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KA designed the project, did the field work, and compiled the data; AN identified the plant species and provided the related details; CSW supervised and finalized the manuscript

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No competing interests have been declared.

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ORIGINAL RESEARCH PAPER

Ethnobotanical investigation of wild vegetables used among local communities in northwest Pakistan

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Abstract

Wild vegetables can contribute to people's food security and health. In northwest Pakistan, almost 40% of the households are classified as food insecure, due to increasing population and natural and man-made catastrophes. There is an urgent need to get an overview of still existing practices of wild vegetable use and to incorporate such knowledge into agricultural policies. The present study, therefore, aims to collect and analyze information on the most widely and commonly used wild vegetables in northwest Pakistan. Semistructured interviews were performed with 126 informants (26–78-year old) from all 24 districts of the Khyber Pakhtunkhwa Province. Information on culinary and medicinal use, cooking methods, and growing and harvest season were collected. A rating scale was used to get the opinion on quality, abundance, and use frequency of wild vegetables. Information on trading was gathered on local and regional markets. Transect walks were done with key informants for specimen collection. A total of 25 wild vegetable species (21 genera, 13 families) were documented. Most of them are herbs (22 spp.). One third of the species needs processing or detoxification prior to cooking. Taste and food quality as perceived by the local people are the main driver for use frequency and commercialization. Length of availability varies from 2 to 7 months with *Rumex dentatus* and *Vicia faba* also available during the winter season. Overall, 21 spp. are also used medicinally, mainly for gastrointestinal diseases. Leaves are the preferred plant part for both vegetables and medicines. Nine species are sold in markets, *Bauhinia variegata* and *Caralluma tuberculata* throughout the whole province. Local communities in northwest Pakistan have a broad knowledge of local plant use, especially on wild vegetables and their adequate processing. The present study suggests that the most commonly used wild vegetables should be promoted to reinforce food safety and most of them may also be commercialized. Conservation priority has to be given to the commercially harvested *Caralluma tuberculata*, which is presently overexploited.

Keywords

ethnobotany; Khyber Pakhtunkhwa; Pakistan; wild vegetables

Introduction

Wild vegetables contribute to people's food security and health in many rural areas of the world [1,2]. They may have remarkable nutrient values and can be an important source of vitamins, fibers, minerals, and fatty acids; and may also show important medicinal properties [3–8]. Wild vegetables can constitute important local commodities fetching high prices on local and regional markets and as such contribute to local cash income [9,10]. However, depending on the ecology of the species and the collected plant parts, commodification may lead to overharvesting and conservation concerns [11,12].

Pakistan is a developing country ranked eleventh on the food security risk index [13]. In northwest Pakistan, almost 40% of the households are classified as food insecure, due to increasing population and natural and man-made catastrophes challenging local livelihood strategies and access to food [14,15]. Wild vegetables can contribute significantly to the nutrient supply of a large part of the population, but knowledge of wild vegetable use is vanishing [16–18]. Therefore, there is an urgent need to get an overview of still existing practices and to incorporate such knowledge into agricultural policies. Several ethnobotanical surveys, including information on wild vegetables, have been conducted in different places of northwest Pakistan [15,19–28]. However, an overview of wild vegetable use in the whole political unit (province) is missing to date but is essential if such knowledge should contribute to policy making and implementation.

The present study, therefore, aims to collect and analyze information on the most widely and commonly used wild vegetables in the Khyber Pakhtunkhwa Province, northwest Pakistan. This includes collection sites and seasonality of the species, processing and cooking methods, local perceptions of quality and taste, as well as abundance, medicinal use, and commodification.

We here define wild vegetables as edible parts of wild or semicultivated plant species that are not usually categorized as grains, fruits, or nuts but are cooked and eaten with bread.

Material and methods

Study site

Khyber Pakhtunkhwa Province of Pakistan, formerly North West Frontier Province (NWFP), is famous for its cultural diversity and traditional lifestyle [29]. It lies between 31.4° to 36.57° N and 69.16° to 74.7° E, bordered by China in the north, Kashmir in the east, and Afghanistan in the west. The province, distributed in 24 districts under seven divisions (Tab. 1), covers an area of 74,521 km². Its altitude varies from 150 to more than 3,000 m, with annual precipitation between 510 and 1,520 mm. Temperature ranges between 5°C and 42°C. An average of 17% of the area is under forest cover ranging from subtropical dry forests to coniferous and alpine forests which are mainly classified as reserve, protected or private (*guzara*) forests and other (plantations/trees on farmland, etc.) forests. The total population counts 17.56 million people (52% male and 48% female), who are predominantly Muslims. Pashto is the main language of the area and is spoken by the Pashtun tribes (68.30%), followed by Hindko spoken by the people of Hazara division (18.13%), Seraiki spoken by the Daman people living in the foothills of the Sulaiman Mountains in Districts of Dera Ismail Khan and Tank (3.95%), and others (7.6%) [30,31]. The economy of the province is dominated by forestry and the area belongs to the poorest regions of the country. Main cash crops include wheat, maize, tobacco, rice, sugarcane, and cultivated fruits. The area has to deal since decades with refugees from Afghanistan and today is embattled with terrorism.

Ethnobotanical data collection

Semistructured interviews with a total of 126 informants were performed by the first author from 2009 to 2011 and from 2014 to 2015. Due to cultural constraints, direct interviews with women were not possible, so the female interviews were included indirectly via their male family members. All 24 districts of the Khyber Pakhtunkhwa Province were visited during different seasons of the year. Informants were selected through snowball sampling, starting from a local contact in each district, and asking for persons knowledgeable about the use and collection of wild vegetables. The number of informants varies for each district and division according to its size and population density (Tab. 1). All informants were natives, and their age ranged from 26 to 78 years, with an average of 48.45 ±13.11 years. The interviews were conducted in the local language of the interviewee, mostly in Pashto.

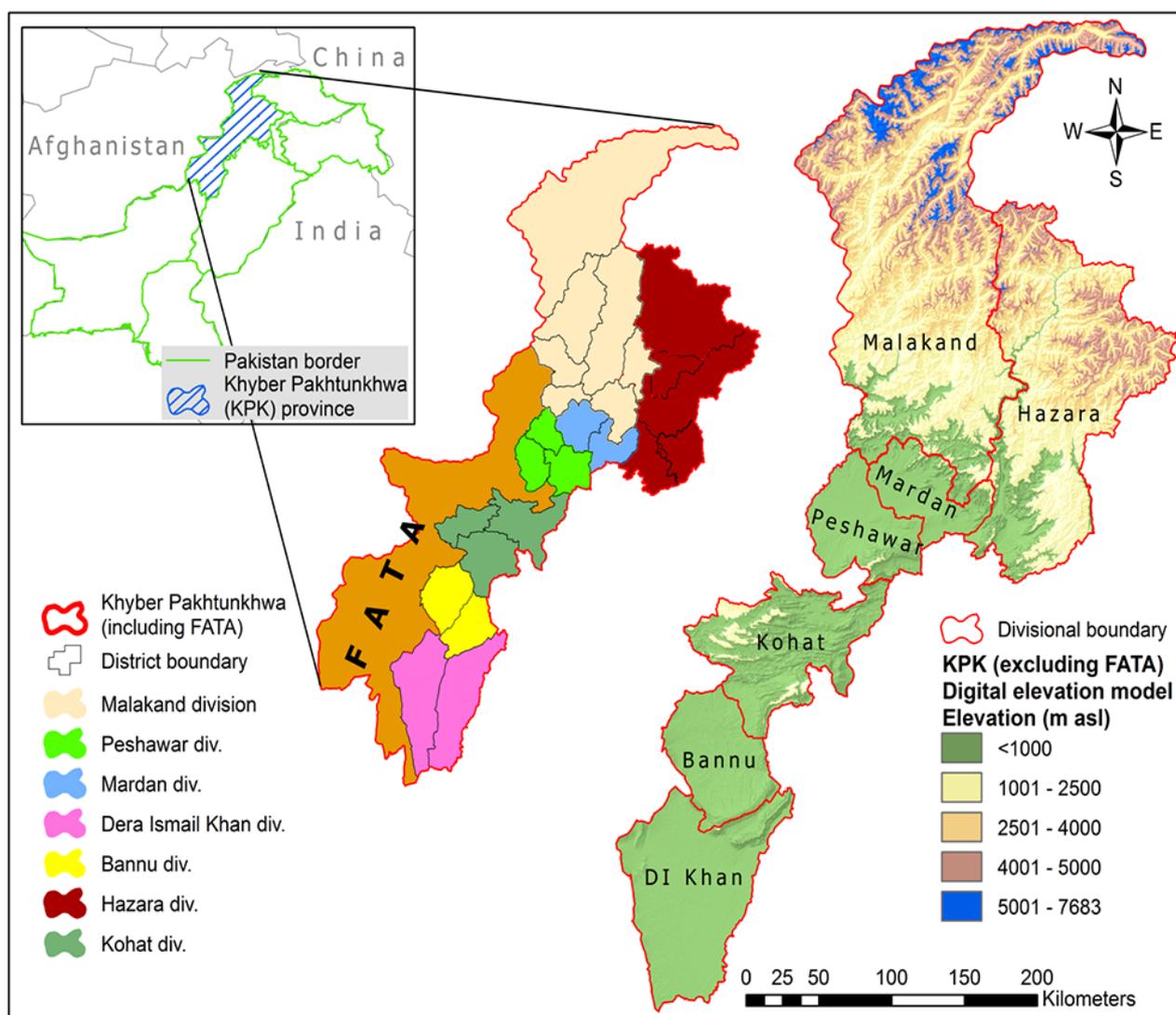


Fig. 1 Study site. Divisions with district boundaries of Khyber Pakhtunkhwa Province.

Ethnobotanical data including local names of the wild vegetables, culinary and medicinal use, cooking methods, availability and use frequency, and growing and harvest season were collected. A 5-point rating scale was used to get the respondent's opinion on the quality and abundance of wild vegetables and use frequency [32,33]. To gather information on the trading of wild vegetables, the main markets of each district and division were visited, and vendors of wild vegetables were interviewed. Transect walks were performed with key informants for specimen collection. Local plant names were confirmed with the literature available for the area [21,22,34].

During the whole study, the ethical guidelines adopted by the International Society of Ethnobiology were strictly followed [35].

Species documentation and identification

Of all documented plants, voucher specimens were prepared. They were identified and have been deposited in the Herbarium of Pakistan (ISL), Quaid-i-Azam University, Islamabad. Identification is based on the available literature of the flora of Pakistan [36,37] and comparison with herbarium specimens. Nomenclature follows [38], and families were assigned according to the Angiosperm Phylogeny Group IV [39]. The distribution of the species at division level was confirmed with the available literature [36,37,40,41].

Tab. 1 Size and population of the divisions of Khyber Pakhtunkhwa Province and interviewees per division and district.

Division	Total area km ²	Total population	Rural population	Districts	Interviewees per district and division (<i>n</i> = 126)	
Hazara	17,064	3,505,581	3,203,566	Abbottabad	5	28
				Battagram	4	
				Haripur	6	
				Kohistan	5	
				Mansehra	8	
Bannu	4,391	1,165,692	1,071,138	Bannu	5	9
				Lakki	4	
Malakand	29,872	4,262,700	3,947,795	Buner	5	39
				Chitral	4	
				Lower Dir	6	
				Upper Dir	5	
				Malakand	5	
				Shangla	7	
				Swat	7	
Dera Ismail Khan (D. I. Khan)	9,005	1,091,211	92,9663	D. I. Khan	6	11
				Tank	5	
Kohat	7,014	1,307,969	1,063,945	Hangu	4	13
				Karak	5	
				Kohat	4	
Mardan	3,175	2,486,904	2,012,562	Mardan	6	12
				Swabi	6	
Peshawer	4,001	3,915,855	2,513,158	Charsadda	5	14
				Nowshera	4	
				Peshawar	5	

Source: GoP [30].

Results

Main wild vegetables of Khyber Pakhtunkhwa Province

A total of 25 wild vegetable species scattered in 21 genera and 13 families were documented as the most commonly used species in Khyber Pakhtunkhwa Province. The species, their local names, habitat, habit, and parts used, growing and harvesting season, and culinary and medicinal use are presented in Tab. 2. Besides one fern species (*Dryopteris ramosa*) all were angiosperms. Most numerous families were Fabaceae and Amaranthaceae (five species each), Brassicaceae (three), and Lamiaceae and Polygonaceae (two each).

Most of the wild vegetables were herbs (22 spp.), two thirds of which were annual and the remaining biennial or perennial. Two subshrubs, i.e., *Aerva javanica* and *Rumex hastatus*, and one medium-sized tree, i.e., *Bauhinia variegata*, were also documented. Usually, the green leaves or young aerial parts of the plants are used, but in the case of *Bauhinia variegata* floral buds and *Carulluma tuberculata* succulent stems are consumed. The wild vegetables are mainly collected in waste lands or as weeds in the fields. A few species are additionally cultivated, i.e., *Apium graveolens*, *Bauhinia variegata*, and *Cichorium intybus*.

Tab. 2 Wild vegetables of Khyber Pakhtunkhwa Province.

Botanical name with accession No., family, local name / common (English) name	Habit	Parts used	Growth place	Distribution (division)	Used (division)	Market status and price in PKR*	Cooking methods	Medicinal uses
<i>Aerva javanica</i> (Burm. f.) Juss. Ex Schult. (127272) Amaranthaceae	Perennial herb	Leaves	Waste land	Entire province	Hazara	Marketed only in Hazara (30–45/kg)	No. 2	Leaves poultice is applied on wound for healing and against abscesses.
Shorakai / Java aerva, kapok bush								
<i>Amaranthus spinosus</i> L. (127273) Amaranthaceae	Annual herb	Leaves, Shoots	Fields (weed)	Entire province, except Malakand	D. I. Khan, Bannu and Kohat	Nonmarketable	No. 1	Leaves poultice is used as antidote against scorpion bite.
Ghinyar, chalyary / thorny pigweed								
<i>Amaranthus viridis</i> L. (127274) Amaranthaceae	Annual herb	Leaves	Fields, waste land	Hazara and Malakand	Hazara and Malakand	Marketed only in Malakand (30–50/kg)	No. 1	Fresh leaves are used against tooth-ache and stomachic.
Ranjaka, ghinyar, chalyary / green amaranth (<i>A. hybridus</i> was also rarely used in some areas)								
<i>Apium graveolens</i> L. (127275) Apiaceae	Biennial to perennial herb	Leaves	Fields (semicultivated)	Entire province, except Hazara and Malakand	D. I. Khan and Bannu	Nonmarketable	No. 2	Leaves and seeds infusion is used as emmenagogue and cholagogue.
Surkhai / celery								
<i>Bauhinia variegata</i> L. (127276) Fabaceae	Tree	Floral buds	Fields (semicultivated)	Entire province, except Malakand	Entire province	Marketed in entire province (40–70/kg)	No. 1	Fresh flowers and also cooked are used as carminative, laxative. Its bark is used as astringent.
Kalyar / orchid tree								
<i>Caralluma tuberculata</i> N. E. Br. (127277) Apocynaceae	Perennial herb	Aerial parts	Waste land	Entire province	Entire province	Marketed in entire province (80–180/kg)	No. 3	Stem is used fresh or cooked against diabetes, rheumatism, and joint pains.
Pamanai, pamankey / caralluma								
<i>Chenopodium album</i> L. (127278) Amaranthaceae	Annual herb	Leaves	Fields (weed), waste land	Entire province	Entire province	Nonmarketable	No. 1	Leaves poultice is applied on ulcers and swellings. Cooked leaves are considered better for jaundice and seminal weakness.
Surma, bathu, udharam / fat hen								
<i>Chenopodium murale</i> L. (127279) Amaranthaceae	Annual herb	Leaves	Fields (weed), waste land	Entire province	Entire province	Nonmarketable	No. 1	Fresh and cooked leaves are used as digestive, tonic, and anthelmintic.
Thor suma, bathu / goosefoot								
<i>Cichorium intybus</i> L. (127280) Asteraceae	Perennial herb	Leaves	Fields (semicultivated)	Hazara and Malakand	Hazara and Malakand	Marketed in Hazara and Malakand (50–80/kg)	No. 2	Cooked leaves are used against gastrointestinal ailments.
Han / blue daisy								

Tab. 2 Continued

Botanical name with accession No., family, local name / common (English) name	Habit	Parts used	Growth place	Distribution (division)	Used (division)	Market status and price in PKR*	Cooking methods	Medicinal uses
<i>Dryopteris ramose</i> (C. Hope) C. Chr. (127281)	Perennial herb	Circinate leaves	Waste land	Hazara and Malakand	Hazara and Malakand	Marketed only in Malakand (50–70/kg)	No. 1	Cooked parts are used as aphrodisiac and for general body weaknesses.
Dryopteridaceae								
Kunjay / hand fern								
<i>Lathyrus aphaca</i> L. (127282)	Annual herb	Leaves, aerial shoots	Fields (weed)	Entire province	Malakand	Nonmarketable	No. 1	Ripe seeds smoke is used for soothing effect and as narcotics.
Fabaceae								
Jangli mater, kukarmany / yellow-flowered pea								
<i>Lepidium apetalum</i> Willd. (127283)	Annual herb	Leaves	Fields (weed), waste land	Entire province	D. I. Khan	Nonmarketable	No. 2	Leaves decoction is used against liver and spleen disorders. Seeds powder mixed with fine sugar is used against indigestion, diarrhea, and dysentery.
Brassicaceae								
Bashky, burchan / garden cress								
<i>Malcolmia cabulica</i> (Boiss.) Hook. f. & Thomson (127284)	Annual to biannual herb	Aerial shoots	Fields (weed), waste land	Entire province	D. I. Khan	Marketed in D. I. Khan, Bannu and Kohat (35–60/kg)	No. 1	No medicinal uses were recorded.
Brassicaceae								
Sag / no English name								
<i>Malva sylvestris</i> L. (127285)	Biannual herb	Leaves	Fields (weed), waste land	Entire province	Hazara	Nonmarketable	No. 1	Fresh leaves decoction is orally given to cure constipation. Fresh leaves are also used against toothache.
Malvaceae								
Khwarzamary, samchal / common mallow (in some areas, <i>M. neglecta</i> and <i>M. parviflora</i> were used in case of unavailability of <i>M. sylvestris</i>)								
<i>Medicago polymorpha</i> L. (127286)	Annual herb	Leaves	Fields (weed), waste land	Entire province	Kohat	Nonmarketable	No. 1	No medicinal uses were recorded.
Fabaceae								
Shpestaray / black medick								
<i>Mentha longifolia</i> (L.) L. (127287)	Perennial herb	Shoots	Fields (weed), waste land	Hazara and Malakand	Hazara and Malakand	Nonmarketable	No. 2	Fresh leaves tea is made for cough and cold. Also used as carminative and against vomiting and indigestion.
Lamiaceae								
Vaylanai / horse mint (<i>M. royleana</i> was also used in some areas)								
<i>Nasturtium officinale</i> R. Br. (127288)	Perennial herb	Leaves, aerial shoots	Waste land	Hazara and Malakand	Hazara and Malakand	Nonmarketable	No. 1	Infusion of fresh leaves are used as diuretic, stimulant, stomachic, while the fresh leaves poultice is used to remove blotches, spots, and blemishes from face.
Brassicaceae								
Tharmere / water cress								

Tab. 2 Continued

Botanical name with accession No., family, local name / common (English) name	Habit	Parts used	Growth place	Distribution (division)	Used (division)	Market status and price in PKR*	Cooking methods	Medicinal uses
<i>Portulaca quadrifida</i> L. (127289) Portulacaceae Warkhorai, lorank / chicken weed	Annual herb	Leaves, aerial shoots	Fields (weed), waste land	Entire province	Entire province	Nonmarketable	No. 1	Slightly warmed leaves are applied topically on swelling joints and as erysipelas. Fresh leaves are used as diuretic in dysuria and as vermifuge.
<i>Rumex dentatus</i> L. (127290) Polygonaceae Sarkari Palak / toothed dock	Annual to biannual herb	Leaves	Fields (weed)	Entire province	Entire province	Nonmarketable	No. 1	The fresh leaves are taken orally as stimulant and diuretic. Leaves boiled tea is taken for bronchitis and asthma.
<i>Rumex hastatus</i> D. Don (127291) Polygonaceae Tarooky, takely / dock sorrel	Shrub	Leaves	Waste land	Hazara and Malakand	Hazara and Malakand	Nonmarketable	No. 1	Fresh leaves infusion is orally taken for jaundice and hepatitis. Cooked leaves are used as laxative, carminative, purgative, and diuretic. Its excessive use may cause seminal weaknesses.
<i>Salvia mukerjeei</i> Bennet & Raizada (127292) Lamiaceae Matter jarrai / glass-wort	Perennial herb	Leaves	Waste land	Hazara and Malakand	Hazara and Malakand	Marketed in Hazara and Malakand (60–100/kg)	No. 2	Roots decoction is used in cold and cough and against fever, while its leaves infusion is used against dysentery and colic.
<i>Solanum americanum</i> Mill. (127293) Solanaceae Kachmacho, malgabai / black nightshade	Annual herb	Leaves	Waste land	Entire province	Hazara	Marketed only in Hazara (30–60/kg)	No. 1	Fresh leaves are used as poultice for rheumatic and joints pains. Leaves decoction is used against enlarged spleen and in heart problems. Cooked leaves are used as anticonstipation.
<i>Taraxacum campyloides</i> G. E. H. (127294) Asteraceae Huan / dandelion	Perennial herb	Leaves	Fields (weed), waste land	Entire province	Hazara	Nonmarketable	No. 2	Rhizome decoction is used against jaundice and as diuretic. Leaves tea is used during hepatitis and kidney problems.
<i>Trigonella gracilis</i> Benth. (127295) Fabaceae Shpestaray / fenugreek	Perennial herb	Leaves	Waste land	Hazara and Malakand	Kohat	Nonmarketable	No. 1	No medicinal uses were recorded.
<i>Vicia faba</i> L. (127296) Fabaceae Pervatha, chilow / beans	Annual herb	Leaves, Shoots	Fields (weed)	Hazara and Malakand	Hazara and Malakand	Nonmarketable	No. 1	No medicinal uses were recorded.

The three cooking methods are described under in "Cooking methods" section. Growth place: fields – the cultivable or semicultivable area where species grow in or nearby as weeds; waste land – non-cultivable area. * 1 PKR = 0.009527 USD (December 31, 2015).

Species distribution and use within the province

Fig. 2 shows use and distribution of the wild vegetables within the seven divisions of Khyber Pakhtunkhwa Province. Of the 25 species, 13 occur in the whole province, but only five of them are used in all divisions (*Caralluma tuberculata*, *Chenopodium album*, *C. murale*, *Portulaca quadrifida*, and *Rumex dentatus*). Distribution and use of the remaining species are more restricted. Overall, Hazara and Malakand are the divisions with the highest number of available and used species, which positively correlates with the total area of the division ($r = 0.82, p = 0.02$ and $r = 0.82, p = 0.02$), and annual rainfall ($r = 0.99, p = 0.000$ and $r = 0.92, p = 0.003$) of the divisions (Fig. 3).

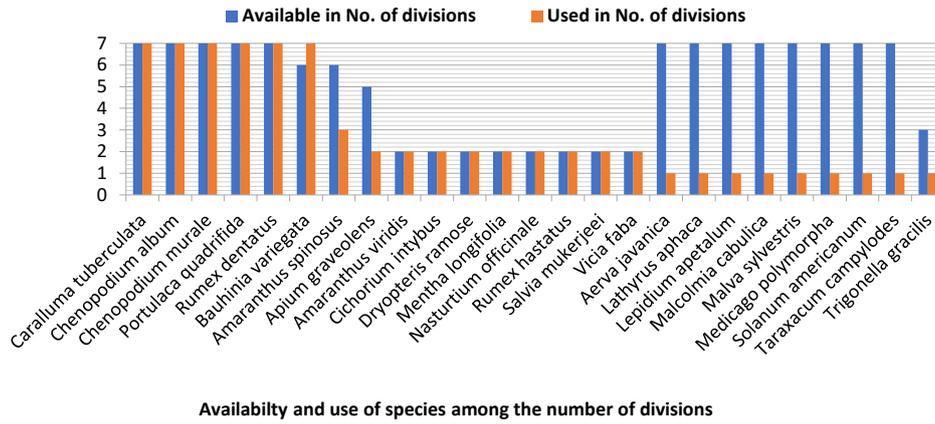


Fig. 2 Distribution and use of wild vegetable species within the seven divisions of Khyber Pakhtunkhwa Province.

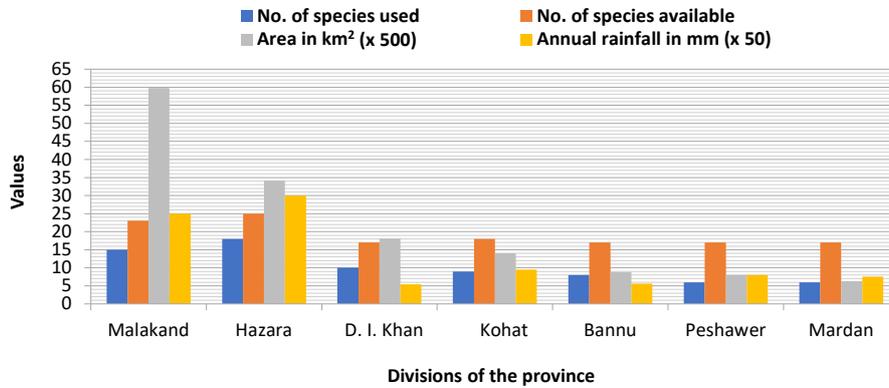


Fig. 3 Comparison of number of species used and available size of the area and annual rainfall for the seven divisions of Khyber Pakhtunkhwa Province. Number of species used significantly correlates with number of species available ($r = 0.95, p = 0.0008$), annual rainfall ($r = 0.92, p = 0.0003$), and with the total area ($r = 0.82, p = 0.02$) of the divisions.

Seasonality of wild vegetables and local perception of their quality and abundance

Seasonality of the climate largely determines the availability of wild vegetables. The highest number of species is available from March to August (83% spp.), while availability decreases in September and reaches a minimum from October to February. *Rumex dentatus* and *Vicia faba*, however, are available during the winter season, i.e., before and after the cropping season. Length of availability varies from 2 to 7 months among the different species (Tab. 3).

Fig. 4 shows the local rating of the abundance of wild vegetables, their use frequency, and quality (taste), whereas use frequency significantly correlates with food quality.

Tab. 3 Seasonal availability of wild vegetables in Khyber Pakhtunkhwa Province.

Species name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avail.*
<i>Aerva javanica</i>			■										3
<i>Amaranthus spinosus</i>			■	■	■	■	■	■					5
<i>Amaranthus viridis</i>			■	■	■	■	■	■					5
<i>Apium graveolens</i>			■	■	■	■	■	■					5
<i>Bauhinia variegata</i>			■	■	■								2
<i>Caralluma tuberculata</i>			■	■	■	■	■	■	■				7
<i>Chenopodium album</i>			■	■	■	■	■	■	■				7
<i>Chenopodium murale</i>			■	■	■	■	■	■	■				7
<i>Cichorium intybus</i>					■	■	■	■	■				3
<i>Dryopteris ramose</i>					■	■	■	■	■				3
<i>Lathyrus aphaca</i>			■	■	■	■	■	■	■				3
<i>Lepidium apetalum</i>				■	■	■	■	■					3
<i>Malcolmia cabulica</i>			■	■	■	■	■	■					3
<i>Malva sylvestris</i>			■	■	■	■	■	■					3
<i>Medicago polymorpha</i>			■	■	■	■	■	■	■	■	■	■	3
<i>Mentha longifolia</i>					■	■	■	■	■	■	■	■	7
<i>Nasturtium officinale</i>				■	■	■	■	■	■				4
<i>Portulaca quadrifida</i>			■	■	■	■	■	■	■				6
<i>Rumex dentatus</i>	■	■										■	4
<i>Rumex hastatus</i>					■	■	■	■	■	■			5
<i>Salvia mukerjeei</i>				■	■	■	■	■	■				4
<i>Solanum americanum</i>			■	■	■	■	■	■	■	■	■		7
<i>Taraxacum campyloides</i>		■	■	■	■	■	■	■	■	■	■		4
<i>Trigonella gracilis</i>					■	■	■	■	■	■	■		4
<i>Vicia faba</i>	■	■	■					■	■	■	■	■	7
Total species available/ month	2	3	13	18	21	16	15	12	7	2	3	2	

* Availability (months).

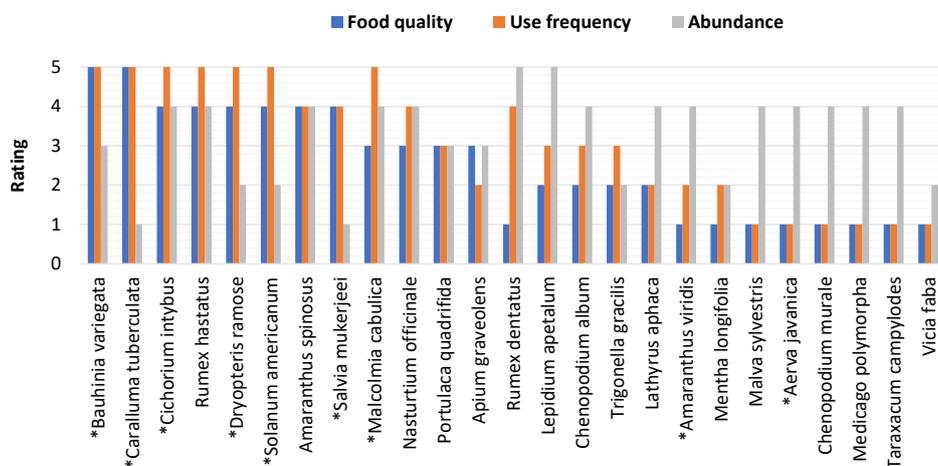


Fig. 4 Local perceptions of quality, use frequency, and abundance of wild vegetables. Use frequency significantly correlates with food quality ($r = 0.9, p = 0.02$). Commercialized species are indicated with an asterisk. Rating scale – food quality: 1 – ok; 2 – good; 3 – better; 4 – best; 5 – excellent.

Cooking methods

The main cooking method for all wild vegetables was the following: onions are fried in oil or ghee together with condiments. Tomatoes, green chilies, garlic, turmeric, coriander, and mint may be added, depending on their availability and taste preferences. Then, the wild vegetables are added and heated until major portions of water are evaporated, and oil or ghee appears on the upper layer of the vegetables.

However, the different species have to be treated according to their texture and secondary compounds. Delicate vegetables like, e.g., *Amaranthus* spp. are chopped into pieces and directly cooked (cooking method No. 1), tougher vegetables like, e.g., *Salvia mukerjeei* are boiled in water first until they become soft and delicate, while the extra water may either be poured away or evaporated (cooking method No. 2), and bitter vegetables like, e.g., *Caralluma tuberculata* are either boiled in salty water or cut into pieces and sprinkled with salt for 1 or 2 hours, and later washed with fresh water before cooking (cooking method No. 3). Knowledge about wild vegetables and their processing is transferred from one generation to the next within the family, or more rarely horizontally within the local community, though the knowledge of wild vegetables and their preparation was mainly held by the elder family members.

Medicinal food

Overall, 21 species (83%) are also used medicinally, mainly for gastrointestinal but also for skeleto-muscular or dermatological ailments (Tab. 2). Species are mainly administered orally (14 species) and more rarely topically (two species) or in both ways but for different purposes (four species). Most species (nine) are used directly without any processing followed by decoction (five species), infusion (four species), and poultice (four species).

Commercialization and conservation status

Of the documented wild vegetables, nine species (36%) are sold on markets, two of them throughout the province (*Bauhinia variegata* and *Caralluma tuberculata*; Tab. 2). Prices fluctuate according to supply and demand with high prices at the beginning and end of the season. The commercialized species are typically perceived as having an excellent taste and are consumed frequently (Fig. 4). An exception is *Malcolmia cabulica*, which is perceived as having an average taste but is never the less sold on the markets.

Discussion

Wild vegetables

All the reported species have been described previously for Khyber Pakhtunkhwa Province and other parts of the country [20,42–45]. Most of the taxa (e.g., Amaranthaceae, Asteraceae, Brassicaceae, Lamiaceae, and Malvaceae) are widespread and typically used as wild vegetables and as such are documented for other countries of Eurasia as well [46–49]. A rather uncommon food taxa is *Caralluma tuberculata*, which belongs to Apocynaceae, a family known for its toxicity and medicinal potential. *Caralluma* is represented by two species in Pakistan, which are widely used as vegetables throughout the country and as famine food in semiarid areas since centuries. However, its extensive use and trade make it vulnerable in the area [34,50,51].

Most of the documented species are weeds. Approximately every tenth plant on earth is a weed and greater part are edible [52–54]. Weeds often have valuable nutritional and medicinal properties and are an important dietary component of many people around the world [53–56]. They are collected wild or are semicultivated and need little attention or management as they tend to be excellent competitors with a broad ecological

amplitude [57,58]. As such, they can play an important role for sustainable nutrition especially during off-seasons and times of food scarcity [59–62].

In our area, the number of documented species is associated with the annual rainfall within a division, which has also been reported for other areas in Pakistan [44]. However, regional differences were found for the use of the 25 most common wild vegetables and in none of the divisions all available species are collected and consumed. Use patterns are probably influenced by the communication and transfer of knowledge between different communities as well as preferences based on the cultural background of ethnic groups [47,63]. Further research is necessary to reveal the exact reasons for the observed variations.

Although cooking methods may slightly vary between clans and families, the main procedures are the same in the whole area, i.e., heating in oil. Two thirds of the documented species need no processing or detoxification prior to cooking, while the remaining are detoxified and processed to various degrees. Processing and detoxification of food plants is essential for humans as raw plant material may not be palatable or important compounds may not be bioavailable [64]. At the same time, cooking can also have a negative effect on nutrients and the antioxidant potential of plants [65]. Sreeramulu et al. [66] and Mathooko and Imungi [67] therefore recommend cooking wild vegetables as short and with as little watering as possible or alternatively to consume the cooking water if it is free of unpleasant compounds.

Medicinal food

A local vegetation usually provides multidimensional services like in the present study where wild vegetables are not only important from a nutritional point of view, but also as medicine. Most often, they are used for gastrointestinal ailments, which may be due to their high fiber content [68]. Different studies argue that humans, in a genetic sense, are still stone agers and adapted to preagricultural diet patterns [69]. Major contemporary lifestyle diseases such as diabetes are thus due to alteration of major functional dietary components which were endowed with prophylactic effect in wild gathered food [70,71]. Leaves are the preferred plant part for both vegetables and medicines, while seeds, rhizomes, and aerial parts may also be used medicinally. Dual uses of species as food and medicine in traditional societies indicate a continuum between medicinal and edible plants and may reflect their joint origin and interconnection [72,73]. This phenomenon has been documented around the world, e.g., Adebooye and Opabode [74] for South West Nigeria, Abbasi et al. [24] for the Lesser Himalayas, Pieroni et al. [16] for Southern Italy, and Ogle et al. [4] for Vietnam. Similarly, the antibacterial and antioxidant activity of many wild vegetables has been documented [4,75].

Commercialization and conservation

Taste and food quality as perceived by the local people seem to be the main driver for use frequency and commercialization of wild vegetables. Wild vegetables sold on local markets fetch relatively high prices compared to conventional vegetables, which shows their local importance. Similar observations are described by Pemberton et al. [76] for local markets in Korea, where wild vegetables are usually sold for higher prices than cultivated ones. Wild vegetables may thus constitute an important source of income for local people and may even help to alleviate poverty [77,78]. However, high market prices may also be one of the major incentives for overharvesting of vulnerable species and gathering market information can therefore be useful to estimate harvest pressure [79].

In our area, conservation priority has to be given to the commercially harvested *Caralluma tuberculata* which is vulnerable due to extensive and unsustainable harvesting. Similarly, vulnerability of *Salvia mukerjeei* may increase with the present culinary usage due to its relative rareness, usage in early vegetative stage, and marketing. It is declared as vulnerable species in conservation assessments [80]. Also, *Bauhinai variegata*'s floral buds are extensively used, but its cultivation as ornamental plant reduces the pressure on the wild species. While harvesting of species with multiple uses can put them under

threat [81], it may also lead to better strategies for their conservation [72]. The present traditional knowledge in rural areas related to wild culinary vegetables is facing the threat of degradation due to changes in lifestyle [44], cultural deprivation, and a lack of knowledge transmission between the generations. This may have negative effects on the health of traditional communities. To maintain this knowledge, supporting local culture and including traditional ecological knowledge in the education of the young generation must be the focus of conservation programs [33,82]. Additionally, as the locals considered the collected species an important entity for their well-being, therefore, such species shall be urgently evaluated for its pharmacological and nutraceutical potential [83].

Conclusion

The local communities of Khyber Pakhtunkhwa Province of northwest Pakistan have broad knowledge of local plant use, especially on wild vegetables and their adequate processing. The positive correlation among the food quality, availability, and use of species elaborate the importance of healthy food, and the need for local flora conservation regarding nutritional importance and related traditional knowledge. The present study advocates that the most commonly used wild vegetables should be promoted to reinforce food safety and may also be commercialized. Their therapeutic properties could be promoted for public health. Most of the species have the potential to be domesticated or semicultivated as they are well adapted to the local conditions and climate, which would avoid overexploitation. However, there is a need for additional research including detailed documentation of all wild vegetables used among the different communities and an analysis of their nutritional potential and medicinal effects. This would provide the basis for their recommendation for and inclusion into nutrition and health policies.

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