, anticholera, constipation (powder, decoction)	Oral	No other use
Fallopia convolvulus	Parvatai	Polygonaceae	Herb	Leaves, seeds	Appetizer, digestive (powder, extract)	Oral, topical	Food, fodder
Ficus drupacea	Inzer	Moraceae	Tree	Fruits, leaves	Laxative, tumors (raw, extract)	Oral	Food, fuel, fodder
Ficus populifolia	Peepal	Moraceae	Tree	Leaves	Veterinary diseases (paste)	Topical	Furniture
Forsskaolea tenacissima	Khar Gul	Urticaceae	Herb	Whole plant	Gastrointestinal disorders (powder)	Oral	Fodder
Fragaria vesca	Ghar strawberry	Rosaceae	Herb	Leaves, fruits, rhizomes	Antioxidant, astringent, antidiarrheal, diuretic (infusion, decoction)	Oral	Food
Galeopsis bifida	Mostan gul	Lamiaceae	Herb	Leaves, stems, flowers	Gastrointestinal disorders, diuretic, expectorant, fever (infusion, decoction)	Oral	Fodder
Glycyrrhiza glabra	Khoga wali	Fabaceae	Shrub	Roots	Hepatoprotective, stomach-ache, and tonic (decoction)	Oral	Food, fodder
Grewia optiva	Postawana	Malvaceae	Shrub	Bark, leaves	Analgesic, astringent, reproductive disorders, labor pain (powder, raw)	Oral	Bark is made into fiber and ropes
Gymnosporia royleana	Kanjghara	Celastraceae	Shrub	Leaves, stem	Antibacterial (decoction)	Oral	Fodder, fuel
Gymnosporia wallichiana	Babara	Celastraceae	Shrub	Roots	Aphrodisiac (fried roots)	Oral	Fodder, fuel
Hedera helix	Tokha prevati	Araliaceae	Climber	Leaves	Expectorant, anti-inflammatory, wound healing (decoction, paste)	Oral, topical	No other use
Heliotropium sarmentosum	Gorakh panra	Boraginaceae	Herb	Roots	Venereal diseases (powder)	Oral	Fodder, crafts
Hypericum perforatum	Gule zakhm	Hypericaceae	Herb	Flowers, leaves	Antidepressant, menstrual disorders (tea)	Oral	Ornamental
Impatiens glandulifera	Thor lakavae	Balsaminaceae	Herb	Leaves, whole plant, flowers	Jaundice, joint pain, skin infections (extract, decoction)	Oral, topical	Food
Indigofera heterantha	Thor lakavae	Fabaceae	Herb	Flowers	Tonic (decoction)	Oral	Fodder

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Isodon rugosus	Sperkay	Lamiaceae	Subshrub	Leaves	Gastrointestinal disorders, headache, respiratory disorders (decoction, infusion)	Oral	Used to repel insects
Juglans regia	Ghōz	Juglandaceae	Tree	Bark, leaves	Gastrointestinal disorders, veterinary colic (extract, decoction)	Oral	Food, tooth cleaner
Jurinea heteromalla	Dardar /Spin gul	Asteraceae	Herb	Fruits, leaves	Skin disorders, astringent (powder)	Oral	Food, fodder, fuel
Justicia adhatoda	Baza	Acanthaceae	Shrub	Bark, flowers, leaves	Antimicrobial, antispasmodic, expectorant, and nose-bleeding (extract, paste, nectar)	Oral, topical	Fuel
Lantana camara	Khar ghwasakay	Verbenaceae	Shrub	Leaves, fruits	Antimicrobial, antispasmodic, expectorant, epistaxis (extract, paste)	Oral	Ornamental
Launaea arborescens	Zarghūnai	Asteraceae	Shrub	Leaves, roots	Pain relief, itching, boils (powder)	Topical	Fuel
Leptopus cordifolius	Sharkanda	Phyllanthaceae	Shrub	Leaves, roots, stem	Antivenom, hepatosplenic disorders, renal infections (decoction, powder)	Oral	Fodder
Lomelosia olivieri	Wahshi botay	Caprifoliaceae	Shrub	Leaves, roots, flowers	Veterinary diseases, diarrhea, dysentery (raw, decoction)	Oral	Fuel
Lysimachia arvensis	Pimpernel	Primulaceae	Herb	Whole plant	Sedative (decoction)	Oral	Fuel
Malva neglecta	Pandeerak	Malvaceae	Herb	Leaves, roots	Astringent, laxative, diuretic (decoction)	Oral	Food
Mentha arvensis	Pudina	Lamiaceae	Herb	Whole plant	Appetizer, skin disorders, gastrointestinal disorders (raw)	Oral	Food, fodder
Mentha longifolia	Jangli pudina	Lamiaceae	Herb	Leaves	Dyspepsia, indigestion, stomachache (raw)	Oral	Boost aroma
Mutarda nigra	Tor sharshem	Brassicaceae	Herb	Roots, seeds	Constipation, itching (extract, oil)	Oral, topical	Insect repellent
Nannorrhops ritchieana	Mazara	Arecaceae	Shrub	Leaves	Stomachache, flu (extract)	Oral	Food, crafts
Nanorrhinum ramosissimum	Zebula	Plantaginaceae	Herb	Whole plant	Antipyretic, analgesic (powder)	Oral	Fodder
Olea europaea subsp. *cuspidata*	Jangli zaitoon	Oleaceae	Tree	Leaves, bark, fruits	Cough, cold, flu, antidiabetic, anemia (decoction, powder)	Oral	Fodder, fuel, and furniture
Oxalis corniculata	Taak matak	Oxalidaceae	Herb	Leaves, flower	Hemorrhage, joint pain, nausea, respiratory disorders (smoke, raw)	Oral and nasal	Culinary (food) and fodder

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Peganum harmala	Speelana	Nitrariaceae	Herb	Roots, seeds	Anthelmintic, skin disorders (powder)	Oral	Ward off evil eyes and repel snakes
Pentanema britannica	Zard Gul Bootay	Asteraceae	Herb	Roots	Stomachache (powder)	Oral	Fodder
Periploca aphylla	Birara	Apocynaceae	Shrub	Leaves, pods	Asthma, gastrointestinal disorders, skin disorders (decoction, paste)	Oral and topical	Fuel
Pistacia chinensis	Shenai	Anacardiaceae	Tree	Bark, fruit, leaves, resin	Antiseptic, asthma, oral infections, wound healing (spray, decoction)	Oral and topical	Food, fodder
Plantago australis	Sagul	Plantaginaceae	Herb	Whole plant	Warts, skin lesions (paste)	Topical	Fodder
Polygala javana	Mastana	Polygalaceae	Herb	Roots	Analgesic, diuretic (decoction)	Oral	Fodder
Populus deltoides	Peepsl	Salicaceae	Tree	Bark, leaves, buds	Fever, muscle cramps, wound healing (decoction, infusion)	Oral and topical	Fast-growing afforestation
Ptilimnium capillaceum	Desi Ajwain	Apiaceae	Herb	Leaves	Gastrointestinal disorders (powder)	Oral	Fodder
Pupalia lappacea	Wreham booti	Amaranthaceae	Herb	Seeds	Anticholera, aphrodisiac, earache (oil)	Oral, topical	Food
Pyrola chlorantha	Sheen sarra	Ericaceae	Herb	Leaves, roots, whole plant	Anti-rheumatic, renal disorders, wound healing (decoction, poultice)	Oral, topical	No other use
Pyrus pashia	Tangi	Rosaceae	Tree	Bark, fruits, leaves	Antipyretic, gastrointestinal disorders, astringent, wound healing (decoction)	Oral, topical	Food, fodder, timber
Pyrus pyrifolia	Patang	Rosaceae	Tree	Fruits, leaves, seeds	Anti-inflammatory, digestive, and respiratory disorders (decoction, raw)	Oral, topical	Food
Quercus glauca	Shala serai	Fagaceae	Tree	Bark, galls	Astringent, wound healing, itching (decoction, poultice)	Oral, topical	Food, fodder, fuel, timber
Quercus ilex	Ghowara serai	Fagaceae	Tree	Bark, acorns	Astringent, antiseptic (decoction, poultice)	Oral, topical	Food, fodder, timber
Rhazya stricta	Gunderi	Apocynaceae	Shrub	Leaves	Anti-rheumatic (poultice)	Topical	Fuel
Ricinus communis	Arand	Euphorbiaceae	Shrub	Leaves, floral leaves	Antibacterial, chest pains, joint pains (leaf extract, poultice)	Oral, topical	Lubricant (oil), and ornamental
Rosa brunonii	Tandorai	Rosaceae	Shrub	Flowers	Antiseptic, antipyretic, skin allergies (decoction)	Oral	Flowering signs cultivation onset

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Rubus thibetanus	Karwara	Rosaceae	Shrub	Bark, bud, roots	Anti-inflammatory, antimicrobial, detoxification (infusion, decoction)	Oral, topical	Food, fuel
Rumex hastatus	Matak	Polygonaceae	Shrub	Whole plants, Fruits	Anti-asthmatic, cough suppressant, antipyretic (decoction)	Oral	Food
Rydingia limbata	Kharpaka	Lamiaceae	Shrub	Flowers, leaves	Oral ulcers, gastrointestinal disorders (decoction, juice)	Oral, topical	Fuel
Sageretia thea	Mamani	Rhamnaceae	Shrub	Leaves, bark	Tonic, analgesic, hypertension (powder, decoction)	Oral	Fodder, fuel
Salix babylonica	Asila vala	Salicaceae	Tree	Bark, leaves, twigs	Detoxification, fever, inflammation, skin infections (powder, infusion)	Oral, topical	Fodder, crafts
Senegalia modesta	Palosa	Fabaceae	Tree	Gums, stem	Dental pain, joint pain, labor pain (gum, paste)	Oral, topical	Hair removal
Sideroxylon mascatense	Gorgora	Sapotaceae	Tree	Leaves, seeds	Purgative, antidiabetic, antimalarial (juice, paste)	Oral	Food, dodder, construction
Silybum marianum	Karpota	Asteraceae	Herb	Leaves, flowers	Cardiovascular disorders, piles, liver disorders (milk extract, juice)	Oral	Fuel
Sium suave	Gharani gajara	Apiaceae	Herb	Root	Detoxification (extract)	Oral	Food
Solanum nigrum	Khorsaba	Solanaceae	Herb	Roots, leaves, fruits	Renal disorders, skin disorders, diuretic (oil, poultice)	Oral and topical	Food, fodder
Taraxacum sect. Taraxacum	Khro kona	Asteraceae	Herb	Rhizome	Jaundice (decoction)	Oral	Food, fodder
Torilis japonica	Pojator	Apiaceae	Herb	Aerial parts, whole plant	Skin disorders, diuretic, gastrointestinal disorders, febrifuge (decoction, paste)	Oral, topical	Food, fodder
Tribulus terrestris	Markundai	Zygophyllaceae	Herb	Leaves	Kidney stones, urinary disorders (infusion)	Oral	Fodder
Vachellia nilotica	Kikar	Fabaceae	Tree	Seeds	Astringent, carminative (powder)	Oral	Fodder, timber
Verbascum thapsus	Khar gwag	Scrophulariaceae	Herb	Leaves	Astringent, emollient (decoction)	Oral	Fuel, insecticide
Withania somnifera	Shapianga	Solanaceae	Shrub	Fruits	Allergy, asthma (decoction)	Oral	No other use
Xanthium strumarium	Gishkae	Asteraceae	Herb	Fruits, leaves, roots	Anti-inflammatory, respiratory disorders, skin conditions (decoction)	Oral	No other use
Zanthoxylum capense	Dambara	Rutaceae	Tree	Fruits, seeds, leaves	Carminative, gastrointestinal disorders (powder, milk)	Oral	Spices, Chatni

Botanical Name	Local Name	Family Name	Habit	Plant Part Use	Major Ethnobotanical Uses (including preparation)	Mode of Application	Non-medicinal Uses
Ziziphus nummularia	Karkanrha	Rhamnaceae	Shrub	Roots	Antipyretic (decoction)	Oral	Food, fodder, adhesives
Zygophyllum indicum	Mazghakai	Zygophyllaceae	Herb	Leaves, roots	Jaundice, skin disorders (oil mixture)	Oral	Leaves in rituals to ward off evil

Cautionary Note: The manuscript describes an ethnographic interpretation of tribal practices and is solely intended for documentation. Considering contemporary medical standards, these traditional uses may involve harmful or unsafe practices, so they shouldn't be considered evidence.

Direct Matrix Ranking: Direct matrix ranking revealed a variation in the multiple purposes of selected plant species. Species such as *Quercus glauca* and *Dalbergia sissoo* obtained comparatively higher cumulative scores, reflecting their broader range of reported uses across multiple categories. In contrast, species with lower total scores, including *Descurainia pinnata*, *Daphne papyracea*, *Torilis japonica*, *Pyrus pashia*, and *Berberis lycium*, were associated with more limited and specialized uses. These rankings are based on the summed scores assigned by informants across predefined use categories.

Informant Consensus Factor: The I_{CF} values ranged from 0.30 to 0.50, indicating a moderate level of consensus among participants on tribal remedies across disease categories. The highest I_{CF} values were recorded for antimicrobial (0.50), antidiabetic (0.48), and anti-inflammatory uses (0.44), suggesting relatively greater consensus among informants for these therapeutic applications. In contrast, comparatively lower I_{CF} values may reflect variability in treatment practices, the availability of multiple therapeutic options, or differences in knowledge distribution among participants rather than limited traditional experience.

Conservation and Sustainability: Based on informant perceptions, field observations, IUCN Red List categories, and KEW extinction risk predictions, medicinal plant species were classified into three conservation categories. Thirty-eight percent of the documented flora were categorized as highly vulnerable, 19% as moderately threatened, and the remaining species were of least concern at the local level (Table 3). Compared with global IUCN conservation categories, field-based evaluations revealed differences in global status and local population trends. There was a decline in abundance and population size of several species classified worldwide as least concern, such as *Justicia adhatoda* and *Tribulus terrestris*, in the study region. Field observations, however, are consistent with global conservation categories, particularly for Eucalyptus camaldulensis (Near Threatened), which were observed to have limited regeneration and decreasing population sizes.

Pearson correlation was conducted to assess the relationship between informant categories and ethnobotanical knowledge, measured as the number of use reports. A positive correlation ($R^2 = 0.88$, $p < 0.05$) was observed between elder informants and the number of use reports, indicating that older participants tended to preserve a greater diversity of plant uses. Similarly, female informants (predominantly housewives) showed a positive association ($R^2 = 0.97$, $p < 0.05$) with reported plant uses. These relationships reflect patterns in the distribution of knowledge among different informant groups (Figure 4).

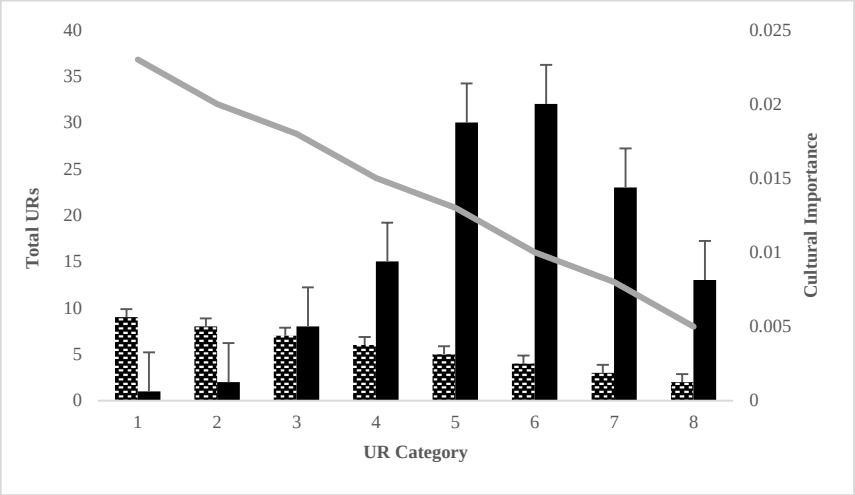

Figure 3. Distribution of use reports and Cultural Importance Index across UR categories in the Orakzai district.

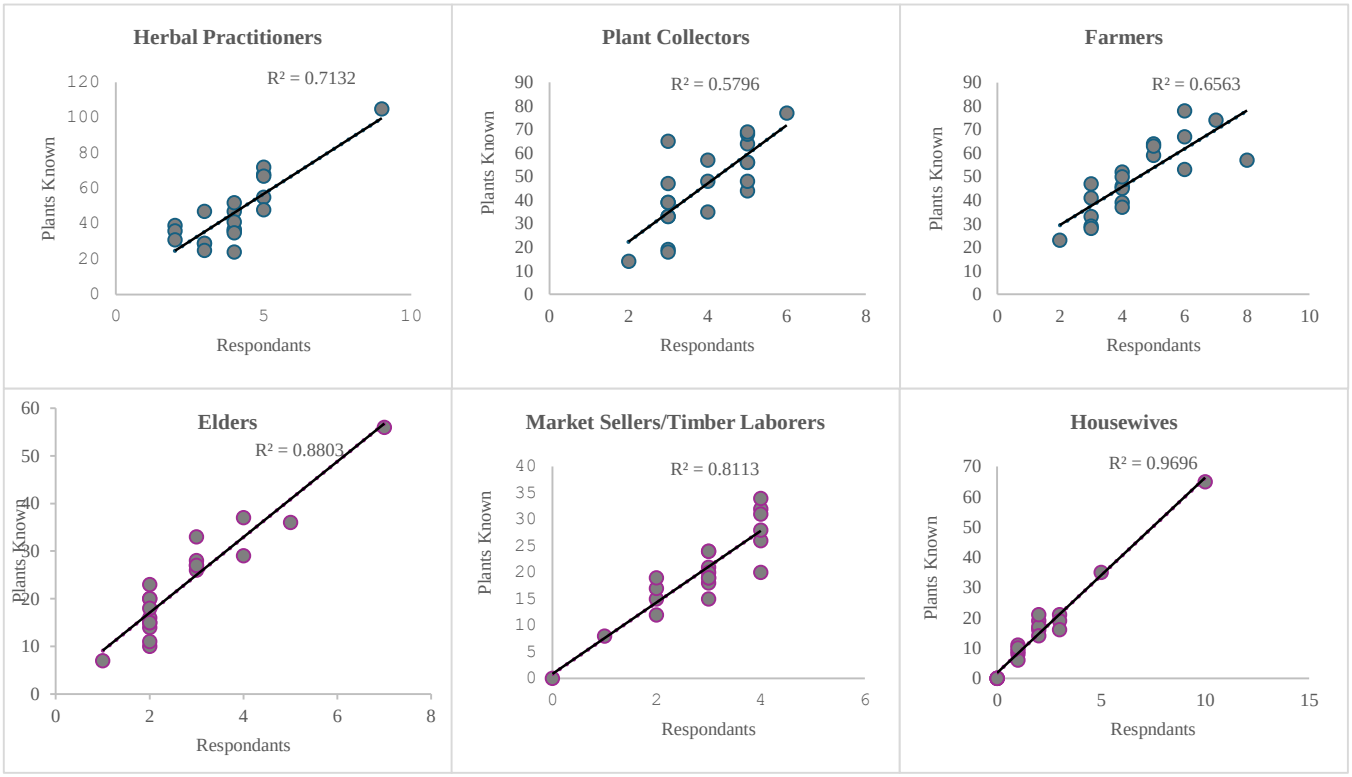

Figure 4. Pearson Correlation among Key Informants and General Informants

4. Discussion

The findings of this study provide significant traditional knowledge associated with wild plant species in the subtropical to temperate regions of the Orakzai district and highlight conservation-associated challenges. Comparable patterns of medicinal plant use, reliance on wild flora for primary healthcare, and liability of both traditional knowledge and medicinal plants have been reported from similar mountainous and tribal regions of Pakistan and adjacent Himalayan regions [31, 32]. Similar dependence on wild plant resources for food security, nutrition, and household resilience has also been documented in tribal communities of the Hindu Kush region [2]. These results likely reflect comparable ecological conditions, limited access to basic healthcare, and a strong reliance on plant-based healing traditions in rural mountain communities. A similar reliance on ethnobotany and traditional medicinal practices has also been documented in mountainous tribal communities surrounding the Pakistan-Afghanistan border [18].

In this study area, tribal plant remedies are still prevalent despite socioeconomic change, which is consistent with research findings from comparable regions [33, 34]. In tribal communities, there may be a lack of livelihood alternatives and limited access to modern healthcare due to continued reliance on traditional ecological knowledge [9]. Farmers, plant collectors, and herbal practitioners acknowledged plant medicine more readily than general participants in previous studies [35]. In ethnobotanical evaluations, housewives and other

elders were identified as key sources of traditional knowledge [36–38]. There is, however, a risk of intergenerational transmission declining because of limited documentation and comparatively lower engagement among youth. A similar trend in traditional knowledge transition has also been reported from ecologically similar areas [39].

According to related regional studies, ethnobotanical knowledge varied across demographic groups, especially with respect to age and livelihood practices [40, 41]. The elderly reported being more familiar with the traditional uses of medicinal plants than the younger participants [42]. Tribal traditions and professions such as lumber work illustrate the importance of direct contact with the environment in preserving cultural botanical knowledge. Similar relationships have been reported in tribal communities, suggesting that occupations that are directly related to natural resources might enhance ethnobotanical knowledge retention [43, 44].

The extent of floristic abundance and diversity is reflected in the reported 123 species of wild plant representing 60 families and 112 genera. The prevalence of Asteraceae, widespread use of herbaceous species, and dependence on leaf-based medicines are generally in line with ethnobotanical patterns documented from nearby hilly and tribal areas [45, 46]. Similar ethnomedical plant-use patterns have also been documented from neighboring tribal districts in northwest Pakistan, including Bajaur district [17]. The dominance of species richness in this family may reflect their ecological adaptation, abundance, and broad traditional value, albeit these associations were not specifically assessed in these findings [19]. Similarly, the prevalence of Poaceae and Fabaceae is consistent with their widespread distribution in subtropical to temperate regions and cultural preference for inclusion in traditional medicines [47]. Bioactive compounds have been reported in a variety of Fabaceae species [48–51]. These characteristics necessitate specific phytochemical and pharmacological studies.

Due to their abundance, rapid regeneration, and adaptability to environmental changes, herbaceous species dominated the study area [52]. *Pistacia chinensis* and *Torilis japonica* have been investigated for their secondary metabolites, including alkaloids, cyanogenic glycosides, flavonoids, sesquiterpenes, and phenolic glycosides [53–56]. Similar to previous ethnobotanical studies [57], leaves were the most commonly reported use plant parts. The active metabolic processes in leaves produce diverse secondary metabolites [58]. The use of ethnobotanicals alone does not prove therapeutic efficacy, highlighting the need for further research to support these claims.

A decoction is the most frequently cited tribal drug formulation, followed by a concoction and an infusion. In folk medicine systems, this preference is often indicated, perhaps because it is easy to prepare and efficiently extracts water-soluble compounds [59]. Nevertheless, further experimental validation is needed to determine the effectiveness of these preparations in terms of their pharmacological properties.

The documented tribal applications were found to be comparatively less reported and regionally undocumented when compared to ethnobotanical literature, regional flora, and previous publications. In the assessment, ethnobotanical records were compared with regional medicinal plant literature and related studies conducted in ecologically similar regions. In spite of the fact that these findings provide important baseline data, assertions about therapeutic efficacy should be made cautiously. Certain taxa, including *Berberis lycium* and *Olea europaea* subsp. *cuspidata*, have been used for a variety of purposes according to

phytochemical and pharmacological evidence [60]. Several secondary constituents, such as biophenols, flavonoids, secoiridoids, and triterpenes, are present in wild olive leaf extracts, which are associated with culturally important household remedies and may be worth conserving. These compounds have been found to have antidiabetic, antimicrobial, and antioxidant properties [61]. Berberine, an alkaloid found in *Berberis lycium*, has been used traditionally to treat liver and spleen diseases [62, 63]. Fumigating fresh leaves of *Daphne papyracea* relieves joint pain and boils, while root and bark formulations ease cutaneous illnesses, dental problems, and migraines [64, 65]. Some species, however, lack scientific basis, and their medicinal uses are based on traditional traditions. It is therefore recommended that future pharmacological and therapeutic studies on these species are more prospective than current traditionally reported medicinal uses.

Several plants, in addition to being used for medical purposes, provide various purposes including forage, food, fuel, and materials for building, in line with trends cited in other resource-dependent mountainous cultures [66, 67]. This multifaceted reliance on wild flora has also been widely observed in comparable rural and tribal areas in the Hindu Kush region [2]. The use of these plants for multiple purposes may result in increased harvesting demands, potentially increasing the pressure on local plant populations.

Despite its ecological and cultural importance, the tribal Orakzai district is subjected to a variety of anthropogenic pressures, including deforestation, overgrazing, land-use change, and prolonged geopolitical instability [68, 69]. A similar trend is being observed in the entire tribal region, which is undergoing significant economic and infrastructure changes [70]. These anthropogenic pressures may pose significant threats to local plant diversity and associated ethnobotanical knowledge systems. Thus, long-term conservation requires ethnobotanical research, ecological harvesting, and collaborative resource management.

A comparison of worldwide conservation databases and local field-based observations revealed that conservation pressures in the tribal district are not always fully reflected in global assessments [70–72]. This study documented local conservation observations based on community perceptions, harvesting pressure, species availability, and repeated field observations, instead of following formal IUCN threat assessment criteria. It is important to realize that even though the IUCN Red List provides a global reference, localized pressures can also lead to population declines that cannot be reflected in global categories. There are three major factors contributing to population decline in local vegetation including, overharvesting, habitat degradation, and land use change. In ecologically transitional mountain systems, climate variability and shifting temperature regimes can further influence taxa distribution and regeneration. Plant collections for medicinal purposes and other domestic use may negatively impact natural regeneration processes due to anthropogenic pressures. As demand for therapeutic plants increases, unsustainable harvest practices may add to the stress on vulnerable ecosystems [73].

The degradation of habitat is further exacerbated by deforestation, overharvesting, and trampling, which hinders the recruitment and recovery of populations. The charcoal production process and fuelwood extraction have also changed the structure and composition of habitats. These pressures may have a greater impact on slow-growing woody species such as *Olea europaea* subsp. *cuspidata* and *Berberis lycium* [74, 75]. When regional population trends are coupled with the global conservation database, conservation targets may be more

properly identified. The integrated approach may provide a context-specific approach to protecting wild plant resources and associated cultural knowledge [76, 77].

This study relied primarily on cross-sectional ethnobotanical interviews and descriptive quantitative measures. Although the data provide a valuable record of indigenous plant knowledge in the Orakzai district, the study did not look into the pharmacological efficacy or clinical validity of the indicated applications. Furthermore, correlations between demographic variables and ethnobotanical knowledge should be approached with caution, as correlation analyses reveal relationships rather than causality.

A limitation of the present study is the comparatively lower participation of female informants due to sociocultural manacles in the study region, which may have influenced the representation of household-based ethnobotanical knowledge traditionally maintained by women.

Although this study provides a comprehensive ethnobotanical appraisal from the Orakzai district, several limitations should be acknowledged. Female participation was comparatively limited because of sociocultural restrictions and accessibility constraints in tribal communities, which may have influenced the representation of household-based traditional knowledge. In addition, ethnobotanical use reports were primarily based on participant knowledge and local practices and therefore do not represent pharmacologically validated therapeutic evidence. A local conservation assessment is context-specific and integrates conservation principles, unlike standardized conservation classifications. There may also have been limitations due to terrain challenges and seasonal accessibility to the region, which may have prevented a systematic representation of plant diversity. This study, however, provides valuable baseline information on ethnobotany and conservation in an understudied region.

5. Conclusion

The purpose of this study is to explore tribal traditions associated with 123 wild plant species used in ethnomedicine as well as local livelihood practices in the Orakzai district of northwestern Pakistan. A significant ethnobotanical knowledge of indigenous origin exists in the district despite its comparatively underexplored status in scientific research.

Traditional medicinal knowledge has been preserved by elder community members, herbal practitioners, and resource-dependent households. However, a low participation rate indicates that intergenerational transmission of knowledge is diminishing among the younger generation.

Numerous multifunctional and medicinally important species were found to be threatened by local harvesting pressure and habitat loss. Accordingly, broader conservation assessments may not always reflect local conservation problems accurately.

This study emphasizes the necessity of comprehensive ethnobotanical documentation, sustainable harvesting practices, and community-based conservation measures in preserving wild plant vegetation and traditional knowledge. To promote phytochemical and pharmacological research, future studies should prioritize locally vulnerable species for ecological monitoring while also assessing culturally significant medicinal plants for further investigation.

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6. Declarations

Funding: This study did not receive funding.

Conflict of interest: The authors declare no competing financial interests.

Data availability: The datasets supporting the conclusions of this study are included in this manuscript. Additional raw data analyzed during the study are available from the corresponding author upon reasonable request.

Author contributions: MZ designed the study, conducted fieldwork, collected and analyzed the data, and drafted the manuscript. MA supervised the study and contributed to the research design, interpretation of results, and manuscript revision. MHH, WM, and SB reviewed and edited the manuscript. All the authors have read and agreed on the approval of the final manuscript.

7. References

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