Quantitative ethnobotany of *Calotropis procera* and associated vegetation: a step forward for conservation and management practice in northern areas of Pakistan

Siraj and Nasrullah Khan

Correspondence

Siraj and Nasrullah Khan*

Department of Botany, University of Malakand, Chakdara Dir Lower (18800), Khyber Pakhtunkhwa Pakistan

*Corresponding Author: nasrullah.uom@gmail.com

Ethnobotany Research & Applications 22:40 (2021)

Research

Abstract

Background: Calotropis procera is one of the most effective herbal medicinal shrubs. Although many studies have explored the ecological aspects of *Calotropis procera*, still a lack of documented information about the quantitative ethnobotanical and conservation attributes on this medicinally endangered plant and its associated vegetation in the Northern regions of Pakistan.

Methods: Semi-structured questionnaires, group discussions, and field observations were used to collect data on the therapeutic uses of *C. procera*, its availability, difficulties, and future conservation measures. These data were quantitatively analyzed using Person's carrying traditional knowledge (PCTK), Relative Frequency Citation (RFC), the report used for plant part (RUPP), plant part value (PPV), specific use (SU), Use Value (UV) and Jaccard Index (JI).

Results: Forty-five plant species belonging to 31 families and 34 genera were recorded in the northern areas of Pakistan. The Asteraceae was a species-rich family (8 species), followed by Poaceae and Euphorbiaceae (4 species each). Quantitative analysis revealed that the most used plant parts (PPV) and use values (UV) for medicinal purposes were leaves and latex (1.462 and 1.295). Furthermore, *C. procera* had a higher PCTK score for thorn pricking (96 %) and wound healing (93.5 %). The UV varied from 0.08 (*Lamium amplexicaule* L.) to 0.79 (*C. procera* W.T. Aiton). The RFC ranged from 0.06 (*Xanthium strumarium* L) to 0.28 (*C. procera* W.T. Aiton). Concerning the similarities between the present work and neighboring countries, India shows higher similarities (5.52) that may reflect the common flora and similar cultural norms.

Conclusions: Our results provide support for the use of *C. procera* in traditional medicine. Hence, the PCTK results of the present work demonstrated that *C. procera* is an endangered (EN) plant species due to its uncontrolled and extensive uses for medicinal and other purposes. Therefore, the indigenous use of medicinal plants needs conservational strategies and further investigation for better utilization of natural resources.

Keywords: *Calotropis procera*, Conservation, Northern areas, Quantitative ethnobotany

Manuscript received: 11/09/2021 – Revised manuscript received: 23/11/2021 - Published: 25/11/2021
http://dx.doi.org/10.32859/era.22.40.1-17

Background

Nature has always served as a repository of scientific knowledge, encouraging human efforts to indulge in exploration activities. Human exploration has not only fulfilled curiosity and inquisitiveness, but it has also led to the discovery of numerous cost-effective and economical remedies for different diseases (Poonam & Singh 2009). Despite marvelous examples like synthesis of novel compounds by chemists across the globe, humans do not compete with natural-synthetic processes and their efficiency (Rani & Sood 2021). Different civilizations from all over the world utilized natural products extracts (Gulzar *et al.* 2019). About 80% of the world's population depends on a plant extract, crude drugs, and formulations (Msomi & Simelane 2018). A considerable range of plant-based formulations is used worldwide to treat various ailments and disorders (Oladeji 2016). The majority of rural people depend on traditional medicine due to cultural conservatism and lack of cheap and reliable conservative health services (Nahashon 2013, Swai 2003). Traditional remedies are easily accessible to people with little financial resources who are also knowledgeable about the medicinal properties of specific plants and have limited access to modern healthcare facilities (Khan *et al.* 2015). Nowadays, regardless of numerous changes in modern medicines, there is a noticeable improvement in medicine and traditional pharmacopeia (Salma *et al.* 2016). Quantitative ethnobotanical techniques are the way to understand the current state of the medicinal flora of any locality (Ullah *et al.* 2020). Quantitative research yields valuable primary data that can be used to establish conservation plans for plant resources (Phillips 1996, Ullah *et al.* 2020).

Ethnobotanical studies have taken a new direction recently; researchers now not only documented medicinally valuable plants but also gave insight into their conservation status (Muhammad *et al.* 2020). Medicinal plants are recognized as a valuable natural resource because a large portion of the global population depends on medicinal plants to treat various health problems (Gurib-Fakim 2006). Though these medicinal plants are abundant in several areas and have a great deal of value in health care, overconsumption of these plants could pose a severe threat to the medicinal flora of that area (Khan *et al.* 2018). Out of 422,000 flowering plants, about 8.29 % to 11.8 % are exploited for therapeutic purposes (Govaerts 2001, Schippmann *et al.* 2002). Around 80 % of the population in developing countries used medicinal plant products for self-medication (WHO 2002, York *et al.* 2011). There are over 6000 wild plants species in Pakistan, out of which nearly 400-600 are being therapeutically beneficial (Malik *et al.* 2005). It is estimated that in Pakistan, approximately 84 % of the population depends on traditional remedies to treat various ailments (Ahmad *et al.* 2012, Ahmed & Murtaza 2014).

Northern regions of Pakistan are considered the richest in the sense of plants as well as their therapeutic efficacy. However, a few studies have been conducted for the conservation efforts in the region (Shinwari 2010). *Calotropis procera* belonging to the family Asclepediaceae is a small tree or perennial shrub (height up to 5.4 m), is also known as apple of Sodom (Azhar *et al.* 2014). It is native to Asia, the Middle East, and tropical and subtropical Africa (Parsons & Cuthbertson 2001). *C. procera* grows in arid and semi-arid sandy soil (Hassan *et al.* 2015, Kumar *et al.* 1998). However, open environmental conditions, disturbed areas, overgrazing pasture, roadsides and poor soil are favorable for its growth, where little competition occurs with associated species (Lottermoser 2011, Parsons & Cuthbertson 2001). Khyber Pakhtunkhwa is the region where *C. procera* is harvested for burning and medicinal purposes (Abbasi *et al.* 2013, Ahmad *et al.* 2021), which leads to rapid degradation of the plant (Irfan *et al.* 2018). This plant is usually growing in almost all parts of the northern regions of Pakistan and utilized as fuelwood; however, regardless of its toxic effect, it is also purposely planted in countries (e.g., India, Saudi Arabia) as a medicinal remedy and as a renewable source of energy (Kabir *et al.* 2003). *C. procera* has been of economic interest as the whole plant is usable, i.e., in folk medicine, to have purgative and anthelmintic properties and has been used to treat leprosy, ulcers, tumors, and piles, as well as anticoagulant, and anticancer. Furthermore, the plant's latex has been known for cardiac glycoside content and contains compounds with pesticide properties. In contrast, its biomass has shown a tendency to be a good source of renewable energy and hydrocarbon (Ara & Sarah 2017). Different parts of this plant have been reported to exhibit anti-inflammatory, analgesic, and antioxidant properties. In Khyber Pakhtunkhwa, *C. procera* is grown mainly, and researchers are looking whether these harvesting techniques are environmentally sustainable (Jan *et al.* 2014). The issue of medicinal species conservation is linked to overexploitation and the technique of harvesting the species (Mbinile *et al.* 2020). Digging and cutting of roots, as well as the removal of bark or the whole plant, are the most common methods of harvesting for *C. procera*. Moreover, human population explosion and climate change are posing more significant threats to the survival and persistence of *C. procera*, and these concerns are expected to intensify in the future.

The species is a forgotten medicinal plant in the vicinity of Khyber Pakhtunkhwa (Kabir *et al.* 2003); therefore, a need was felt to conduct this research work to reintroduce this plant for its medicinal purposes. The present study was designed to determine the economic and ethnomedicinal significance of *C. procera* for the local inhabitants

andlocal plant experts from Khyber Pakhtunkhwa. It is also one of the aims, to explore the ecological and ethnobotanical aspects of the plant, which will not only help in the conservation of the plant but will bring awareness to people about its medicinal importance.

Materials and Methods

Study area

Khyber Pakhtunkhwa (KP) province is spinning between 34°1' 33.3012" N and 71°33' 36.4860" E, having a total area of 128961 km^2 (Fig. 1). In the northeast of KP is Gilgit Baltistan, Punjab in the southeast, while Azad Jammu and Kashmir are in the north. Furthermore, the seventy-two thousand four hundred and ninety-seven (72,497) km^2 is covered by the most prominent mountains in KP, Pakistan. This region includes the Himalayan foothills, Hindukush, and the Karakorum, where plant species are used for aromatic, food, and medicinal purposes (Humayun 2003, Ali & Qaiser 2011). In the KP, the annual temperatures range between 3.4 °C and 34.3 °C (Hussain & Mudasser 2007). During winter, the mountains experience below-freezing temperatures. The average annual precipitation ranges between 600 to 1450 millimeters (Marwat *et al.* 2010). The variability in the edaphic conditions, altitude, and climatic factors has resulted in a diverse spectrum of biodiversity in Khyber Pakhtunkhwa (Haq *et al.* 2010). Hence, biodiversity in this territory reflects a transition zone between the different provinces of Afghanistan and Punjab and Balochistan provinces in Pakistan (Ullah *et al.* 2019). People of KP are mostly dependent on plants for health care, fuel, fodder, and many other purposes due to conservative and less developmental nature of people (Barkatullah *et al.* 2015, Murad *et al.* 2013). In Khyber Pakhtunkhwa, around 10% of the total known vascular plants are utilized medicinally, although they are becoming scarce due to poverty, overuse, and population pressure (Shinwari 2010). Old cultural traditions, festivals, costumes, and ceremonies can be found throughout the area. The majority of the population speaks Pushto, with Potohari, Gujrati, and Hindko being another native language.

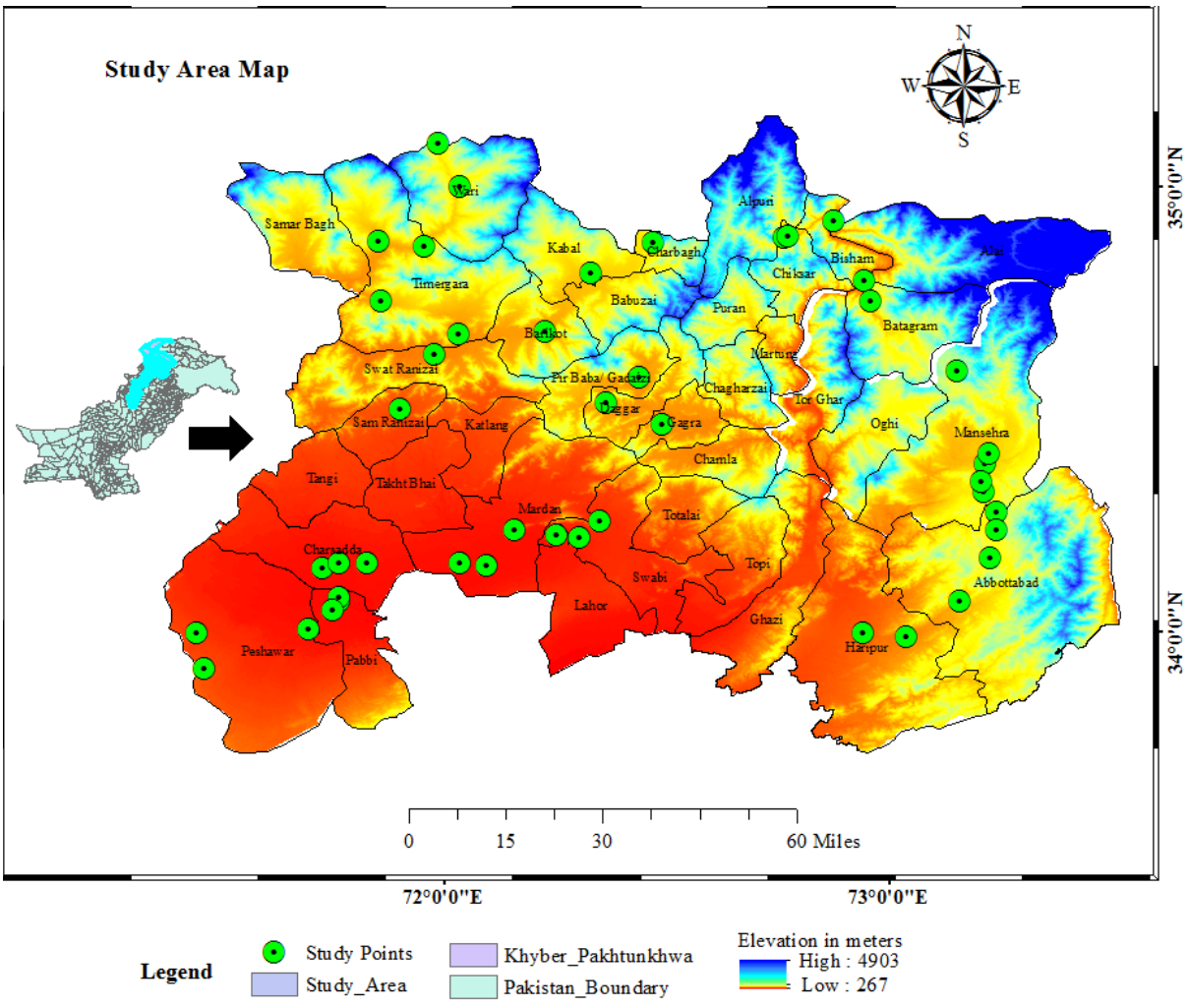

Figure 1. Study area map showing study points surveyed in northern areas of Pakistan

Data collection

A purposive sampling design was used to collect data in three selected divisions of the study areas: Malakand, Peshawar, and Hazara. Two hundred respondents were interviewed, and a semi-structural open-ended questionnaire was designed to collect information about ethnomedicinal uses of the plant. Respondents were interviewed individually and engaged in group discussions intended to obtain information about plant use. The questionnaire was translated to local languages (Pashto or Urdu) according to the applicant response and need in which we were assessed by local trained peoples. Anthropogenic pressure and activities were also visualized by a ground survey (Mbinile *et al.* 2020), including investigating the impacts of human activities faced by *C. procera,* such as root digging, debarking, fire, and removal of the whole plant. The investigation also focused on *C. procera* distribution across various land-use types. The data collected from the questionnaires were used to gather information and provide suggestions for utilization, threats, and conservation strategies of *C. procera* for the local community.

Collection procedure and identification

For proper identification, reported plant species were collected, pressed, and mounted on herbarium sheets. The plant specimen was taken to the Department of Botany, the University of Malakand, for identification and with the help of the Flora of Pakistan. Identified plant species were stored in the Herbarium at the Department of Botany, University of Malakand.

Statistical analysis

The obtained information was tabulated using spreadsheets excel (Version 2019) and analyzed statistically using SPSS Statistics 20 software. The Graph pad prism version 5.03 was used to develop graphs. Mann-Whitney U test was used to find a significant relationship between the average number of reported medicinal plants among different groups. Table 1 presented some fundamental quantitative matrices that have been estimated for current data following the presentation of Barkatullah *et al.* (2015).

Table 1. Statistical formulae applied for data analysis for data interpretation and conclusion

Formula used	Formula expansion and expression
Relative frequency of citation (RFC)	RFC = FC/N Where FC is used for the number of informants who mentioned the use of species and N is the total number of informants
Use value (UV)	UV = ∑Us/N Where ∑Us used for some of the uses mentioned for species and N for a total number of informants
Persons carrying traditional knowledge (PCTK) score (%)	PCTK % = NP/FC×100 Where NP is used for the number of informants for a particular disease and FC is for the total number of informants for the particular plant
Reported uses of particular plant part (RUPP)	Total number of reported uses for particular plant parts
Plant part value (PPV)	PPV = RUPP/RU Where RUPP is used for the total number of reported uses for each plant part and RU for the total reported uses for a given plant
-specific use (SU)	Total number of specific uses for particular plant part which was maximally used among the reported uses
Jaccard index (JI)	JI= c/a+b-c×100 where "a" is the recorded number of species of the study area "A," "b" is the documented number of species of the area "B" and "c" is the common number of species in both areas "A" and "B."

Results

Demographic analysis of respondents

Two hundred (200) respondents, including farmers, housewives, herb practitioners, teachers, and students were interviewed in the present study. The proportion of male and female respondents were found non-significant ($P > 0.05$), although the female respondents (39.5%) were fewer than males (60.5%) (Table 2). There was a significant difference ($P < 0.05$) between the senior ($40 \leq 70$) and junior ($25 \leq 39$) age groups of the respondents. The junior age group had 60% respondents compared to the senior age group with 40%. Moreover, most of the respondents

were educated (62%), while 38% were uneducated; however, the educational level of the majority of the informants was primary level. Occupation-wise distribution shows that 23.5% of the total respondents were professional healers, while 76.5% were others, including farmers, housewives, laborers, students, and professors (Table. 2).

Table 2. Demographic profile of the respondent using Mann-Whitney U test on the average number of reported medicinal plants among different groups in the survey (N = 200)

Parameter	Informant group	N	%	Average ± SD	Z-value	P-value
Gender	Men	121	60.5	47.38±5.43	-1.92	0.42
	Women	79	39.5	39.35±4.33		
Age	Junior (less than 40)	119	59.5	4.56±2.38	-5.02	0.000**
	Senior (greater than 40)	81	40.5	6.05±2.12		
Educational status	Illiterate	76	38	13.43±5.48	-4.81	0.000**
	Literate	124	62	7.87±4.12		
Profession	Professional healer	47	23.5	1.45±5.44	-0.31	0.73
	Local people	153	76.5	9.75±4.32		
Total		**200**	**100**			

Note; **Significance at the 0.05 level (p<0.05)

PCTK score and Medicinal plant parts used

C. procera was more familiar and traditionally used plant in the study area. The results declared that out of a total of 27 medicinal uses, wound healing (96.0 %), boil (93.5 %), joint pain (35.62%), asthma (31.87 %), and snakebites (20 %) were the most frequent diseases mentioned from PCTK cured by the *C. procera* (Table 3). On the other hand, ringworm (1.02 %), Chickenpox (0.90 %), skin diseases (0.83 %) and digestive system (0.77 %) were less frequent diseases mentioned from PCTK. Different plant parts of *C. procera* were ranked according to frequency and medicinal uses (Table 4). Quantitative data analysis shows that leaves (PPV = 0.166) and latex (PPV = 0.148) of *C. procera* were the most frequently used plant parts. However, the root and stem were less frequently used plant parts (0.055, 0.092).

Table 3. PCTK score percentage of *C. procera* in the study area

Ethnomedicinal uses	PCTK strength (%)	Ethnomedicinal uses	PCTK strength (%)
To cure wound healing	96.0	Curing stomachache	3.75
To cure boils	93.5	Curing earache	3.22
Pollution monitoring	58	Curing pneumonia	3
Curing joint pain	35.62	Curing appetizer	2.87
Used for fuel	30	Curing diabetes	2.55
Curing Asthma	31.87	Curing purgative	2.12
Curing snake bite	20	Used for Scorpion stings	1.97
As a fodder	20	As anti-lice	1.63
To cure cough	17.33	Curing Women diseases	1.14
Thorn removal	13.56	Curing ringworm	1.02
Curing toothache	9.52	Curing Chickenpox	0.90
Curing jaundice	7.34	Help in skin diseases	0.83
Curing piles	5.42	Curing digestive system	0.77
As a blood purifier	4.32		

Traditional medical care and modern medical care systems

Information was collected from respondents about preference between traditional and modern medical care systems (Fig. 2). Among the respondents, 89 % favored traditional methods of healthcare over modern medicine (11 %) due to traditional medicine being cheaper (89.3%), safer (83.4%), and easily accessible (71.8 %). Additionally, some respondents felt that it was essential to preserving this tradition (50.4 %) because of the presence of the diverse medicinal plant in the area (29.1 %) and the unavailability of the modern care system (76.50 %).

Table 4. Quantitative analysis of study area with special reference to *C. procera*

Plant part	FC	RFC	RUPP	PPV	SU	∑Us	UV
Fruit	15	0.277	4	0.074	Eye treatment	35	0.648
Flower	18	0.333	6	0.111	Pneumonia, diabetes	42	0.777
Leave	83	1.537	9	0.166	Wounds, boils	79	1.462
Stem	54	1	5	0.092	Sunstroke	47	0.870
Root	37	0.685	3	0.055	Jaundice	30	0.555
Latex	73	1.351	8	0.148	Scorpion stings	70	1.295
Whole plant	64	1.185	7	0.129	Asthma	63	1.161

Note: (N = 200; RU = 54)

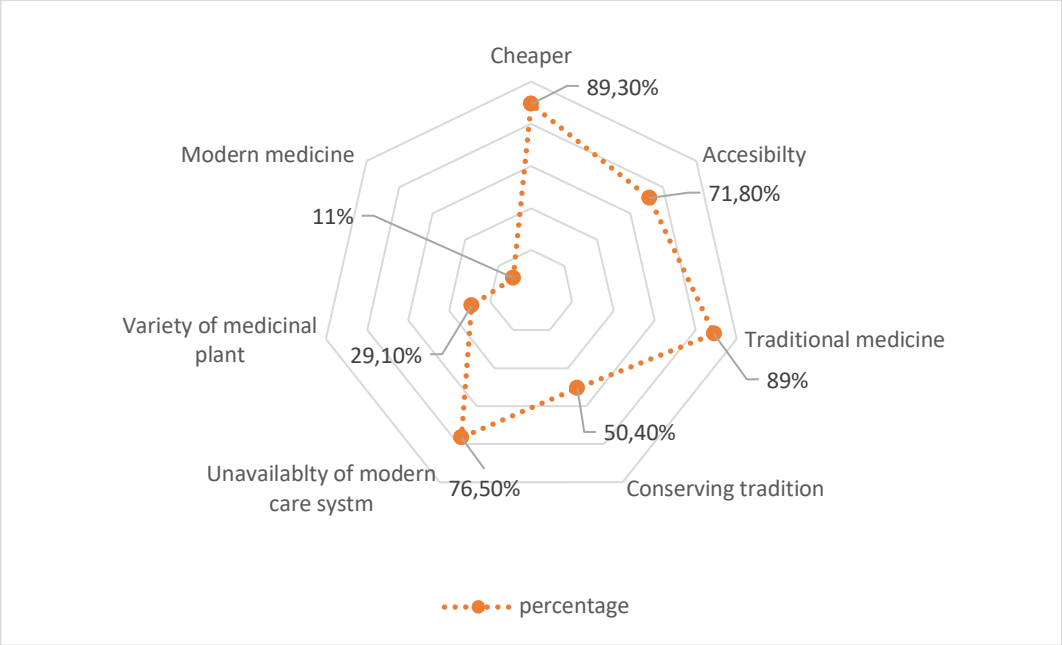

Figure 2. Radar charts showing the percentage of traditional medicine treatment over modern health care system

Quantitative and medicinal uses of associated species

A total of 45 associated plant species belonging to 44 genera and 31 families with *C. procera* has been documented in the present work (Table 5). The largest number of species belong to the family Asteraceae having eight species, followed by Poaceae and Euphorbiaceae (4 species each), Lamiaceae, and Moraceae (two species each). In comparison, the remaining families consist of only one species. It is further clarifying that the most dominant life form of the species was herb (26), shrub (7), climber (5), and trees (7). In the medicinal uses of the plant, leaves are primarily used (41%), roots are (26%), flowers (14%), fruits (9%), seeds (8%), bulbs, and barks (1%).

The various plant communities associated with *C. procera* of the area were also tested for habitat similarities and differences (Fig. 3). The data revealed that Site.6 and Site.12 were located in the river category. Site.3, Site.11, and Site.5 have the same habitat type and are put in the field/farmland category, while Site.4, Site.13, and Site.8 and Site.14 were in the cluster of rural area and urban sites.

Relative frequency of citation and Use value

Relative frequency of citation was calculated for each plant species (Table 5) and it was found that three species, i.e., *C. procera* (0.28), *Mentha longifolia* (0.28), and *Aloe vera* (0.27), attained the highest relative frequency of citation. However, *Xanthium strumarium* (0.06), *Sisymbrium irio* (0.06), and *Sonchus asper* (0.07) have the lowest relative frequency of citation. The relative importance of the plant was evaluated through the use-value index. The *C. procera* (0.79), *Zanthoxylum armatum* (0.73), *Medicago denticulata* (0.67), *Dodonaea viscosa, Ficus carica*, and *Cannabis sativa* (0.60), *Eucalyptus lanceolata* (0.56), and *Amaranthus viridis* (0.58) were reported to have high UV. The lowest use value was calculated for *Utrica dioica* (0.03), *Lamium amplexicaule* (0.08) and *Jasminum officinale* (0.12).

Table 5. medicinal uses and quantitative analysis of associated vegetation of *C. procera* of the study area

Family	Species Name	Habit/ life span	Part used	Medicinal use	FC	RFC	∑Ui	UV
Asclepiadaceae	*Calotropis procera* W.T. Aiton		Whole plant	Wound healing, cough, constipation, diabetes	56	**0.28**	39	**0.79**
Leguminosae	*Acacia nilotica* L. Delile.		root	Diabetes, stomach pain, cough, anemia	45	0.22	9	0.36
Xanthorrhoeaceae	*Aloe vera* auct. Mill		Latex	Wound healing, anti-cancer, anti-inflammatory,	55	**0.27**	12	0.32
Amaranthaceae	*Amaranthus viridis* L.		Whole plant	Urinary disease, blood purification, constipation	42	0.21	7	0.58
	Chenopodium album L.		Young shoot	Hepatitis, constipation	35	0.17	10	0.28
Asteraceae	*Artemisia absinthium* L		Leave	Cold, fever, carminative	26	0.13	5	0.19
	Carthamus oxyacantha M. Bieb.		Leaves, flowers, seeds	Jaundice, laxative, pain killer, reduce salivation	20	0.10	7	0.35
	Conyza bonariensis L.		Seed, leaves	Diabetes, diarrhea, wound healing	9	0.04	3	0.33
	Parthenium hysterophorus L.		Leaves	Diarrhea, dysentery, malaria, urinary tract infection	29	0.14	15	0.51
	Silybum marianum L.		Whole plant	Hepatitis, stomachic, jaundice	23	0.11	10	0.43
	Sonchus asper L. Hill		Whole plant	Fever, cough, body tonic, vomiting jaundice	15	0.07	5	0.33
	Taraxacum officinale Weber.		Whole plant	Skin infection, anti-inflammatory, laxative, kidney and liver disorder	18	0.09	8	0.44
	Xanthium strumarium L.		Leaves, seeds	Indigestion, diarrhea, smallpox	12	0.06	5	0.14
Asparagaceae	*Asparagus gracilis* Royle		Root, young shoot	Fever, kidney stone	23	0.11	10	0.43
Sapindaceae	*Dodonaea viscosa* L. Jacq.		Leaves	Sprain, bone fracture, wound healing	43	0.21	26	0.60
Cannabaceae	*Cannabis sativa* L.		Flower and leaves	Diarrhea, indigestion, narcotic, pain killer	26	0.13	18	**0.69**

Brassicaceae	*Sisymbrium irio* L.		Leaves, flower	Liver disorders, cough and chest congestion, wound healing	13	0.06	6	0.46
Poaceae	*Eragrostis minor* L.		Leaves, Seed	Contusions, headache	15	0.07	7	0.46
	Avena sativa L.		Seeds	Constipation, kidney disorders, bladder weakness, gallstone	35	0.17	16	0.45
	Cynodon dactylon L.		Whole plant	Wound healing	23	0.11	9	0.39
	Triticum aestivum L.		Whole plant	Cancer, diarrhea, dysentery, fertility, and fever	15	0.12	18	0.44
Polygonaceae	*Rumex dentatus* L.		Whole plant	Purgative, Wound healing, skin rash, piles, urinary complaints	34	0.17	5	0.41
Apiaceae	*Eryngium billardieri* Delile		Whole plant	Menstrual cramps, urinary disorder, anti-inflammatory	39	0.19	8	0.16
Myrtaceae	*Eucalyptus lanceolata* L.		Leaves, seed	Anti-septic, cough, and fever	25	0.12	14	0.56
Convolvulaceae	*Ipomoea purpurea* (L.) Roth		Whole plant	Laxative, purgative, hallucinogen	29	0.14	12	0.41
Oleaceae	*Jasminum officinale* L.		Flower	Hepatitis, dysentery, sedative	32	0.16	4	0.13
Aizoaceae	*Trianthema portulacastrum* L.		Leaves	Jaundice, wound healing, blood diseases, cancer	30	0.15	13	0.43
Lamiaceae	*Mentha longifolia* (L.) Huds		Leaves	Abdominal pain, diarrhea, vomiting	56	**0.28**	23	0.41
	Lamium amplexicaule L.		Whole plant	Laxative, stimulant, diaphoretic	57	0.28	5	0.08
Malvaceae	*Malva parviflora* L.		Leaf, root, seed	Cough, ulcer, hair tonic	26	0.13	17	**0.65**
Meliaceae	*Melia azedarach* L.		Leaves, seed	Laxative, antiseptic, liver disease	17	0.08	9	0.53
Moraceae	*Morus alba* L.		Fruit	Increase digestion, constipation	21	0.10	11	0.52
	Ficus carica L.		Fruit, latex	Stomach disorders, removal of wort.	28	0.14	17	**0.61**
Solanaceae	*Solanum nigrum* L.		Whole plant	Skin disease, asthma, body tonic, dysentery,	28	0.14	17	**0.61**
Salicaceae	*Populus nigra* L.		Leaf buds, bark	Pain killer, anti-inflammatory, digestive disorders, anti-septic	35	0.17	17	0.48

Euphorbiaceae	*Ricinus communis* L.		Seeds, root, leaves, bark	Purgative, anti-inflammatory, pain killer	28	0.14	15	0.53
	Chrozophora tinctoria (L.) A. Juss		Leaves	Diabetes, wound healing	23	0.12	9	0.39
	Euphorbia helioscopia L.		Latex	Cholera, kidney stone	23	0.11	12	0.52
Fabaceae	*Trifolium repens* L.		Leaves	Cough, leucorrhea	19	0.09	8	0.42
	Medicago denticulata L.		Leaves	Anti-diabetic, anti-inflammatory, cancer, anti-viral	28	0.14	19	**0.67**
Urticaceae	*Urtica dioica* L.		Leaves	Cardiovascular disorder, kidney stone, cancer	47	0.23	2	0.04
Scrophulariaceae	*Verbascum thapsus* L.		Leaves	Otitis media	24	0.12	4	0.16
Vitaceae	*Vitis vinifera* L.		Leave, fruit	Cholera, smallpox, liver and kidney disease, nausea	28	0.14	3	0.11
Rutaceae	*Zanthoxylum armatum* DC. Prodr		Fruit	Gum pain, abdominal pain, cooling agent	49	**0.24**	34	**0.74**
Rhamnaceae	*Ziziphus oxyphylla* Edgew		Root, fruit, leave	Diabetes, constipation, loss of appetites	37	0.18	18	0.48

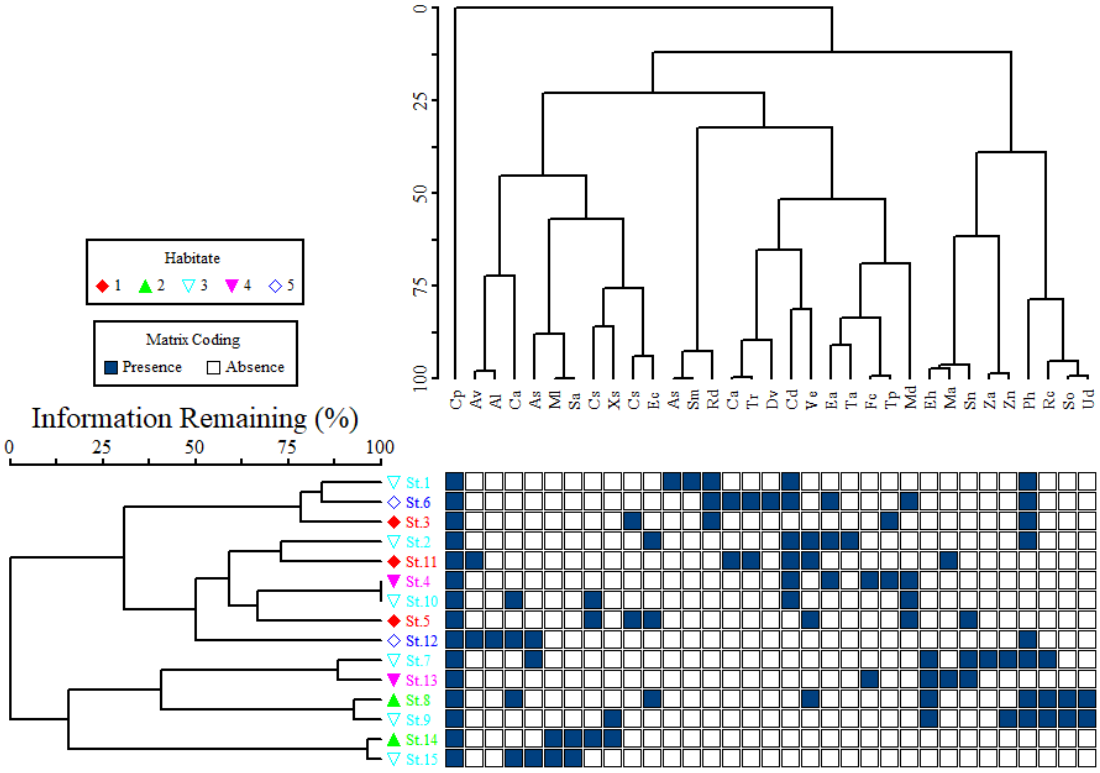

Figure 3. Two-way cluster analysis showing habitat of the target plant *C. procera*. Habitat (1=Field, 2=Urban area, 3= Roadside, 4=Rural areas,5=River side)

Jaccard index (JI)

The current study was compared with other twenty-three studies conducted in India, Kashmir, Namibia, Ethiopia, Nepal, Iran, Italy, China, and Morocco including Pakistan, using the Jaccard index (JI)**.** The top three highest degrees of similarities were recorded from Pakistan with studies conducted by Khan *et al.* (2014), Muhammad *et al.* (2018), and Ali *et al.* (2018) with JI values 20.43, 19.60 and 17, respectively (Table 6). Among the neighboring countries, the highest degree of similarities was recorded from India with studies conducted by Singh *et al.* (2014) with JI values 5.52. In foreign countries, the highest JI (8.63) was found in Italy, while the lowest degree of similarities was found in Namibia and Morocco, having a JI of 1.92 and 1.51.

Discussion

The present work declared that most respondents had a primary level of education, while others were illiterate (Table 3). As a result, they are entirely dependent on natural resources, placing the conservation efforts of *C. procera* at risk. Ngondya *et al.* (2011), has revealed that educated people are aware of ecological conservation and the values that drive it, and they may be able to contribute significantly to the implementation of environmental conservation methods. Furthermore, it has been revealed that an individual's academic ability significantly impact on the rate at which new natural resource conservation and management approaches, including therapeutic plants, are embraced by society (Brewer 2006). Low levels of education also make it more difficult for people to find formal work, requiring them to rely on natural resources to make a living (either as herbalists or charcoal merchants), both of which are detrimental to conservation efforts (Mpondo *et al.* 2021). According to Mbinile *et al.* (2020), there is a need to encourage communities to provide environmental conservation education to their residents, starting at the most elementary levels. Furthermore, the government should concentrate on teaching the public through regular conservation seminars and the participation of community leaders. This method will have positive long-term results and reduce the chances of a plant species becoming extinct in a given area.

Table 6. Comparison between present and previous studies at neighboring, regional, and global level as performed by Jaccard Index (JI)

Study area	Year	Total species (A)	Total species in present work(B)	Same use in both work	Different use in both work	Common plant in both areas (C)	Jaccard index (JI)	Citation
Northern Pakistan	2018	193	45	9	5	14	6.25	Malik *et al.* 2018
Sarban hill, Abbottabad Pakistan	2015	74	45	13	2	15	14.42	Ijaz *et al.* 2015
District Bannu Khyber Pakhtunkhwa	2017	55	45	9	4	9	9.89	Shaheen *et al.* 2017
Devi gali Azad Kashmir	2017	98	45	12	7	17	13.49	Anam *et al.* 2017
Oshikoto Namibia	2011	61	45	2	0	2	1.92	Ahmad *et al.* 2011
Sakrdu valley Pakistan	2014	50	45	0	0	1	1.06	Banu *et al.* 2014
Khyber Pakhtunkhwa Pakistan	2014	67	45	15	3	19	20.43	Khan *et al.* 2014
Uttarakhand India	2014	89	45	3	4	7	5.52	Singh *et al.* 2014
Shangla Kohistan Pakistan	2017	61	45	13	2	11	11.57	Shinware *et al.* 2017
Southwest Morocco	2020	22	45	9	3	1	1.51	Ouhadou *et al.* 2020
Malakand Pakistan	2018	77	45	11	2	20	19.60	Muhammad *et al.* 2018
Tirat valley Swat KpK	2017	65	45	12	4	16	17	Ali *et al.* 2017
Rawalkot Azad Kashmir	2019	41	45	1	2	5	6.17	Hussain *et al.* 2019
Khurram agency Pakistan	2018	52	45	4	1	13	15.47	Hussain *et al.* 2018
Khyber Pakhtunkhwa Pakistan	2019	52	45	16	0	7	7.77	Ullah *et al.* 2019
Ethiopia	2010	57	45	2	2	5	5.15	Teklehaymanot & Giday 2010
Tata province morocco	2012	163	45	4	2	7	3.48	Abouri *et al.* 2012
Hatay province, Turkey	2015	202	45	18	4	18	7.86	Güzel *et al.* 2015
Yunnan china	2011	199	45	4	1	5	2.09	Ghorbani *et al.* 2011
Parbat district Nepal	2015	132	45	4	2	6	3.51	Malla *et al.* 2015
Kerman, Iran	2017	115	45	6	0	6	3.89	Saddat *et al.* 2017
Italy	2016	106	45	5	7	12	8.63	Fortini *et al.* 2016
Gokand valley Khyber Pakhtunkhwa	2020	109	45	15	5	20	14.92	Suliman *et al.* 2020

PCTK score and harvesting

Calotropis procera is well-integrated in the cultural inheritance and showed a higher PCTK score in the study area. *C. procera* offers a wide range of medicinal uses, particularly in wound healing, body aches, fever, pneumonia, cough, snake bites, joint problems, asthma, and abdominal pain, these findings were in line with the studies conducted by different researchers (i.e., Kaur *et al.* 2015, Verma *et al.* 2010). According to the survey, a lesser PCTK score indicated that the plant is endangered or threatened ethnomedicinally (Kaur *et al.* 2015). Medicinal uses in recurrence are supported by a high PCTK score that shows wound healing in *C. procera* with a PCTK score of 91.47%. However, the majority of the uses were less than 10 % PCTK score, which shows the endangered position of *C. procera*. Verma *et al.* (2010) reported that the latex and leaves had higher concentrations of active chemicals than other plant components and are widely utilized for medical treatments. Moreover, roots and bark were unwisely overexploited by the local inhabitants that could affect the sustainable use of the plant species unless proper implementation of harvesting is adopted (Kuma *et al.* 2015). It may be inferred that *C. procera* is at significant risk of sustainability failure. Therefore, conservation measures such as agriculture practices, educating local communities about the need for conservation, proper harvesting, and sustainable utilization of plant parts could reduce the risk of it becoming an endangered species in the region.

Preference for traditional medicine

Most respondents chose traditional medications rather than professional allopathic medicines (Fig 4), the grounds for which are that traditional medicines are cheaper, safer, and more accessible than modern medicines. Moreover, sufficient modern health systems are not available in the majority of the study area. Similar observations were reported by (Augustino *et al.* 2014, Kitula 2007). The majority of the inhabitants in the remote communities have low revenues and lack sophisticated transportation technology, water availability, power, and a modern health care system (Ullah *et al.* 2019). Rural people are almost entirely dependent on herbal medicines (Ibrar *et al.* 2007, Kamble & Jadhav 2013), meaning that in the future will lead to the extinction of the *C. procera* species because many of the plants are collected in the wild. Therefore, the researcher further suggests that several individuals who belong to rural regions should be better served by social services and encouraged to conserve the medicinal plant.

Quantitative and medicinal uses of associated specie

Asteraceae was the most dominant family reported in terms of medicinal plants because out of 350,000 identified flowering plants, 10 % belong to the Asteraceae family. Similarly, Lamiaceae has a maximum proportion in ethno-medicine (Amira & Okubadejo 2007). The findings of the current study regarding the predominance utilization of Asteraceae in Khyber Pakhtunkhwa are supported by the study conducted by Bano *et al.* (2014) and Malik *et al.* (2018) in Pakistan. The high degree of ethnomedicinal plants of the Asteraceae family is due to their wide availability in the traditional uses by the local people. However, in the current study, more species belong to Asteraceae, Poaceae and Euphorbiaceae. Among these medicinal plant species, herbs were commonly used because most of the species are naturally abundant and easily accessible in Khyber Pakhtunkhwa (Abbasi *et al.* 2013). In the present work, leaves of the plant species were the most commonly used plant parts. These results supported previous studies conducted in different parts of the world, where the leaves are cited as commonly used parts of the medicinal plants (Bano *et al.* 2014, Rashid *et al.* 2015, Hussain *et al.* 2019). Medicinal plants are used in folk herbal remedies for the use of various diseases in the province (Shah *et al.* 2020).

The high number of citations indicated the significance of the selected plant species to the participants and their use in the area (Ahmad *et al.* 2017). The high UV suggested that these plants are prevalent in the area, as well as the indigenous inhabitants mostly dependent on them. According to results, plants that are utilized repetitively are likely to have high UV and biological activities (Amjad *et al.* 2017). Participants are familiar with the dominant plant species in the research area with high UV (Shaheen *et al.* 2017a). Moreover, the reliability of the plant species has been proven by using different medicinal plants used for the same purpose and brings the attention of the pharmacists towards further research (Ribeiro *et al.* 2017). In addition, it is also recommended by Mukherjee *et al.* (2012) that plants with high use value remain a good source for drug discoveries. However, plants with low use-value are not useless, but the participants do not know about the usage of species in the common diseases. Another cause has been studied by Leonti (2011) stated that the low use value lost their value due to geographical constraints.

Jaccard index

The high degree of similarity index in the folk uses may reflect the same type of vegetation, climatic condition, and cultural exchange among the local Participants (Ahmad *et al.* 2017, Faruque *et al.* 2018). Similarly, lower JI observed from European countries reflects the long-distance, different flora and different cultures between sites (Faruque *et*

al. 2018). In the present work, JI varies between 1.06 and 20.43 %. Plant communities present in the surrounding areas have more similar plants, while far away countries have different uses in common traditional therapeutic (Shaheen *et al*. 2017b). In the same way, the low similarity index of the medicinal plants shows their less social trade among the countries in the near past (Aziz *et al*. 2017). Moreover, Geological detachment among groups has an incredible effect on change in vegetation composition and change of social learning, where this may be a reason for the loss of ethnobotanical information (Amjad *et al*. 2017).

Conclusions

In recent years, ethnobotanical and traditional uses of medicinal plants have received much attention as they are well known for their efficacy and are generally believed to be safe for human use. The research design achieved the answers to the research questions and objectives in ethnobotanical data collection and analysis of *C. procera*. *C. procera* is well-known for its ancient ethnomedicinal properties and its religious integration. Information regarding the uses of *C. procera* by the local community of Khyber Pakhtunkhwa is matched with available literature. However, the uncontrolled uses of this plant suggested that the conservation of the plant species in question and other medicinal plants of the area should be encouraged. As part of the field inventory, it was discovered that a few locals were actively involved in the conservation of *C. procera*, and partial care was being given during the harvesting of medicinal plants. However, these conservation efforts will have slight effectiveness in the long term as the demand for medicinal plants grows, and most of the harvested plant material is just roots, leaves, and stem barks. Moreover, the use of this plant, which is unknown to the area's local community, should be widely disseminated to exploit its benefits for their well-being in daily life.

Declarations

Ethics approval and consent to participate: All participants provided prior informed consent.
Conflict of interest: The authors declare that they have no conflict of interest
List of abbreviations: Not applicable
Funding: This research work is a part of the doctoral research of the principal author and claims no funding sources to avail this project.

Acknowledgments

The present authors would like to express our thanks to Dr. Zahid Ullah for identifying plants from the Department of Botany, University of Swat. I sincerely acknowledge Dr. Faisal Khan for his untiring assistance during the manuscript write-up and support in the analysis and software use. I also acknowledge Mr. Rafi Ullah for his time and support in the manuscript.

Literature cited

Abbasi AM, Khan MA, Shah MH, Shah MM, Pervez A, Ahmad M. 2013. Ethnobotanical appraisal and cultural values of medicinally important wild edible vegetables of Lesser Himalayas-Pakistan. Journal of Ethnobiology and Ethnomedicine 9(1):1-13.

Abouri M, El Mousadik A, Msanda F, Boubaker H, Saadi B, Cherifi K. 2012. An ethnobotanical survey of medicinal plants used in the Tata Province, Morocco. International Journal of Medicinal Plants Research 1(7):99-123.

Ahmad L, Riaz M, Jan HA, Semotiuk AJ, Ahmad I, Khan I, Ali F, Rashid W, Bussmann RW. 2021. An ethnobotanical survey of wild food plants used by the local communities of Kumrat Valley in District Upper Dir, Pakistan. Ethnobotany Research and Applications 22:1-13.

Ahmad KS, Hamid A, Nawaz F, Hameed M, Ahmad F, Deng J, Mahroof S. 2017. Ethnopharmacological studies of indigenous plants in Kel village, Neelum valley, Azad Kashmir, Pakistan. Journal of Ethnobiology and Ethnomedicine 13(1):1-16.

Ahmad KS, Qureshi R, Hameed M, Ahmad F, Nawaz T. 2012. Conservation assessment and medicinal importance of some plant's resources from Sharda, Neelum Valley, Azad Jammu and Kashmir, Pakistan. International Journal of Agriculture Biology 14:997-1000

Ahmed MJ, Murtaza G. 2014. A study of medicinal plants used as ethnoveterinary harnessing potential phytotherapy in Bheri, District Muzaffarabad (Pakistan). Journal of Ethnopharmacology 159:209-214.

Ali H, Qaiser M. 2011. Contribution to the Red List of Pakistan: a case study of the narrow endemic *Silene longisepala* (Caryophyllaceae). Oryx 45(4):522-527.

Ali K, Khan N, Inayat-Ur R, Khan W, Ali M, Uddin M, Nisar M. 2018. The ethnobotanical domain of the Swat Valley, Pakistan. Journal of Ethnobiology and Ethnomedicine 14(1):1-15.

Ali M, Begum R, Ali K, Nisar M, Khan W, Hassan N, Khan N. 2017. Ethnobotanical survey of wild medicinal plants of Tirat Valley District, Swat, Khyber-Pakhtunkhwa. Journal of Biodiversity and Environmental Sciences 11(3):91-101.

Amira OC, Okubadejo NU. 2007. Frequency of complementary and alternative medicine utilization in hypertensive patients attending an urban tertiary care center in Nigeria. BMC Complementary and Alternative Medicine 7(1):1-5.

Amjad MS, Qaeem MF, AhmadI, Khan SU, Chaudhari SK, Zahid MN, ... & Khan AM. 2017. Descriptive study of plant resources in the context of the ethnomedicinal relevance of indigenous flora: A case study from Toli Peer National Park, Azad Jammu and Kashmir, Pakistan. PloS one 12(2)..

ARA M, Sarah SQ. 2017. Population ecology and economic importance of *Calotropis procera* as an exotic medicinal plant. Journal of Ecology and Nature 1:1.

Augustino S, Hall JB, Makonda FB, Ishengoma RC. 2014. Medicinal plant parts and practices used by communities around the Miombo woodlands of Urumwa, Tanzania. Journal of Medicinal Plants Research 8(15):599-606.

Azhar MF, Siddiqui MT, Ishaque M, Tanveer A. 2014. Study of ethnobotany and indigenous use of *Calotropis procera* (Ait.) in cholistan desert, Punjab, Pakistan. Journal of Agriculture and Research 52(1):117-126.

Aziz MA, Khan AH, Adnan M, Izatullah I. 2017. Traditional uses of medicinal plants reported by the indigenous communities and local herbal practitioners of Bajaur Agency, Federally Administrated Tribal Areas, Pakistan. Journal of Ethnopharmacology 198:268-281.

Bano A, Ahmad M, Hadda TB, Saboor A, Sultana S, Zafar M, Ashraf MA. 2014. Quantitative ethnomedicinal study of plants used in the skardu valley at high altitude of Karakoram-Himalayan range, Pakistan. Journal of Ethnobiology and Ethnomedicine 10(1):1-18.

Barkatullah IM, Rauf A, Hadda TB, Mubarak M, Patel S. 2015. Quantitative ethnobotanical survey of medicinal flora thriving in Malakand Pass Hills, Khyber Pakhtunkhwa. Pakistan. Journal of Ethnopharmacology 169:335-346.

Brewer C. 2006. Translating data into meaning: Education in conservation biology. Conservation Biology 20:689-691.

Faruque MO, Uddin SB, Barlow JW, Hu S, Dong S, Cai Q, Hu X. 2018. Quantitative ethnobotany of medicinal plants used by indigenous communities in the Bandarban District of Bangladesh. Frontiers in Pharmacology 9:40.

Fortini P, Di Marzio P, Guarrera PM, Iorizzi M. 2016. Ethnobotanical study on the medicinal plants in the Mainarde Mountains (central-southern Apennine, Italy). Journal of Ethnopharmacology 184:208-218.

Gulzar H, Hazrat A, Gulzar K, Ali F, Khan N, Nisar M, Khan I, Ullah A. 2019. Medicinal plants and their traditional uses in Thana Village, District Malakand, Khyber Pakhtunkhwa, Pakistan. International Journal of Endorsing Health Science Research 7(1):11-21.

Ghorbani A, Langenberger G, Feng L, Sauerborn J. 2011. Ethnobotanical study of medicinal plants utilised by Hani ethnicity in Naban river watershed national nature reserve, Yunnan, China. Journal of Ethnopharmacology 134(3):651-667.

Gurib-Fakim A. 2006. Medicinal plants: traditions of yesterday and drugs of tomorrow. Molecular aspects of Medicine 27(1):1-93.

Güzel Y, Güzelşemme M, Miski M. 2015. Ethnobotany of medicinal plants used in Antakya: a multicultural district in Hatay Province of Turkey. Journal of Ethnopharmacology 174:118-152.

Hamayun M. 2003. Ethnobotanical studies of some useful shrubs and trees of District Buner, NWFP, Pakistan. Ethnobotany Leaflets 12.

Haq F, Ahmad H, Alam M. 2011. Traditional uses of medicinal plants of Nandiar Khuwarr catchment (District Battagram), Pakistan. Journal of Medicinal Plants Research 5(1):9-48.

Hassan LM, Galal TM, Farahat EA, El-Midany MM. 2015. The biology of *Calotropis procera* (Aiton) WT. Trees 29(2):311-320.

Hussain S, Hamid A, Ahmad KS, Mehmood A, Nawaz F, Ahmed H. 2019. Quantitative ethnopharmacological profiling of medicinal shrubs used by indigenous communities of Rawalakot, District Poonch, Azad Jammu and Kashmir, Pakistan. Revista Brasileira de Farmacognosia 29(5):665-676.

Hussain SS, Mudasser M. 2007. Prospects for wheat production under changing climate in mountain areas of Pakistan-An econometric analysis. Agricultural Systems 94(2):494-501.

Hussain W, Badshah L, Ullah M, Ali M, Ali A, Hussain F. 2018. Quantitative study of medicinal plants used by the communities residing in Koh-e-Safaid Range, northern Pakistani-Afghan borders. Journal of Ethnobiology and Ethnomedicine 14(1):1-18.

Ibrar M, Hussain F, Sultan A. 2007. Ethnobotanical studies on plant resources of Ranyal hills, District Shangla, Pakistan. Pakistan Journal of Botany 39:329

Ijaz F, Iqbal Z, Alam J, Khan SM, Afzal A, Rahman IU, Sohail M. 2015. Ethnomedicinal study upon folk recipes against various human diseases in Sarban Hills, Abbottabad, Pakistan. World Journal of Zoology 10(1):41-46.

Irfan M, Nabeela IK, Kamil M, Ullah S, Khan S, Shah M, Murad W. 2018. Ethnobotanical Survey of the Flora of Tehsil Balakot, District Mansehra, Khyber Pakhtunkhwa, Pakistan. Journal of Applied Environmental and Biological Sciences 8(8):1-13.

Jan G, Jan FG, Hamayun M, Khan K, Khan A. 2014. Diversity and conservation status of vascular plants of Dir Kohistan valley, Khyber Pakhtunkhwa Province. Journal of Biodiversity and Environmental Sciences 5(1):164-72.

Kabir H, Naz A, Khan NA. 2003. Unani medicinal plants in Hamdard University campus [India]. Hamdard Medicus (Pakistan).

Kamble VS, Jadhav VD. 2013. Traditional leafy vegetables: a future herbal medicine. International Journal of Agriculture and Food Science 3(2):56-58.

Khan I, Khan U, Khan K, Nawaz M, Khan N, Ali F. 2018. In vitro anti-pseudomonal potential of *Juglans regia* and *Otostegia limbata* leaves extract against planktonic and biofilm form of Pseudomonas aeruginosa. Pakistan Journal of Botany 50(2):827-833.

Khan AA, Ali F, Ihsan M, Hayat K, Nabi G. 2015. Ethnobotanical study of the medicinal plants of Tehsil Charbagh, district Swat, Khyber Pakhtunkhwa, Pakistan. American Eurasian Journal of Agriculture and Environmental Sciences 15:464-1474.

Kaur J, Rani S, Singh G, Sood N. 2015. Intensity and depth of traditional knowledge of two medicinally important plants-Thevetia peruviana and *Calotropis procera* presently conserved in rural areas of Haryana. Journal of Medicinal Plants 3(6): 4-32.

Khan N, Abbasi AM, Dastagir G, Nazir A, Shah GM, Shah MM, Shah MH. 2014. Ethnobotanical and antimicrobial study of some selected medicinal plants used in Khyber Pakhtunkhwa (KPK) as a potential source to cure infectious diseases. BMC Complementary and Alternative Medicine 14(1):1-10.

Kuma F, Birhanu T, Hirpa E, Nekemte E. 2015. Advanced review on anthelmintic medicinal plants. children, 13, 14.

Kumar A. 1998. Biomass energy crops of semi-arid regions of India and their energy potential. Biomass for energy and industry. Germany/Carmen 345-348.

Leonti M. 2011. The future is written: impact of scripts on the cognition, selection, knowledge and transmission of medicinal plant use and its implications for ethnobotany and ethnopharmacology. Journal of Ethnopharmacology 134(3):542-555.

Lottermoser BG. 2011. Colonization of the rehabilitated Mary Kathleen uranium mine site (Australia) by *Calotropis procera*: toxicity risk to grazing animals. Journal of Geochemical Exploration 111(1-2):39-46.

Malik K, Ahmad M, Bussmann RW, Tariq A, Ullah R, Alqahtani AS, Shah SN. 2018. Ethnobotany of anti-hypertensive plants used in northern Pakistan. Frontiers in Pharmacology 9:789.

Malla B, Gauchan DP, Chhetri RB. 2015. An ethnobotanical study of medicinal plants used by ethnic people in Parbat district of western Nepal. Journal of Ethnopharmacology 165:103-117.

Marwat KB, Hashim S, Ali H. 2010. Weed management: a case study from north-west Pakistan. Pakistan Journal of Botany 42:341-353.

Mbinile SD, Munishi LK, Ngondya IB, Ndakidemi PA. 2020. Conservation and Management Challenges Facing a Medicinal Plant Zanthoxylum chalybeum in Simanjiro Area, Northern Tanzania. Sustainability,12(10):4140.

Mpondo FT, Ndakidemi PA, Treydte AC. 2021. Balancing Bees and Livestock: Pastoralist Knowledge, Perceptions and Implications for Pollinator Conservation in Rangelands, Northern Tanzania. Tropical Conservation Science:14.

Msomi NZ, Simelane MB. 2018. Herbal Medicine. In Herbal Medicine. IntechOpen.

Muhammad N, Khan MKU, Uddin N. 2020. Ethnoveterinary medicines used against various livestock disorders in the flora of Shamozai Valley, Swat, KP Pakistan. Traditional Medicine Research 5(5):377-388.

Muhammad Z, Ali H, Khan WM, Rehmanullah GJ, Majeed A. 2018. 1. Conservation status of plant resources of Hazar Nao hills, district Malakand, Pakistan. Pure and Applied Biology (PAB) 7(3):931-945.

Mukherjee PK, Nema NK, Venkatesh P, Debnath PK. 2012. Changing scenario for promotion and development of Ayurveda way forward. Journal of Ethnopharmacology 143:424-434

Murad W, Azizullah A, Adnan M, Tariq A, Khan KU, Waheed S, Ahmad A. 2013. Ethnobotanical assessment of plant resources of Banda Daud Shah, district Karak, Pakistan. Journal of Ethnobiology and Ethnomedicin 9(1):1-10.

Nahashon M. 2013. Conservation of Wild-harvested Medicinal Plant Species in Tanzania: Chain and consequence of commercial trade on medicinal plant species 50.

Ngondya IB, Ibrahim RIH, Choo GC. 2011. Are poverty and illiteracy to blame for forests degradation? A case study of Mbeya range forest reserve. Mbeya-Tanzania. Journal of Forest and Environmental Science 27(2):93-99.

Oladeji O. 2016. The Characteristics and roles of medicinal plants: Some important medicinal plants in Nigeria. Indian Journal of Natural Products 12(3):102.

Ouhaddou HOH, Alaqui A, Sezgin AYAN. 2020. Ethnobotanical survey of medicinal plants used for treating diabetes in Agadir Ida Outanane region, Southwestern Morocco. Arabian Journal of Medicinal and Aromatic Plants 6(2):72-86.

Parsons WT, Cuthbertson EG. 2001. *Noxious weeds of Australia*. CSIRO publishing.

Phillips OL. 1996. Some quantitative methods for analyzing ethnobotanical knowledge. Advances in Economic Botany 10:171-197.

Poonam K, Singh GS. 2009. Ethnobotanical study of medicinal plants used by the Taungya community in Terai Arc Landscape, India. Journal of Ethnopharmacology 123(1): 67-176.

Rani P, and Sood N. 2021. Qualitative and quantitative ethnobotanical analysis of *Ricinus communis* L. and *Azadirachta indica* A. Juss. in Sonipat District of Haryana, India. Journal of Natural Remedies 21(1):61-69.

Rashid S, Ahmad M, Zafar M, Sultana S, Ayub M, Khan MA. 2015. Ethnobotanical survey of medicinally important shrubs and trees of Himalayan region of Azad Jammu and Kashmir, Pakistan. Journal of Ethnopharmacology 166:340-351. doi: 10.1016/j.jep.2015.03.042

Ribeiro RV, Bieski IGC, Balogun SO, de Oliveira Martins DT. 2017. Ethnobotanical study of medicinal plants used by Ribeirinhos in the North Araguaia microregion, Mato Grosso, Brazil. Journal of Ethnopharmacology 205:69-102.

Sadat-Hosseini M, Farajpour M Boroomand N, Solaimani-Sardou F. 2017. Ethnopharmacological studies of indigenous medicinal plants in the south of Kerman, Iran. Journal of Ethnopharmacology 199:194-204.

Salma M, Abdellah F, El Houssine A, Kawtar B, Dalila B. 2016. Comparison of the chemical composition and the bioactivity of the essential oils of three medicinal and aromatic plants from Jacky Garden of Morocco. International Journal of Pharmacognocy and Phytochemical Research 8:537-545.

Schippmann U, Leaman DJ, Cunningham AB. 2002. Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. Biodiversity and the ecosystem approach in agriculture, forestry and fisheries. 143-167.

Shabir A, Naveed I, Uneeza, J, Noor UAIZ. Hina J, Farhat Y. 2017. Ethnobotanical Wisdom of Inhabitant of Devi Galli Azad Kashmir. Biomedical Journal of Science and Technology Research 1(6):1618-1627.

Shah S, Khan S, Bussmann RW, Ali M, Hussain D, Hussain W. 2020. Quantitative ethnobotanical study of Indigenous knowledge on medicinal plants used by the tribal communities of Gokand Valley, District Buner, Khyber Pakhtunkhwa, Pakistan. Plants 9(8):1001.

Shah SM, Amin M, Gul B, Begum M. 2020. Ethnoecological, Elemental, and Phytochemical Evaluation of Five Plant Species of Lamiaceae in Peshawar, Pakistan. Scientifica 2020.

Shaheen H, Qaseem MF, Amjad MS, Bruschi P. 2017a. Exploration of ethno-medicinal knowledge among rural communities of Pearl Valley; Rawalakot, District Poonch Azad Jammu and Kashmir. PloS one 12(9)..

Shaheen HS, Aziz, MEUI, Dar. 2017b. Ecosystem services and structure of western Himalayan temperate forests stands in Neelam valley, Pakistan. Pakistan Journal of Botany 49(2):707-714.

Shinwari S, Ahmad M, Luo Y, Zaman W. 2017. Quantitative analyses of medicinal plants consumption among the inhabitants of Shangla-Kohistan areas in Northern-Pakistan. Pakistan Journal of Botany 49(2):725-734.

Shinwari ZK. 2010. Medicinal plants research in Pakistan. Journal of Medicinal Plants Research 4(3):161-176.

Sing H, HusainT, Agnihotri P, Pande PC, Khatoon S. 2014. An ethnobotanical study of medicinal plants used in sacred groves of Kumaon Himalaya, Uttarakhand, India. Journal of Ethnopharmacology 154:98-108. doi: 10.1016/j.jep.2014.03.026

Swai RE. 2003. Utilization and commercialization of medicinal tree products in Tanzania. Journal of Ethnopharmacology 86(1):1-10.

Teklehaymanot T. Giday M. 2010. Quantitative ethnobotany of medicinal plants used by Kara and Kwego semi-pastoralist people in lower Omo River Valley, Debub Omo zone, southern nations, nationalities and peoples regional state, Ethiopia. Journal of Ethnopharmacology 130(1):76-84.

Ullah M, Mehmood S, Ali M, Bussmann RW, Aldosari A, Khan RA, Shah MAR. 2019. An ethnopharmacological study of plants used for treatment of diabetes in the Southern and Tribal regions of Khyber Pakhtunkhwa province, Pakistan. Ethnobotany Research and Applications 18:1-20.

Ullah S, Khan N, Ali F, Badshah L, Asghar A, Muhammad N. 2020. An ecological assessment of *Justicia adhatoda* L. in Malakand Division, Hindukush range of Pakistan. Bioscience Research 17:1082-1094

Verma R, Satsangi G, Shrivastava J. 2010. Ethno-Medicinal Profile of Different Plant Parts of *Clotropis procera* (Alt.) R. Br. Ethnobotanical Leaflets 14:721-742.

WHO, 2002.Traditional Medicine: Growing Needs and Potentials, Geneva.

York T, De Wet H, Vuuren SF. 2011. Plants used for treating respiratory infections in rural Maputaland, KwaZulu-Natal, South Africa Journal of Ethnopharmacology 135:696-710