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

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\textbf{Abstract}

\textbf{Background:} \textit{Calotropis procera} is one of the most effective herbal medicinal shrubs. Although many studies have explored the ecological aspects of \textit{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.

\textbf{Methods:} Semi-structured questionnaires, group discussions, and field observations were used to collect data on the therapeutic uses of \textit{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).

\textbf{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, \textit{C. procera} had a higher PCTK score for thorn pricking (96 \%) and wound healing (93.5 \%). The UV varied from 0.08 (\textit{Lamium amplexicaule} L.) to 0.79 (\textit{C. procera} W.T. Aiton). The RFC ranged from 0.06 (\textit{Xanthium strumarium} L.) to 0.28 (\textit{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.

\textbf{Conclusions:} Our results provide support for the use of \textit{C. procera} in traditional medicine. Hence, the PCTK results of the present work demonstrated that \textit{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.

\textbf{Keywords:} \textit{Calotropis procera}, Conservation, Northern areas, Quantitative ethnobotany

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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 Asclepiadaceae 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, overgrowing 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 purposefully 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 ethnomedical significance of C. procera for the local inhabitants.
and local 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 km² (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) km² 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.

![Study Area Map](image)

**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 ≤ 70) and junior (25 ≤ 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           | 2.95              |
| 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 (76.5%).
Table 4. Quantitative analysis of study area with special reference to *C. procera*

| Plant part | FC  | RFC  | RUPP | PPV  | SU   | ΣUs  | 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 | ∑Ul | 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|
|                 | *Amaranthus retroflexus* 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|
| Family         | Species                                      | Part Used          | Uses                                                                 | ED  | SI  | AI  |
|---------------|----------------------------------------------|--------------------|----------------------------------------------------------------------|-----|-----|-----|
| Brassicaceae  | *Sisymbrium irio* L.                         | Leaves, flower     | Liver disorders, cough and chest congestion, wound healing           | 13  | 0.06| 6   |
| Poaceae       | *Eragrostis minor* L.                        | Leaves, seed       | Contusions, headache                                                | 15  | 0.07| 7   |
|              | *Avena sativa* L.                           | Seeds              | Constipation, kidney disorders, bladder weakness, gallstone         | 35  | 0.17| 16  |
|              | *Cynodon dactylon* L.                       | Whole plant        | Wound healing                                                       | 23  | 0.11| 9   |
|              | *Triticum aestivum* L.                      | Whole plant        | Cancer, diarrhea, dysentry, fertility, and fever                    | 15  | 0.12| 18  |
| Polygonaceae  | *Rumex dentatus* L.                         | Whole plant        | Purgative, Wound healing, skin rash, piles, urinary complaints      | 34  | 0.17| 5   |
| Apiaceae      | *Eryngium billardieri* Delile               | Whole plant        | Menstrual cramps, urinary disorders, anti-inflammatory              | 39  | 0.19| 8   |
| Myrtaceae     | *Eucalyptus lanceolata* L.                  | Leaves, seed       | Anti-septic, cough, and fever                                       | 25  | 0.12| 14  |
| Convolvulaceae| *Ipomoea purpurea* (L.) *Roth*             | Whole plant        | Laxative, purgative, hallucinogen                                  | 29  | 0.14| 12  |
| Oleaceae      | *Jasminum officinale* L.                    | Flower             | Hepatitis, dysentry, sedative                                      | 32  | 0.16| 4   |
| Aizoaceae     | *Trianthema portulacastrum* L.              | Leaves             | Jaundice, wound healing, blood diseases, cancer                    | 30  | 0.15| 13  |
| Lamiaceae     | *Mentha longifolia* (L.) *Huds*             | Leaves             | Abdominal pain, diarrhea, vomiting                                  | 56  | 0.28| 23  |
|              | *Lamium amplexicaule* L.                    | Whole plant        | Laxative, stimulant, diaphoretic                                   | 57  | 0.28| 5   |
| Malvaceae     | *Malva parviflora* L.                       | Leaf, root, seed   | Cough, ulcer, hair tonic                                           | 26  | 0.13| 17  |
| Meliaceae     | *Melia azedarach* L.                        | Leaves, seed       | Laxative, antiseptic, liver disease                                 | 17  | 0.08| 9   |
| Moraceae      | *Morus alba* L.                             | Fruit              | Increase digestion, constipation                                   | 21  | 0.10| 11  |
|              | *Ficus carica* L.                           | Fruit, latex       | Stomach disorders, removal of wort.                                | 28  | 0.14| 17  |
| Solanaceae    | *Solanum nigrum* L.                         | Whole plant        | Skin disease, asthma, body tonic, dysentry,                        | 28  | 0.14| 17  |
| Salicaceae    | *Populus nigra* L.                          | Leaf buds, bark    | Pain killer, anti-inflammatory, digestive disorders, anti-septic  | 35  | 0.17| 17  |
| Family                | Species                        | Part(s)                       | Uses                                                      | Rating | Efficacy | Selectivity |
|----------------------|--------------------------------|-------------------------------|-----------------------------------------------------------|--------|----------|-------------|
| Euphorbiaceae        | *Ricinus communis* L.          | Seeds, root, leaves, bark     | Purgative, anti-inflammatory, pain killer                 | 28     | 0.14     | 15          |
|                      | *Chrozophora tinctoria* (L.) A. Juss | Leaves                      | Diabetes, wound healing                                   | 23     | 0.12     | 9           |
|                      | *Euphorbia helioscopia* L.     | Latex                        | Cholera, kidney stone                                     | 23     | 0.11     | 12          |
| Fabaceae             | *Trifolium repens* L.          | Leaves                       | Cough, leucorrhea                                         | 19     | 0.09     | 8           |
|                      | *Medicago denticulata* L.      | Leaves                       | Anti-diabetic, anti-inflammatory, cancer, anti-viral      | 28     | 0.14     | 19          |
| Urticaceae           | *Urtica dioica* L.             | Leaves                       | Cardiovascular disorder, kidney stone, cancer             | 47     | 0.23     | 2           |
| Scrophulariaceae     | *Verbascum thapsus* L.         | Leaves                       | Otitis media                                             | 24     | 0.12     | 4           |
| Vitaceae             | *Vitis vinifera* L.            | Leaf, fruit                  | Cholera, smallpox, liver and kidney disease, nausea      | 28     | 0.14     | 3           |
| Rutaceae             | *Zanthoxylum armatum* DC. Prodr | Fruit                        | Gum pain, abdominal pain, cooling agent                   | 49     | 0.24     | 34          |
| Rhamnaceae           | *Ziziphus oxyphylla* Edgew     | Root, fruit, leave           | Diabetes, constipation, loss of appetites                 | 37     | 0.18     | 18          |
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           |
| Sakrdhu 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, Lamiaeaceae has a maximum proportion in ethnomedicine (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 J1 observed from European countries reflects the long-distance, different flora and different cultures between sites (Faruque et
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

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