



Phytotherapeutic and ethnobotanical relevance of weed flora: A quantitative assessment from the cultivated fields of District Bajaur, Pakistan

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Research

Abstract

Background: Agricultural weeds are widely used in traditional medicine due to their rich bioactive compounds that help treat a diverse range of diseases. This study was carried out to comprehensively document the ethnobotanical knowledge related to the weed flora associated with the agricultural landscapes of District Bajaur. This study provides the first systematic evaluation of the phytotherapeutic potential of weeds, offering a foundational baseline for subsequent pharmacological and ethnomedicinal research.

Methods: Ethnobotanical data were gathered from local inhabitants through semi-structured questionnaires and interviews. Quantitative ethnobotanical indices, namely relative frequency of citation (RFC), use value (UV), and fidelity level (FL), were employed to assess the medicinal importance of each species and to elucidate their cultural and therapeutic relevance.

Results: A total of 47 weed species belonging to 23 families were documented, with Poaceae being reported as the most dominant family (9 species). Among these, 36 species (77%) were dicotyledons and 11 species (23%) were monocotyledons, with annual weeds representing the majority (66%). Ethnobotanical information was obtained from 116 respondents (21 females and 95 males). The whole plant was the most commonly utilized part (70%). *Silene conoidea* L. exhibited the highest UV (0.89), while *Plantago lanceolata* recorded the lowest (0.51). The highest RFC was observed for *Mentha longifolia* (0.76), whereas *Buglossoides arvensis* showed the lowest (0.21). Similarly, *Mentha longifolia* demonstrated the highest FL (95.45%) used for the treatment of digestive disorders, dysentery, vomiting and abdominal pain, whereas *Phalaris minor* has the lowest FL (45.65%) used for cough and dysentery.

Conclusions: The study confirms that local communities in Bajaur rely on medicinal weeds for primary healthcare needs. The comprehensive checklist of agriculture fields associated with weeds provides valuable baseline data for future research. Effective conservation measures are needed to preserve these important phytotherapeutic resources for sustainable use.

Keywords: Ethnobotany; Ethnomedicinal Uses, Quantitative indices, Weed plants, Tib-e-Unani

Background

Ethnobotanical studies investigate the complex relationship between indigenous communities and their surrounding ecosystems, emphasizing cultural traditions, resource utilization, and the preservation of traditional knowledge (Amjad *et al.* 2020). For centuries, plants have been indispensable in treating a wide range of human ailments, serving as an accessible and reliable source of therapy (Ahmad *et al.* 2016). The therapeutic effectiveness of medicinal plants lies in their phytochemical constituents, which exert physiological effects on the human body and contribute to their broad pharmacological significance (Haq *et al.* 2022). This ethnomedicinal wisdom, preserved and transmitted across generations, continues to play a pivotal role in the primary healthcare systems, particularly among rural communities with limited or no access to modern medicine (Iftikhar *et al.* 2019; Sher *et al.* 2023). Weed flora represent an important component of traditional knowledge, providing remedies for a variety of diseases while also serving as fodder, food, and fuel. Despite being considered agricultural nuisances, these species embody cultural resilience and ecological value. Therefore, they warrant scientific documentation, conservation, and pharmacological exploration to ensure their sustainable utilization for future generations (Ali *et al.* 2017).

Plants represent the cornerstone of life on Earth and are among the most crucial natural resources for human survival (Murad *et al.* 2013). Their diversity and medicinal potential are shaped by ecological conditions, including soil structure and conservation practices. Many wild plant species are recognized for their bioactive compounds, which contribute to the well-being of communities worldwide (Irfan *et al.* 2018; Musa *et al.* 2022). Globally, around 80% of developing nations and 50% of industrialized countries rely on herbal medicines for healthcare (Bodeker and Kronenberg, 2002). In Pakistan, over 80% of the population, particularly those residing in rural areas, relies on traditional herbal remedies as a primary source of medicine (Ibrar *et al.*, 2007). However, rapid urbanization, lifestyle changes, and modern healthcare facilities have led to a gradual decline in traditional plant knowledge (Jan *et al.* 2021). Although Pakistan harbors approximately 6000 plant species, only 600-700 are documented as medicinally important (Irfan *et al.* 2023).

Traditional healing practices reflect a collective knowledge system that integrates cultural wisdom, ideas, and experiences to enhance overall health and combat disease (Younis *et al.* 2018; Rahman *et al.* 2023; Haq *et al.* 2023; Ali *et al.* 2025). These practices remain vital for holistic physical and mental well-being (Irfan *et al.* 2017; Ullah *et al.* 2022). Nevertheless, their utilization is now largely confined to rural settings (Ali *et al.* 2023; Gul *et al.* 2025), as modernized health services in urban areas attract increasing reliance (Awan and Murtaza, 2013).

Recent evidence highlights that many agricultural weeds, often dismissed as unwanted flora, are rich in bioactive secondary metabolites with remarkable medicinal potential. Numerous studies have confirmed their ethnomedicinal applications across diverse regions, suggesting a promising role in future drug discovery (Padhan and Panda, 2015). In addition to their therapeutic significance, weeds also contribute as sources of food, fodder, and ecological services, strengthening rural livelihoods. However, despite their multipurpose value, the ethnobotanical knowledge of medicinal weeds remains under-documented in many regions of Pakistan.

Although ethnobotanical studies are essential, the medicinal and multipurpose weed flora of District Bajaur remains largely underexplored, with limited quantitative assessments and insufficiently documented traditional knowledge. Commonly regarded as agricultural nuisances, these weeds possess substantial therapeutic, nutritional, and ecological value. Located in the northwestern region of Pakistan within the Hindu Kush mountain range, Bajaur hosts diverse microhabitats supporting plant life ranging from hydrophytes to xerophytes, making it an ideal setting for studying plant-human interactions.

This study addresses existing knowledge gaps by providing the first comprehensive documentation of ethnomedicinal practices related to weed species in agricultural fields of the region, with particular emphasis on species-specific uses, conservation priorities, and pharmacological potential. The objectives of the study were to (i) document indigenous ethnobotanical knowledge concerning medicinal applications, and (ii) generate baseline data to support future research in ethnobotany, ethnopharmacology, plant ecology, and conservation. Additionally, the study aims to enhance community awareness regarding the conservation of medicinal weed flora and to collect and preserve representative specimens for accurate identification and future reference.

Materials and Methods

Study area description

Bajaur, a tribal district in the Khyber Pakhtunkhwa province of Pakistan, encompasses an area of 1,290 km² and lies at an elevation of 1,126 meters above sea level, between 30°-34° and 34°-58° latitude and 71°-11° and 71°-30° longitude. Geographically, Bajaur lies in the northwestern part of Pakistan, bordering Afghanistan along the Durand Line, with a 52 km boundary adjoining Kunar Province—an area of considerable strategic significance for Pakistan (Fig. 1). Climatically, Bajaur receives an average annual rainfall of about 800 mm, which sustains its predominantly agricultural landscape (Haq *et al.* 2022). Out of the total land area, 75,350 hectares are cultivated, while 53,685 hectares remain uncultivated. Of the total area, approximately 54,000 hectares are rain-fed, while 14,061 hectares are cultivated under irrigation. Additionally, forests cover nearly 87,169 acres, enhancing the ecological significance of the area.

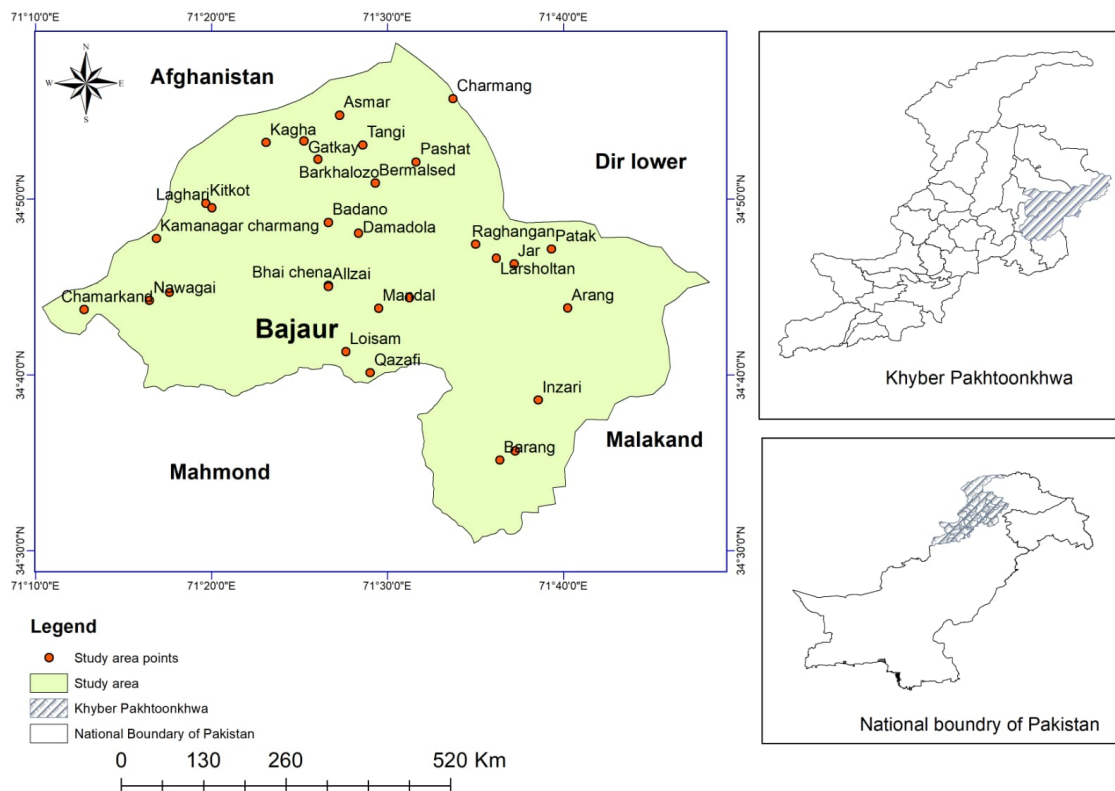


Figure 1. Study area map

Collection, identification and preservation of weeds

The collected plant species were dried, pressed, and mounted on standard herbarium sheets following the prescribed protocols (Bridson and Forman, 1998; Ali, 2011). For long-term preservation, samples were treated with 70% ethanol and 0.1 g of mercuric chloride. Taxonomic identification was performed using the published works of Nasir and Ali (1972-1992) and the Flora of Pakistan (Ali and Qaiser, 1993-2023). Properly preserved voucher specimens were subsequently deposited in the Herbarium Hazara University, Mansehra, Pakistan (HUP) for future reference.

Ethnobotanical profiling of the information

Ethnobotanical data were collected by using semi-structured questionnaires, personal interviews, and group discussions with local inhabitants, particularly traditional healers (hakims) and elderly community members (Mir *et al.* 2022; Haq *et al.* 2023). Information was documented on multiple aspects of weed species, including habitat, growth habit, vernacular names, plant parts utilized, and associated ethnobotanical attributes.

Quantitative analysis of ethnobotanical data

Quantitative ethnobotanical analysis facilitates the identification of plant species with potential pharmacological relevance. In the present study, the therapeutic significance of each plant species was determined by using established indices (RFC, UV, and FL).

Relative frequency of citation (RFC)

The relative frequency of citation (RFC) was employed to evaluate the local significance of each plant species, and its value was calculated by using the standard formula (Vitalini *et al.* 2013; Haq *et al.* 2022).

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

Here, *FC* denotes the number of informants who cited the use of a particular weed species, while *N* represents the total number of informants interviewed. The RFC thus reflects the relative cultural significance of each species, independent of specific use categories.

Use value (UV)

The use value (UV) was applied to illustrate the relative significance of each plant taxon, and its calculation followed the formula proposed by Phillips and Gentry (1993).

$$UV = \frac{U_i}{N}$$

In this formula, *U_i* represents the total use reports by each informant for a given plant species, while *N* represents the total number of informants interviewed. A higher UV value reflects a greater ethnomedicinal significance of the species.

Fidelity level (FL)

The fidelity level (FL) was calculated to determine the weed species most frequently preferred for treating specific ailments, using the formula proposed by Friedman *et al.* (1986).

$$FL = \frac{I_p}{I_u} \times 100$$

In this formula, *I_p* denotes the number of informants citing the use of a plant species for a particular ailment, while *I_u* denotes the total number of informants reporting any use of that species. A higher FL value specifies a stronger consensus about the effectiveness of a plant species for a particular condition.

Results and Discussion**Demographic characteristics of the study area**

A total of 116 local informants participated and were interviewed, including 95 males (81.90%) and 21 females (18.10%). The majority of male respondents were farmers, whereas most female respondents were housewives. Female participation was limited due to cultural restrictions in tribal communities that discourage interaction with outsiders and restrict women's mobility in public spaces. Age-wise distribution revealed that ethnomedicinal knowledge was concentrated among older individuals. The majority were between 46-60 years (53.45%), followed by 31-45 years (25.86%), above 61 years (12.93%), and 20-30 years (7.76%), with no informants below 20 years (Table 1). This indicates that older community members hold greater knowledge of medicinal plants, while younger generations show declining interest due to the growing preference for allopathic medicine. Nearly 90% of respondents noted the lack of enthusiasm among youth for preserving traditional practices.

Among the respondents, six male traditional health practitioners (Hakims) above 40 years of age were identified, representing 5.17% of the sample. These Hakims, regarded as custodians of ancestral knowledge, play a significant role in local healthcare. Their practices align with the broader Pakistani context, where around 50,000 registered healers practice Tibb-e-Unani, serving approximately 60% of rural populations (Wangchuk and Tobgay, 2015; Irfan *et al.* 2018; Ullah *et al.* 2021). However, many practitioners remain reluctant to share their knowledge, guarding it as family secrets or disclosing it only for compensation.

Educationally, 93.96% of informants were uneducated, while only small proportions had completed primary education (3.45%) or middle education (2.59%) of schooling. None reported higher education. This highlights that reliance on ethnomedicine is most prominent among less educated and rural communities. A possible explanation is that illiterate individuals maintain closer and more frequent interaction with medicinal plants, thereby possessing greater familiarity with their traditional uses. In contrast, educated individuals show comparatively less interest in traditional medicine, largely due to their greater reliance on and exposure to modern healthcare systems (Ahmad *et al.* 2017). Comparable findings were also reported by Kayani *et al.* (2014) from Gallies, Abbottabad, Northern Pakistan. The current findings suggest that traditional

knowledge in Bajaur is primarily preserved by elderly, uneducated men and Hakims. The lack of youth interest and restricted female involvement pose significant challenges to the intergenerational transfer of this valuable ethnobotanical heritage.

Table 1. Demographic information of the study area

| Parameters | Categories | Number of participants | % age of participants |
|--|--------------------------------------|------------------------|-----------------------|
| Participant categories | Local Health Practitioners | 6 | 5.17 |
| | Local Peoples | 110 | 94.83 |
| Gender | Male | 95 | 81.9 |
| | Female | 21 | 18.1 |
| Age | Less than 20 years | 0 | 0 |
| | 21 - 30 years | 9 | 7.76 |
| | 31 - 45 years | 30 | 25.86 |
| | 46 - 60 years | 62 | 53.45 |
| | above 60 years | 15 | 12.93 |
| Education | Uneducated | 109 | 93.96 |
| | Primary level (1-4 yrs) | 4 | 3.45 |
| | Middle level (5-8 yrs) | 3 | 2.59 |
| | Secondary level (9-10 yrs) | 0 | 0 |
| | Higher Secondary level (11-12 years) | 0 | 0 |
| | Bachelor's education (14 yrs) | 0 | 0 |
| | Master's education (16 yrs) | 0 | 0 |
| Total Experience of the Traditional Health Practitioners | < 1 year | 0 | 0 |
| | 1 to 4 years | 1 | 16.67 |
| | 4 to 8 years | 3 | 50 |
| | > 8 years | 2 | 33.33 |

Ethnobotanical diversity and ecological significance of weed flora

The current study recorded 47 weed species that belong to 45 genera and 23 families from cultivated fields in District Bajaur, Khyber Pakhtunkhwa, Pakistan. Poaceae was found the most dominant family with nine species which was followed by Brassicaceae (seven species), Asteraceae (five species), and Fabaceae (three species), whereas several families were represented only by one or two species (Table 2; Fig. 2). With respect to the biological spectrum, dicotyledons (36 species) predominated over monocotyledons (11 species). Life-form analysis further indicated that annuals constituted the majority (39 species), while perennials and biennials were represented by six and two species, respectively. The family Poaceae contributing species were *Acrache racemosa*, *Avena fatua*, *Bromus lanceolatus*, *Cynodon dactylon*, *Hordeum murinum*, *Lolium temulatum*, *Phalaris minor*, *Poa annua*, and *Rostraria cristata*. The weed flora of the area reflects its distinctive geography and climatic conditions, resulting in a unique assemblage of species adapted to temperate to sub-temperate dry environments. The floristic composition supports diverse ethnobotanical uses, as local communities utilize weeds for medicinal, fodder, and household purposes (Haq and Badshah, 2021). Such interactions highlight the ethnobotanical significance of weed flora in sustaining traditional knowledge and livelihoods. The dominance of Poaceae is particularly significant given its nutritional and pharmacological value, as members of this family exhibit antioxidant, anti-inflammatory, antimicrobial, and diuretic properties. Bhatt *et al.* (2021) conducted a study on weed ethnomedicine at Kanchanpur district of western Nepal and reported Poaceae as the dominant family. Similar results were also reported by Cao *et al.* (2020) from Jiangcheng County, Southwest China. However, Jalali *et al.* (2024) reported Brassicaceae as the dominant family from Semnan province, Iran. Species of Brassicaceae, characterized by their glucosinolate content, are traditionally employed in the management of respiratory and digestive disorders, whereas members of Asteraceae are recognized for their antipyretic and analgesic activities. Families with fewer representatives, such as Amaranthaceae and Apiaceae, though limited in number, still contribute valuable ethnomedicinal resources, reflecting ecological diversity and cultural heritage. These widely distributed plant families and their excessive medicinal usage might be associated with their wide range of biologically active constituents (Tugume *et al.* 2010).

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Table 2. Quantitative ethnobotanical description of weed plants of the agricultural fields of District Bajaur

| Species name/ Voucher No. | Family | Habit | Plant parts | Ethnobotanical Usages | Form of Uses | Plant Condition (Fresh/Dry) | Flowering period | Locality (Tehsil) | FC | RFC | UR | UV | FL |
|---|---------------|-------|-------------|---|------------------------------------|-----------------------------|-------------------|---|----|-----|----|-----|------|
| <i>Acrachne racemosa</i> (Heye) Ohwi. ZS.BOT.HUP.01 | Poaceae | AH | WP | Used as fodder for grazing animals | Forage | F | May to August | Slarzai, Khar, Utman Khel and Nawagai | 40 | 0.3 | 26 | 0.7 | 43.8 |
| <i>Lysimachia arvensis</i> (L.) U. Manns & Anderb. ZS.BOT.HUP.02 | Primulaceae | AH | WP | Used to treat liver disorders, as an anti-inflammatory, and as fodder for cattle | Forage and dried form | F&D | March to May | Slarzai, Utman Khel, Mamond and Nawagai | 70 | 0.6 | 48 | 0.7 | 88.6 |
| <i>Avena fatua</i> L. ZS.BOT.HUP.03 | Poaceae | AH | LV, SM | Used for constipation, as a stimulant, and in dried form as fuel and fodder | Dried form and forage | F&D | March to June | Throughout Bajaur | 51 | 0.4 | 24 | 0.5 | 68 |
| <i>Bromus lanceolatus</i> ZS.BOT.HUP.04 | Poaceae | AH | SM, LV | Serves as fodder for grazing animals | Forage and dried form | F&D | April to July | Utman Khel, Mamond and Nawagai | 28 | 0.2 | 18 | 0.6 | 41.1 |
| <i>Buglossoides arvensis</i> (L.) I. M.Johnst. ZS.BOT.HUP.05 | Boraginaceae | AH | WP | Used as a diuretic and as fodder for cattle | Infusion and forage | F&D | March to April | Throughout Bajaur | 24 | 0.2 | 16 | 0.7 | 60 |
| <i>Calendula arvensis</i> (Vaill.) L. ZS.BOT.HUP.06 | Asteraceae | AH | WP | Has antispasmodic and diaphoretic properties and is also used as fodder | Juice extract and forage | F | March to April | Slarzai, Utman Khel, Mamond and Nawagai | 63 | 0.5 | 54 | 0.9 | 90 |
| <i>Calepina irregularis</i> (Asso) Thell. ZS.BOT.HUP.07 | Brassicaceae | AH | WP | Use as fodder for cattle and a fuel in dry form | Forage and dried form | F&D | March to May | Slarzai, Mamond and Nawagai | 49 | 0.4 | 26 | 0.5 | 49 |
| <i>Capsella bursa-pastoris</i> (L.) Medik. ZS.BOT.HUP.08 | Brassicaceae | BH | WP | Used to treat headache, hematuria, hematemesis, urinary infection and also used as fodder for cattle and fuel | Cooked food, forage and dried form | F&D | April to May | Utman Khel, Mamond and Nawagai | 50 | 0.4 | 35 | 0.7 | 71.2 |
| <i>Carthamus oxyacanthus</i> M. Bieb ZS.BOT.HUP.10 | Asteraceae | AH | WP | Use as fuel in dry form | Dried form | D | August to October | Salarzai, Utman Khel, and Nawagai, | 56 | 0.5 | 40 | 0.7 | 41.1 |
| <i>Chenopodium album</i> L. ZS.BOT.HUP.11 | Amaranthaceae | AH | LV | For the treatment of abdominal pain, stomach ailments, and as a vegetable food | Cooked food | F&D | March to May | Throughout Bajaur | 64 | 0.6 | 41 | 0.6 | 78.1 |

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| <i>Convolvulus arvensis</i> L. ZS.BOT.HUP.12 | Convolvulaceae | AH | WP | Used to treat constipation, increase milk production, cure stomach disorders, control dandruff, treat dysentery, and also as fodder | Juice extract and forage | F | March to July | Throughout Bajaur | 79 | 0.7 | 61 | 0.8 | 94.9 |
| <i>Cynodon dactylon</i> (L.) Pers. ZS.BOT.HUP.13 | Poaceae | PH | WP | Used for respiratory disorders, blood purification, and also as an ornamental plant, fuel and fodder | Forage and dried form | F&D | April to September | Throughout Bajaur | 86 | 0.7 | 61 | 0.7 | 84.9 |
| <i>Descurainia sophia</i> (L.) Webb ex Prantl. ZS.BOT.HUP.14 | Brassicaceae | AH | WP | Acts as a mosquito repellent and serves as fuel | Forage and dried form | F&D | April to July | Utman Khel, Mamond and Nawagai | 47 | 0.4 | 38 | 0.8 | 62.9 |
| <i>Erodium ciconium</i> L. ZS.BOT.HUP.15 | Geraniaceae | AH | WP | Used as fuel and fodder | Forage and dried form | F&D | April to May | Salarzai, Utman Khel, and Mamond | 29 | 0.3 | 19 | 0.7 | 57.3 |
| <i>Euphorbia helioscopia</i> L. ZS.BOT.HUP.16 | Euphorbiaceae | AH | LX | Poisonous causes swelling, helps treat athlete's foot, and is also used as fuel | Dried form and Juice | F&D | April to July | Throughout Bajaur | 65 | 0.6 | 57 | 0.9 | 51.1 |
| <i>Fumaria indica</i> (Hauskn.) Pugsley ZS.BOT.HUP.17 | Fumariaceae | AH | ST, LV | Used as a blood purifier, for athlete's foot, to reduce body heat, to control acne, and as fodder for cattle | Decoction and forage | D | April to June | Throughout Bajaur | 72 | 0.6 | 58 | 0.8 | 94.4 |
| <i>Hordeum murinum</i> L. ZS.BOT.HUP.18 | Poaceae | AH | ST, LV | Used as fodder | Dried form | F | May July | Throughout Bajaur | 73 | 0.6 | 60 | 0.8 | 49.7 |
| <i>Ixiolirion tataricum</i> (Pall.) Herb. ZS.BOT.HUP.19 | Ixioliraceae | AH | BLB | Utilized for gastric diseases and as a vegetable food | Juice | F | April to May | Salarzai, Khar, Mamond and Nawagai | 53 | 0.5 | 31 | 0.6 | 72.4 |
| <i>Lamium amplexicaule</i> L. ZS.BOT.HUP.20 | Lamiaceae | AH | WP | Acts as a stimulant, laxative, and is used as fodder for cattle | Dried form | F | March to May | Throughout Bajaur | 59 | 0.5 | 41 | 0.7 | 72.9 |
| <i>Lepidium didymum</i> L. ZS.BOT.HUP.21 | Brassicaceae | BH | WP | Used for itching, pimples, and as fodder for cattle | Cooked food and forage | F&D | March to September | Salarzai, Khar and Mamond | 67 | 0.6 | 46 | 0.9 | 59.7 |

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|---|--------------|----|-----------|--|-------------------------------------|-----|--------------------|--|----|-----|----|-----|------|
| <i>Lolium multiflorum</i> Lam. ZS.BOT.HUP.22 | Poaceae | AH | SM, LV | Used as fodder for cattle | Forage and Dried form | F&D | April- August | Salarzai, Utman Khel, Mamond and Nawagai | 62 | 0.5 | 51 | 0.8 | 57.7 |
| <i>Malva neglecta</i> Wallr. ZS.BOT.HUP.23 | Malvaceae | AH | WP | Used to treat kidney stones, flatulence, and also used as a salad with food, and as fodder for cattle | Extract and cooked food | F&D | May to October | Throughout Bajaur | 45 | 0.4 | 31 | 0.7 | 73.2 |
| <i>Medicago polymorpha</i> L. ZS.BOT.HUP.24 | Fabaceae | AH | WP | Used as a vegetable and as fodder for cattle | Cooked food and dried form | F&D | March to April | Throughout Bajaur | 74 | 0.6 | 58 | 0.8 | 68.3 |
| <i>Medicago sativa</i> L. ZS.BOT.HUP.43 | Fabaceae | AH | WP | Used as a vegetable food and fodder for cattle | Cooked and dried forms | F | March to May | Throughout Bajaur | 83 | 0.7 | 62 | 0.8 | 57.3 |
| <i>Mentha longifolia</i> (L.) Huds. ZS.BOT.HUP.25 | Lamiaceae | PH | LV, ST | Used to treat vomiting, dysentery, digestive problems, abdominal pain, and is eaten as a salad with food | Powder and dried form | D | May to November | Salarzai, Khar, Utman Khel and Mamond | 88 | 0.8 | 76 | 0.8 | 95.5 |
| <i>Moraea sisyrinchium</i> Ker. Gawl. ZS.BOT.HUP.26 | Iridaceae | AH | LV | Used to treat parasitic worms and gastrointestinal nematodes | Dried form | D | March to May | Throughout Bajaur | 68 | 0.6 | 55 | 0.8 | 89.7 |
| <i>Neslia paniculata</i> (L.) Desv. ZS.BOT.HUP.27 | Brassicaceae | AH | WP | Used to treat chest pain and as a fodder for cattle | Powder and dried form | F&D | March to April | Throughout Bajaur | 66 | 0.6 | 47 | 0.7 | 62.3 |
| <i>Oxalis corniculata</i> L. ZS.BOT.HUP.28 | Oxalidaceae | PH | WP | Used to stop bleeding, improve digestion, treat stomach troubles, and also used as fodder for cattle | Forage and Dried form | F&D | April to June | Throughout Bajaur | 81 | 0.7 | 66 | 0.8 | 93.8 |
| <i>Papaver dubium</i> L. ZS.BOT.HUP.29 | Papaveraceae | AH | WP | Use for ornamental purposes and as fodder for cattle | Forage | F | March to April | Throughout Bajaur | 54 | 0.5 | 38 | 0.7 | 57.7 |
| <i>Phalaris minor</i> Retz. ZS.BOT.HUP.30 | Poaceae | AH | WP | Used to treat cough, dysentery, and also as fodder for cattle | Forage | F | March to May | Throughout Bajaur | 46 | 0.4 | 33 | 0.7 | 45.7 |

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| <i>Plantago lanceolata</i> L. ZS.BOT.HUP.31 | Plantaginaceae | PH | WP | Employed for constipation, dysentery, as an expectorant, and used as fodder for cattle | Paste and dried form | F&D | March to June | Salarzai, Utman Khel and Nawagai | 57 | 0.5 | 29 | 0.5 | 50.9 |
| <i>Poa annua</i> L. ZS.BOT.HUP.32 | Poaceae | AH | WP | Used to improve digestion, for cleaning food utensils, and as fodder for cattle | Forage | F | April to October | Throughout Bajaur | 76 | 0.7 | 55 | 0.7 | 93.4 |
| <i>Phonus lanatus</i> (L.) Hill ZS.BOT.HUP.09 | Asteraceae | AH | WP | Used as food, fuel and fodder | Dried form and forage | F&D | May to August | Salarzai, Utman Khel, and Mamond | 37 | 0.3 | 23 | 0.6 | 53.3 |
| <i>Ranunculus arvensis</i> L. ZS.BOT.HUP.33 | Ranunculaceae | AH | WP | Serves as fodder for grazing animals | Forage | F | May to July | Utman Khel, Khar, Mamond | 29 | 0.3 | 18 | 0.6 | 51.1 |
| <i>Ranunculus muricatus</i> L. ZS.BOT.HUP.34 | Ranunculaceae | AH | WP | Employed as a laxative, and used as fodder for cattle | Forage | F | March to April | Khar, Utman Khel, and Mamond | 26 | 0.2 | 15 | 0.6 | 72.1 |
| <i>Rostraria cristata</i> (L.) Tzvelev. ZS.BOT.HUP.35 | Poaceae | AH | WP | Serves as fodder in forage form for cattle | Dried form and forage | F&D | April to July | Throughout Bajaur | 61 | 0.5 | 42 | 0.7 | 48.8 |
| <i>Scandix pecten-veneris</i> L. ZS.BOT.HUP.36 | Apiaceae | AH | WP | Used to treat urinary infections, and is used as vegetables and as fodder for cattle | Cooked food and dried forms | F&D | March to May | Salarzai, Khar, Utman Khel, and Mamond | 73 | 0.6 | 57 | 0.8 | 90.4 |
| <i>Silene conoidea</i> L. ZS.BOT.HUP.37 | Caryophyllaceae | AH | WP | Used to treat constipation, as a vegetable food, and fodder for cattle | Cooked food and dried form | F&D | March to April | Salarzai, Utman Khel, Mamond and Nawagai | 82 | 0.7 | 73 | 0.9 | 95.1 |
| <i>Sisymbrium irio</i> L. ZS.BOT.HUP.38 | Brassicaceae | AH | Seeds | Used as a body coolant, reduces inflammation, and also as fodder for cattle | Powder and forage | F&D | March to May | Throughout Bajaur | 48 | 0.4 | 28 | 0.6 | 93.8 |
| <i>Sonchus oleraceus</i> L. ZS.BOT.HUP.39 | Asteraceae | AH | WP | Promotes muscle strength, milk production, and serves as fodder for cattle | Mixture and dried forms | F&D | April to May | Throughout Bajaur | 76 | 0.7 | 61 | 0.8 | 57.3 |
| <i>Stellaria media</i> (L.) Vill. ZS.BOT.HUP.40 | Caryophyllaceae | AH | ST, LV | Used to treat ringworm, swelling, and as a vegetable food and fodder for cattle | Powder, cooked food and forage | F&D | April to May | Salarzai, Khar, Utman Khel, and Mamond | 80 | 0.7 | 42 | 0.5 | 68.8 |

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|---|----------------|----|--------|--|----------------------------|-----|------------------|--|----|-----|----|-----|------|
| <i>Strigosella africana</i> (L.) Botsch. ZS.BOT.HUP.41 | Brassicaceae | AH | WP | Serves as fuel and fodder | Dried form and forage | F&D | April to May | Throughout Bajaur | 44 | 0.4 | 30 | 0.7 | 42.2 |
| <i>Taraxacum officinale</i> Weber ex F.H.Wigg. ZS.BOT.HUP.42 | Asteraceae | PH | WP | Used to treat asthma, cough, fever, bile and liver infections, and also as fodder for cattle | Cooked food and dried form | F&D | April to June | Throughout Bajaur | 84 | 0.7 | 67 | 0.8 | 51.2 |
| <i>Valerianella leiocarpa</i> (K.Koch) Kuntze ZS.BOT.HUP.44 | Caprifoliaceae | AH | WP | Serves as fodder for grazing animals | Dried forms | F | April to May | Salarzai, Utman Khel, and Mamond | 59 | 0.5 | 37 | 0.6 | 41.2 |
| <i>Verbena officinalis</i> L. ZS.BOT.HUP.45 | Verbenaceae | PH | ST, LV | Used for fever and acne treatment, and also as fodder for cattle and as fuel | Cooked food and dried form | F&D | April to October | Throughout Bajaur | 46 | 0.4 | 32 | 0.7 | 77.8 |
| <i>Veronica persica</i> Poir. ZS.BOT.HUP.46 | Plantaginaceae | AH | FT | Used to treat stomach and kidney problems and serves as fodder for cattle | Dried forms | F | March to April | Throughout Bajaur | 85 | 0.7 | 69 | 0.8 | 92.9 |
| <i>Vicia sativa</i> L. ZS.BOT.HUP.47 | Fabaceae | AH | WP | Act as an emollient, enhances taste, and serves as fodder for cattle | Mixture and dried forms | F | March to April | Salarzai, Utman Khel, Mamond and Nawagai | 69 | 0.6 | 54 | 0.8 | 72.9 |

Key: AH - Annual herb; BH - Biennial herb; PH - Perennial herb; WP - Whole plant; LV - Leaves; SM - Stem; FT - Fruit; BL - Bulb; LX - Latex; ST - Shoot; SD - Seed, FC - Frequency of Citation; RFC - Relative Frequency of Citation; UR - Use Report; UV - Use Value; FL - Fidelity Level.

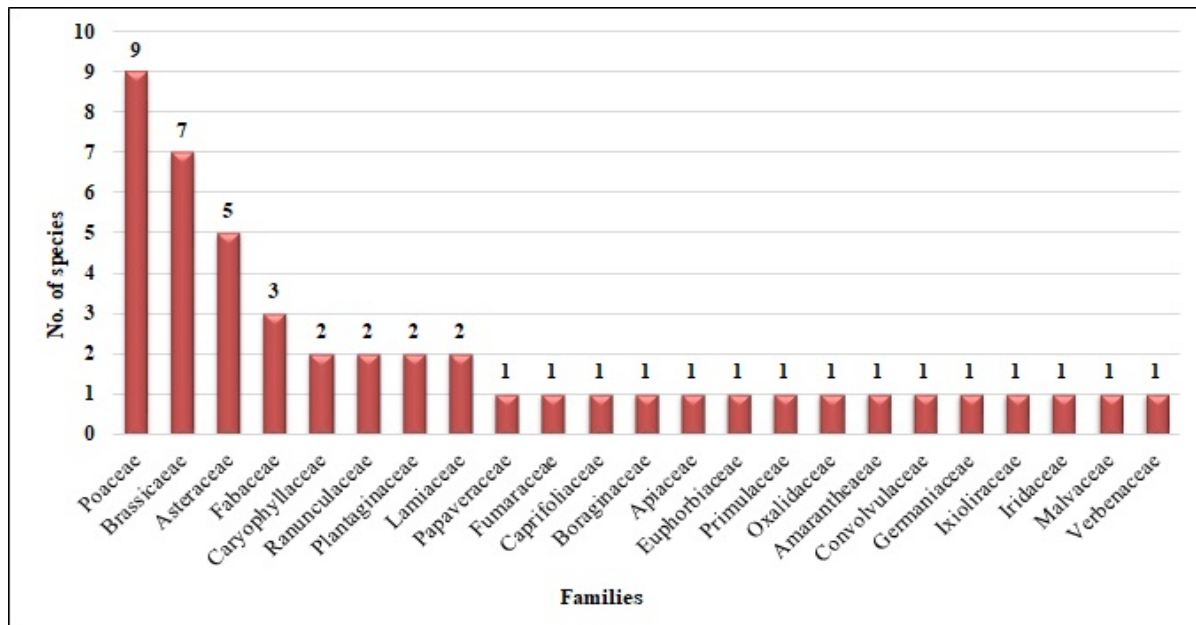


Figure 2. Family-wise distribution of the species of weed plants

Ethnobotanical uses, preparation modes, and multipurpose significance of weed flora

The weed flora of District Bajaur demonstrates considerable ethnobotanical and phytotherapeutic value, in addition to their ecological roles in farming systems. Many species are used in traditional medicine, as food, fodder, or fuel, reflecting the close relationship between local communities and their surrounding biodiversity. The ethnobotanical survey of the study area documented 47 plant species, which were used for various purposes, with medicinal applications being the most dominant, as 32 species (68.1%) were employed in treating different human ailments. Fodder use ranked second with 11 species (23.4%), reflecting the agro-pastoral lifestyle of local communities and the significance of livestock in their livelihoods. The majority of these fodder species were highly palatable and preferentially consumed by livestock, particularly sheep and goats, during the spring and summer seasons when fresh herbage is abundant. Farmers reported that tender shoots and young leaves were especially consumed eagerly by livestock, contributing to improved milk production and animal health (Haq and Badshah, 2023). In comparison, only 2 species (4.2%) were reported as vegetables, while a single species (2.1%) each was utilized for food and fuel (Fig. 3). The predominance of medicinal plants underscores the reliance of local communities on traditional herbal remedies, largely attributable to limited access to modern healthcare facilities—a pattern similarly reported in other areas of Pakistan and neighboring countries.

Several medicinal plants documented in this study are widely used in traditional healthcare practices for a variety of ailments (Table 2). *Anagallis arvensis* is commonly employed for liver disorders and inflammation, while *Fumaria indica* and *Cynodon dactylon* act as blood purifiers, particularly for skin and respiratory issues. *Chenopodium album* and *Oxalis corniculata* serve both as vegetables and as remedies for digestive disorders, whereas *Taraxacum officinale* is traditionally used to treat asthma, fever, cough, and liver infections. *Mentha longifolia* is a multipurpose species, consumed in salads and used to manage gastrointestinal problems. It is highly valued throughout South and Central Asia for its carminative, antispasmodic, antimicrobial, and anti-inflammatory properties. Traditionally, its leaves are used to treat gastrointestinal ailments, colds, and respiratory congestion. Phytochemical studies have identified significant amounts of menthol, flavonoids, and phenolic acids, which support its medicinal applications (Eftekhari *et al.* 2021). *Silene conoidea* is widely used for its diuretic, antimicrobial, and anti-inflammatory properties. Local communities prepare leaf decoctions to treat skin infections, urinary disorders, and wounds, with saponins and triterpenoids likely contributing to their therapeutic potential (Laldingliani *et al.* 2022). Similarly, *Verbena officinalis*, *Plantago lanceolata*, and *Convolvulus arvensis* are used for fever, constipation, and gastrointestinal complaints. *Verbena officinalis* is highly valued as a nervine tonic and for treating respiratory infections, fever, gastrointestinal disorders, and wounds. Its anti-inflammatory, anxiolytic, and hepatoprotective effects are attributed to compounds such as verbenalin and iridoid glycosides (Mohini *et al.* 2022).

Plantago lanceolata is recognized for its anti-inflammatory, wound-healing, expectorant, and antimicrobial properties. The leaves are traditionally used for cough, sore throat, skin irritation, and diarrhea, with efficacy linked to aucubin, acteoside, mucilage, and flavonoids (Abate *et al.* 2022). Similarly, the *Convolvulus arvensis* is traditionally used for various ailments and

shows notable therapeutic activities due to its alkaloids, flavonoids, and resin glycosides (Selehi *et al.* 2020). Other important species include *Moraea sisyrinchium*, which is employed against gastrointestinal nematodes, and *Stellaria media*, used for ringworm and swellings. *Euphorbia helioscopia*, despite its toxicity, is applied externally for conditions such as athlete's foot, reflecting its broad therapeutic potential. The plant's latex and aerial parts are rich in diterpenoids, tannins, and phenolic compounds, which contribute to its antimicrobial, anticancer, and antioxidant activities (Benjamaa *et al.* 2022).

Most of the weed species recorded in this study serve as year-round fodder for livestock, including *Avena fatua*, *Bromus lanceolatus*, and *Vicia sativa*. Similar trends have been observed in other regions; for instance, in Ethiopia, *Avena fatua* and *Vicia sativa* are important sources of seasonal livestock feed. Rahman *et al.* (2022) emphasized the crucial role of local grasses and legumes as reliable, year-round fodder resources that support sustainable livestock production. In addition, certain species, such as *Calepina irregularis* and *Verbena officinalis*, are utilized as dried fuel, emphasizing their multipurpose value in rural households. This dual utility is consistent with observations from India and Morocco, where weed plants provide both energy and essential household resources (Rao *et al.* 2020; Ghanimi *et al.* 2022).

The relatively small number of species used as vegetables, food, or fuel may be attributed to the availability of alternative resources, cultural practices, or dietary preferences, a pattern also reported in Mediterranean and Southeast Asian ethnobotanical surveys. Conversely, the presence of multipurpose species demonstrates adaptive strategies by local communities to maximize plant utility. Such multifunctional use is widely recognized in ethnobotanical literature, where plants are valued for their medicinal, nutritional, and economic contributions (Luo *et al.* 2024). Ethnobotanical practices are largely centered on medicinal and fodder applications, underscoring the dependence on traditional healthcare systems and the vital role of livestock in local livelihoods. These weed plants have the potential to contribute to the local and regional economy if sustainably managed. The enlisted species can be commercially utilized for the production of essential oils, herbal teas, and natural health products, creating income opportunities for local communities. The study underscores the necessity of documenting these plant resources, promoting their conservation, and further exploring their pharmacological potential to ensure sustainable management and enhance community resilience.

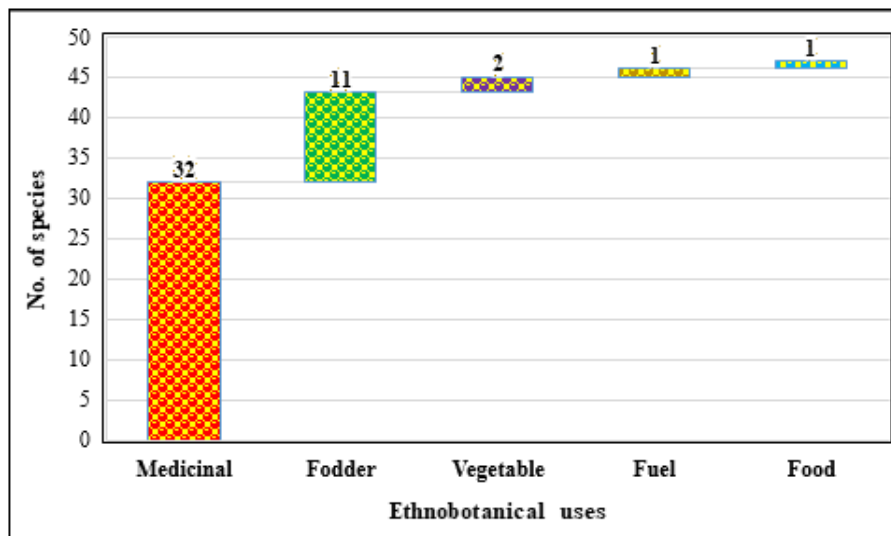


Figure 3. Ethnobotanical uses of weed plants

The present study highlights the diverse ethnomedicinal applications of weed flora, where local communities employ different plant parts, including seeds, fruits, stems, leaves, bulbs, latex, and whole plants. Among the reported plant parts, the entire plant was most frequently utilized (70%), followed by shoots and leaves (17%), and leaves alone (5%). Seeds, fruits, stems, bulbs, and latex were less commonly employed, each accounting for only 2% of the reported uses (Fig. 4). The preference for whole plants reflects their easy accessibility, cultural familiarity, and broader therapeutic potential due to the presence of multiple biologically active constituents. Similar reliance on whole plants has been reported from other ethnobotanical studies conducted in various areas of Pakistan (Ahmad *et al.* 2017; Wali *et al.* 2019). Bhatt *et al.* (2021) reported that leaves and the whole plant are widely used as medicine in the Kanchanpur district of Nepal. The ethnobotanical uses divulged that the majority of plant species were used as fodder for cattle, such as *Acrache racemosa*, *Bromus lanceolatus*, *Hordeum murinum*, while others had medicinal applications, such as treatment of gastrointestinal problems, respiratory disorders, fever, headache, skin diseases, kidney ailments, blood purification, and liver infections. Several species

were also utilized as food and vegetables, including *Medicago polymorpha*, *Chenopodium album*, *Medicago sativa*, *Mentha longifolia*, and *Malva neglecta*, whereas a few species, such as *Euphorbia helioscopia*, were reported to exhibit toxic effects. Additional uses included fuel, ornamental, body cooling, milk production, and taste enhancement.

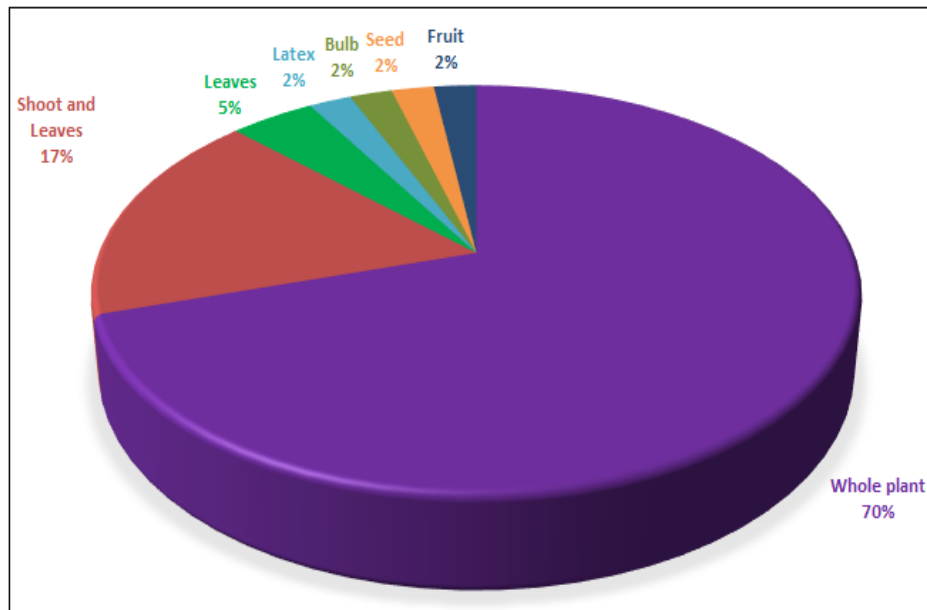


Figure 4. Ethnobotanical uses of plant parts

Remedies preparation methods

Traditional remedies were prepared using diverse methods, with forage being the most frequently reported practice (50 species), followed by dried form (31 species) and cooked food (9 species). Less common preparations included juice (4 species), powder (4 species), extract (3 species), paste (1 species), decoction (1 species), and infusion (1 species). Although these latter methods were rarely employed, they were generally used for treating specific health conditions despite requiring more effort in preparation and having a shorter shelf life (Fig. 5). Most remedies were prepared at the household level and employed to address common health issues, including gastrointestinal disorders, respiratory infections, and dermatological conditions, reflecting the community’s reliance on simple, affordable, and readily accessible plant-based treatments.

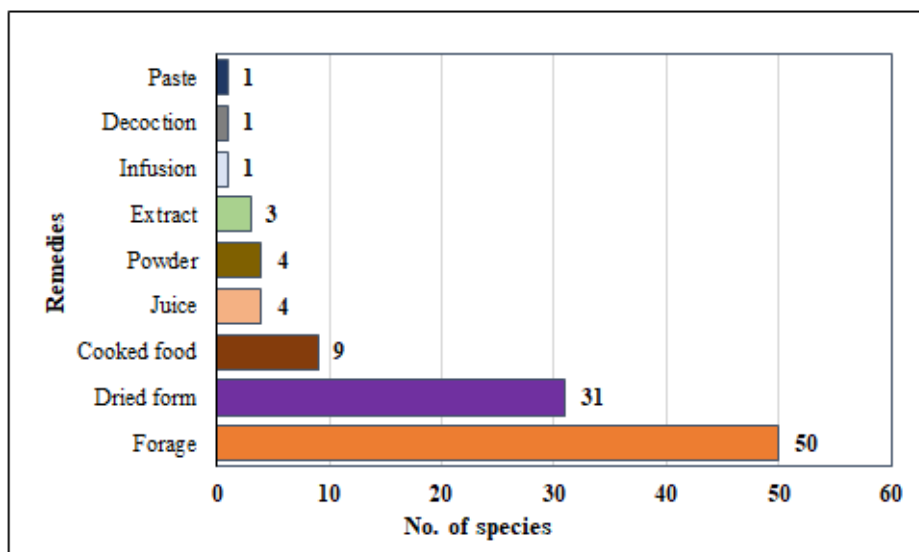


Figure 5. Remedies preparation methods

The widespread use of dried and cooked plant forms further highlights the integration of medicinal plants into local diets, ensuring their availability throughout the year. Additionally, the use of these species as forage underscores their essential

role in livestock care. Beyond medicinal applications, the documented plants also provide food, fodder, fuel, and vegetables, emphasizing their multifunctional contribution to sustaining rural livelihoods. In Pakistan, rural communities depend on plants for healthcare, nutrition, and livestock feeding, illustrating the socio-economic and cultural significance of local flora (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). These findings highlight the critical need for documenting ethnobotanical knowledge, promoting sustainable resource management, and exploring the pharmacological potential of these species.

Comparative ethnobotanical importance of weed species

The Venn diagram becomes particularly important in this ethnobotanical context, as it highlights both the shared and unique plant resources across the tehsils. The strong overlap among the tehsil Salarzai, Mamond, and Khar suggests a common pool of ethnobotanically significant species accessible to a wide range of communities, reflecting shared cultural practices and ecological conditions (Fig. 6). Conversely, Nawagai, with its high number of unique species, represents a distinct ethnobotanical reservoir, where locally adapted weeds such as *Avena fatua* and *Bromus lanceolatus* may serve as critical fodder resources for livestock-based livelihoods. Similarly, the presence of rare or localized taxa in Barang, such as *Malva neglecta* and *Verbena officinalis*, highlights specialized knowledge linked to microhabitats. Thus, the Venn diagram not only illustrates ecological distribution but also underscores how the overlap and uniqueness of species directly shape the ethnobotanical diversity of Bajaur, where common weeds form a shared cultural heritage, while localized species preserve unique traditional practices.

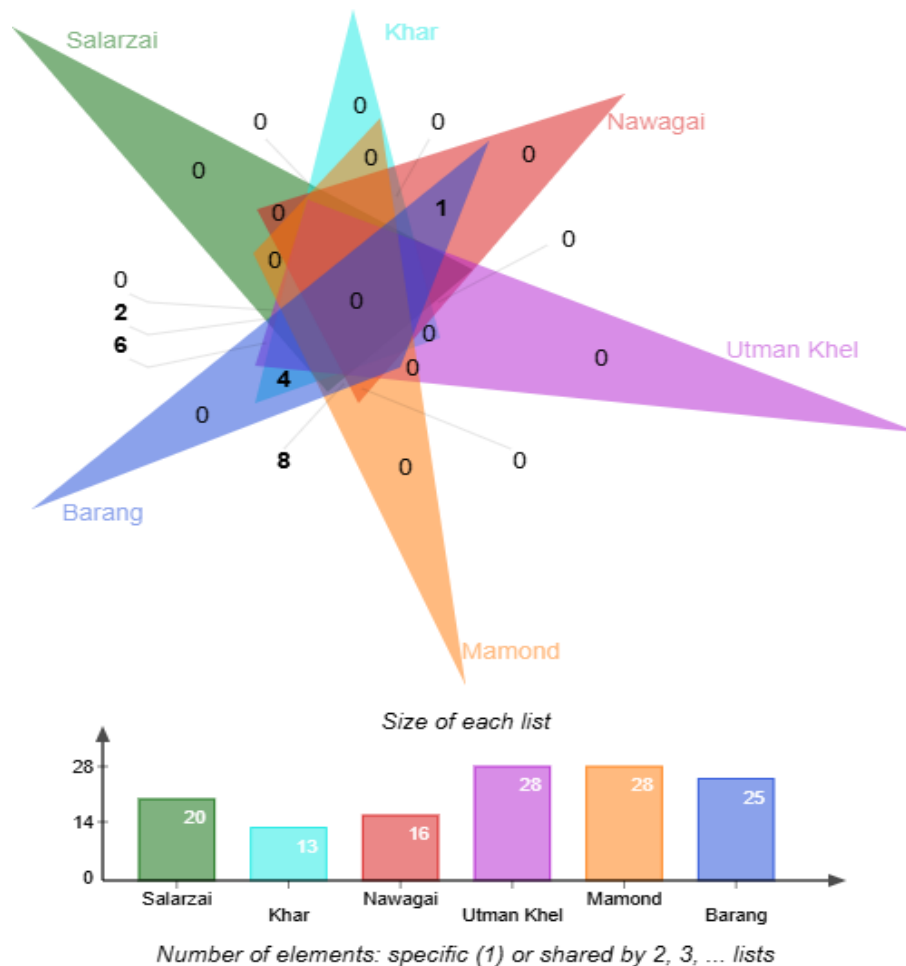


Figure 6. Comparative assessment of weed species in different tehsils of Bajaur

Quantitative ethnobotanical indices of weeds

The medicinal significance of 47 weed species was evaluated using quantitative ethnobotanical indices. Data analysis was conducted through UV, FC, RFC, and FL, which collectively provide insights into the cultural importance and medicinal potential of each plant species.

Use value (UV)

Use value (UV) analysis offered deeper insights into the cultural significance and practical applications of the documented species. The highest UV was recorded for *Silene conoidea* (0.89), reflecting its diverse applications in treating constipation, as a vegetable, and as fodder. This high score indicates both its physiological activity and cultural reliance. In contrast, the lowest UV was documented for *Plantago lanceolata* (0.51), suggesting either reduced local awareness of its uses or a decline in its ethnomedicinal prominence. Intermediate values were observed for several widely used fodder and medicinal plants, such as *Fumaria indica*, *Taraxacum officinale*, *Malva neglecta*, and *Mentha longifolia*, showing balanced cultural importance (Table 2).

According to ethnobotanical principles, plants with higher UVs are considered more pharmacologically active and culturally significant (Mustafa *et al.* 2023). However, species with lower UVs should not be neglected, as they may represent underutilized resources or reflect the erosion of indigenous knowledge (Abdin *et al.* 2022). The low value might be due to unawareness of the residents of the area and a lack of proper knowledge regarding medicinal plant usage (Ahmad *et al.* 2017). Thus, while *Silene conoidea* emerges as the most important species in the local context, lesser-valued taxa like *Plantago lanceolata* may still hold hidden potential for future pharmacological and agricultural research.

Frequency of citation (FC)

The frequency of citation (FC) reflects the extent to which local informants rely upon and recall a particular plant species for ethnomedicinal and fodder purposes. High citation frequencies indicate greater familiarity, cultural significance, and practical use, while lower frequencies may reflect limited distribution, reduced availability, or specialized applications. In the present study, *Mentha longifolia* (88 citations) emerged as the most frequently cited species, followed closely by *Cynodon dactylon* (86 citations), as shown in Table 2. These plants are widely distributed, easily accessible, and hold multiple ethnomedicinal and fodder roles. For instance, *Mentha longifolia* is commonly used as a digestive stimulant, treatment for gastrointestinal ailments, and as a refreshing vegetable. Similarly, *Cynodon dactylon* is a well-known fodder grass that also holds therapeutic value in urinary infections, respiratory problems, and wound healing. Their high FC values, therefore, emphasize not only their availability and abundance in Bajaur but also their strong cultural embedding and reliability in daily healthcare and livestock management (Haq and Badshah, 2024). Plants having high RFC values are well-known among the indigenous people (Ahmad *et al.* 2017). Such plants could be assessed further for their phytochemical composition and for drug discoveries in the near future (Mukherjee and Wahile, 2006) and should be exposed to further pharmacological investigations for commercial yields (Mukherjee *et al.* 2012). On the other hand, species such as *Buglossoides arvensis* and *Ranunculus muricatus* received the lowest citation frequency (24 citations each). Although less frequently reported, these plants still retain ethnomedicinal importance for treating specific ailments. For example, *Ranunculus muricatus* has traditionally been used for dermatological conditions and wound healing, whereas *Buglossoides arvensis* is cited in relation to digestive problems and fodder use. Their comparatively low FC may reflect restricted local distribution, seasonality, or gradual erosion of traditional knowledge associated with them. The variation in FC values highlights the uneven distribution of traditional plant knowledge within the community. Plants with high FC are often considered culturally dominant and highly reliable, while those with low FC may still represent niche but valuable resources for addressing specific health problems (Ouelbani *et al.* 2018; Haq *et al.* 2022). Importantly, underreported species should not be overlooked, as they may harbor untapped pharmacological potential and could gain wider ethnomedicinal prominence with further research.

Relative frequency of citation (RFC)

The relative frequency of citation (RFC) serves as a key indicator of the local popularity and cultural acceptance of plant species, calculated as the proportion of informants citing a given taxon relative to the total number of respondents (Tardío and Pardo-de-Santayana, 2008). Higher RFC values indicate that a species is well-recognized and widely used in traditional healthcare or subsistence practices, whereas lower RFC values may reflect limited distribution, specialized use, or declining knowledge among younger generations.

The ethnobotanical survey recorded 47 weed species with RFC values ranging from 0.2 to 0.8, underscoring their broad therapeutic and nutritional importance in the Bajaur district. *Mentha longifolia* showed the highest value (0.8), indicating its broad medicinal and culinary use. Several species (*Cynodon dactylon*, *Taraxacum officinale*, *Stellaria media*, etc.) had RFC 0.7, reflecting high cultural acceptance. Moderately cited taxa (0.5-0.6) demonstrated consistent significance, while species with lower RFC (0.2-0.3) were rarely used (Table 2). This plant is widely employed as a digestive stimulant, a remedy for gastrointestinal disorders, treatment of respiratory problems, and as a common leafy vegetable, which explains its frequent recognition across a large proportion of respondents. The high popularity of *Mentha* species aligns with previous ethnobotanical studies from Pakistan and other regions, where they have consistently been reported as dominant

components of traditional healthcare systems (Ahmad *et al.* 2017; Umair *et al.* 2019). In contrast, *Buglossoides arvensis* exhibited the lowest RFC (0.21), suggesting that it is either less familiar to the general community or has a narrower scope of ethnomedicinal use. Nevertheless, even species with low RFC values remain culturally significant for specific therapeutic practices. Such underreported taxa often represent underutilized traditional resources that may deserve further pharmacological investigation (Ahmad *et al.* 2017; Ouelbani *et al.* 2018). The remaining species showed RFC values within this range, reflecting intermediate levels of cultural importance depending on their availability, ease of collection, and versatility in treating multiple ailments. These results align with previous ethnobotanical findings where species with broad ethnomedicinal spectra tend to achieve higher RFC values, while those used for rare or specialized ailments achieve lower ones (Kayani *et al.* 2014; Khan *et al.* 2018; Mustafa *et al.* 2023). RFC values indicate that species such as *Mentha longifolia* and *Cynodon dactylon* occupy a central role in local ethnomedicine and subsistence practices. Conversely, species with lower RFC values, though less frequently cited, may embody valuable traditional knowledge that is increasingly vulnerable to erosion under the influence of modernization and shifting lifestyles.

Fidelity level (FL)

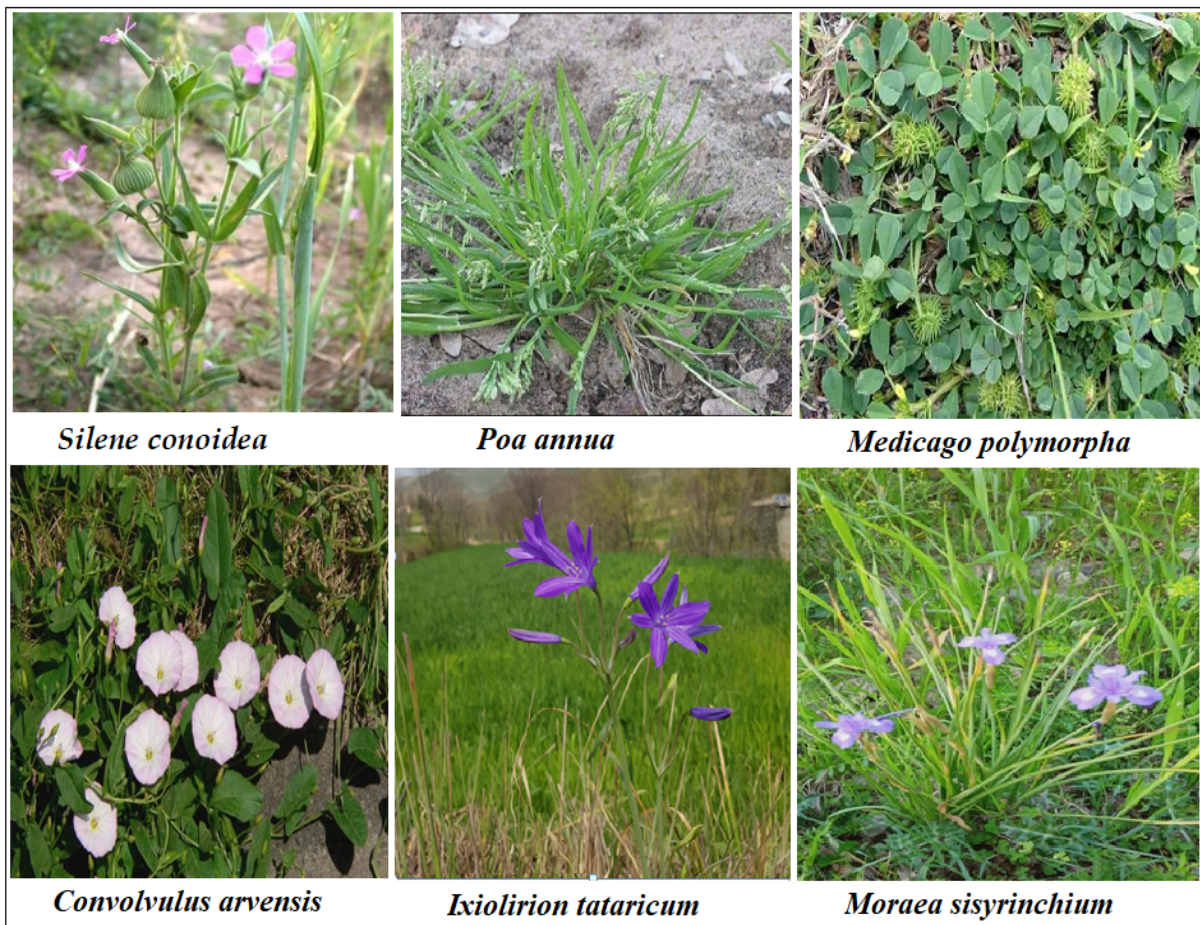
The fidelity level index was employed to assess species preference for treating specific ailments and to determine the consensus of local informants regarding the therapeutic efficacy of particular weeds (Friedman *et al.* 1986; Alexiades, 1996). In this study, FL values for 21 medicinally significant weed species ranged from 46% to 96%, reflecting differing degrees of community consensus regarding their therapeutic applications. *Mentha longifolia* exhibited the highest FL (95.45%) for vomiting, dysentery, digestive problems, and abdominal pain, confirming its strong cultural acceptance and therapeutic reputation within the community (Table 2). This aligns with previous ethnomedicinal studies across South Asia, where *Mentha* species consistently recorded high FL values for gastrointestinal disorders (Kayani *et al.* 2014; Umair *et al.* 2019). In contrast, *Phalaris minor* showed the lowest FL (45.65%) against cough and dysentery, indicating lower informant consensus and possibly reflecting either its restricted use or lower perceived efficacy compared to other taxa. Species with high FL values are often regarded as strong candidates for pharmacological and phytochemical investigations, as the high level of informant consensus indicates a confirmed therapeutic potential (Heinrich *et al.* 1998; Srithi *et al.* 2009). However, species with lower FL should not be disregarded. They may represent rare, endangered, or locally restricted ethnomedicinal knowledge that requires further documentation before being lost (Gazzaneo *et al.* 2005; Ouelbani *et al.* 2018).

Ethnobotany plays a vital role in identifying conservation challenges, particularly in cases where harvesting pressures surpass natural regeneration rates (Hamilton, 2004; Shinwari, 2010). Overharvested medicinal weeds require urgent conservation measures to safeguard their long-term availability, ensuring that future generations can continue to benefit from these valuable natural resources, often described as “gifts of nature to humankind.” Such conservation initiatives must involve collaboration between local communities, scientists, and conservation experts for sustainable resource management (Hamilton, 2004). Unfortunately, much traditional ethnobotanical knowledge is rapidly disappearing due to westernization, indigenous cultures, and even the extinction of whole tribal groups (Phillips and Gentry, 1993; Martin, 1995). A key objective of this study is therefore to document, preserve, and revitalize local natural history, which has traditionally been transmitted orally across generations. Such preservation not only safeguards the cultural heritage but also provides practical foundations for community development, biodiversity conservation, and sustainable utilization of medicinal resources (Martin, 1995; Cotton, 1996; Kunwar *et al.* 2013).

Conclusion

This study documented 47 weed species representing 45 genera and 23 families, which contribute substantially to the traditional healthcare practices, livelihoods, and ecological systems of Bajaur, Khyber Pakhtunkhwa. Among these, Poaceae was the leading family with nine species, which is followed by Brassicaceae and Asteraceae, reflecting their ecological adaptability as well as their medicinal relevance. Data also revealed a predominance of dicots (36 species) over monocots (11 species), highlighting the greater ecological and ethnomedicinal diversity of dicotyledonous species. Life form analysis further showed that annual weeds (66%) dominated the flora, which can be attributed to their rapid growth, high seed production, and colonization ability in cultivated fields. Ethnobotanical findings indicated that various plant parts—especially whole plants (70%)—were widely used in traditional remedies, prepared mainly as infusions, decoctions, and powders. Multipurpose uses, including fodder, food, fuel, and vegetables, demonstrated the weeds’ broader role in sustaining rural livelihoods beyond medicine. Quantitative ethnobotanical indices, including Use Value (UV), Relative Frequency of Citation (RFC), and Fidelity Level (FL), identified species such as *Silene conoidea*, *Mentha longifolia*, and *Cynodon dactylon* as highly valued, while even species with lower scores were acknowledged for their distinctive therapeutic relevance. Importantly, older community members possessed richer ethnobotanical knowledge than the younger generation, reflecting a gradual erosion of indigenous traditions due to cultural shifts and reliance on allopathic medicine. The study recommended

implementing in-situ and ex-situ conservation for ethnobotanically important weeds through community initiatives, seed banks, and botanical gardens. It emphasized sustainable harvesting, documentation of traditional knowledge, pharmacological research, and community education. Recognizing weeds as valuable resources supports biodiversity, community well-being, and the discovery of novel plant-derived medicines.



Some of the common weeds of the cultivated fields

Acknowledgments

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Declarations

Ethics approval and consent to participate: All participants gave prior informed oral consent.

Availability of data: Data can be accessed by consulting the first author.

Consent to publication: Not applicable.

Conflict of interest: The authors declare that there is no conflict of interest.

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Authors' contributions: All authors declare that they have made equal, direct, and intellectual contributions to this work and have approved it for submission to this journal. Furthermore, all authors have read and agreed to the final published version of the manuscript.

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