



RESEARCH ARTICLE

Reckoning the ethnomedicinal potential of the endemic pitcher plant (*Nepenthes khasiana* Hook. f.) for its conservation through people's voices in Meghalaya, India

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Received: 28 October 2025; Accepted: 19 April 2026; Available online: Version 1.0: 08 June 2026; Version 2.0: 10 June 2026

Cite this article: Anindita B, Sarah GM, Prabal S. Reckoning the ethnomedicinal potential of the endemic pitcher plant (*Nepenthes khasiana* Hook. f.) for its conservation through people's voices in Meghalaya, India. Plant Science Today. 2026; 13(2): 1-9. <https://doi.org/10.14719/pst.12455>

Abstract

The pitcher plant, *Nepenthes khasiana* Hook. f., is an endemic and endangered species with immense pharmacological potential and is used to treat several ailments. It requires urgent conservation, as it is currently threatened with extinction due to various human-induced factors in the Garo, Khasi and Jaintia Hills of Meghalaya, India. The present study was initiated to evaluate the ethnomedicinal value of *N. khasiana*, along with its conservation measures, as perceived by the people. Both open-ended and closed-ended questionnaires were administered to document the ethnomedicinal properties of the pitcher plant with respect to age, gender, occupation, education and regional differences to understand the ethnomedicinal use and people's knowledge and willingness towards conservation and the importance of the plant in their livelihood. The present study revealed that older people, male members and residents of Jaintia Hills primarily use pitcher plants as medicines; however, younger generations are apathetic towards preserving this indigenous knowledge. The plant was used to treat various ailments related to the eye, gastrointestinal, leprosy, skin, kidney, diabetes and gynaecological problems. The pitcher fluid of the plant was used more compared to other parts of the pitcher plant. Additionally, most of the informants of young age groups, in the Garo and Khasi Hills area, abstain from any inclination on the conservation perspective of pitcher plants growing in Meghalaya. Consequently, public awareness, stakeholder participation and integration of the significance of the pitcher plant in people's culture and tradition are requisite for the conservation of indigenous knowledge and the pitcher plant.

Keywords: conservation; ethnomedicine; indigenous knowledge; *Nepenthes khasiana*; pitcher plant

Introduction

Nepenthes khasiana Hook. f., a carnivorous plant belonging to the family Nepenthaceae under the order Caryophyllales, is the only species of the genus *Nepenthes* (Fig. 1). Globally, around 810 species of carnivorous plants are found in North America, South Asia and Australia (1). India is home to approximately 44 species of carnivorous plants from the families Droseraceae (*Drosera*: 3; *Aldrovanda*: 1), Lentibulariaceae (*Utricularia*: 38; *Pinguicula*: 1) and Nepenthaceae, which includes a single species of pitcher plant (2, 3). *Nepenthes khasiana* is the only pitcher plant species that is endemic to the Garo, Khasi and Jaintia Hills of Meghalaya in Northeast India (4). Due to habitat destruction, overexploitation and its limited distribution, *N. khasiana* is classified as Endangered in the IUCN Red Data Book, listed under Appendix I of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and included in the Government of India's Negative List of Export (5–8).

The plant *N. khasiana* is closely associated with the indigenous communities of Meghalaya, who use its pitchers and plant extracts in traditional medicine to treat various ailments, including stomach disorders, diabetes and eye diseases, highlighting its ethnobotanical significance in the region (9–12). About 1878 kg of pitchers are used

annually in traditional medicine in Khasi and Jaintia Hills, whereas pitcher plants are collected from Nokrek Biosphere Reserve for medicinal purposes, as a result of which their population is decreasing sharply (13). Further, lack of public awareness and objections regarding the cultivation of medicinal plants by some traditional healers hinder the conservation process (14). The importance of pitcher plants needs to be addressed among the inhabitants and stakeholders in general. Henceforth, the conservation of pitcher plants needs urgent attention, considering their immense pharmacological potential (15, 16).

Various studies reported the use of pitcher plant in treating various ailments in Meghalaya and it adjoining areas (17–23). Those studies were general and did not focus on firm statistical analysis along with conservation of a species in the light of people's choice, especially for the endemic species such as *N. khasiana*. Thus, a concrete report on the endangered species is essential to understand the people's attitude, knowledge and the importance of the plant in their daily lives. The importance of understanding the endemic species will not only be helpful for its conservation planning, but also its ethnomedicinal importance can be expanded in future pharmacological research. The study aimed to understand the role of the species in the primary healthcare of the people of Meghalaya and their attitudes towards



Fig. 1. Pitcher plant, *Nepenthes khasiana*, endemic to Northeast India.

conservation of the species.

Materials and Methods

Study area

The present study was carried out in the state of Meghalaya, India, situated between latitudes 24° 58' N and 26° 07' N and longitudes 89° 48' E and 92° 51' E (Fig. 2). The state encompasses a total area of 22429 square km, with a forested area of 8510 square km. Meghalaya is home to various forest types, including tropical moist and dry deciduous forests, tropical evergreen forests, tropical semi-evergreen forests, grasslands and savannas, temperate forests and sacred groves, which support a diverse range of mammals, birds and plant species. The western region of this northeastern state experiences an average annual rainfall of approximately 2600 mm, while northern Meghalaya receives annual rainfall ranging from 2500 to 3000 mm. In contrast, the southeastern part of Meghalaya receives more than 4000 mm of



rainfall annually (24). The primary inhabitants of Meghalaya include the Garos, Khasis and Jaintias.

Sampling and data collection

A multi-stage sampling method was used to identify the sample from the study area. At first, 5 villages from each hill of Meghalaya were randomly selected for this study (Garo Hills: Balsri Gittim, Baghmara, Bhawanipur, Matcha-Nokpante and Bandarigre; Jaintia Hills: Ksietphare, Tuber Sohshrich, Rymbai, Bataw, Umtasai and Mustem areas; Khasi Hills: Nonglang, Phlangdilion, Ranikor, Lawbah and Pynursla). From each village, 12 households (6 male and 6 female respondents) were randomly identified as respondents. Prior to the interview, informed consent was taken from the respondents to publish the findings of the research. Senior members of a household were interviewed for the survey; however, in case the senior member was reluctant to speak, the immediate senior above 18 years of age was selected. We also prioritised the selection of respondents in three different age groups, namely,

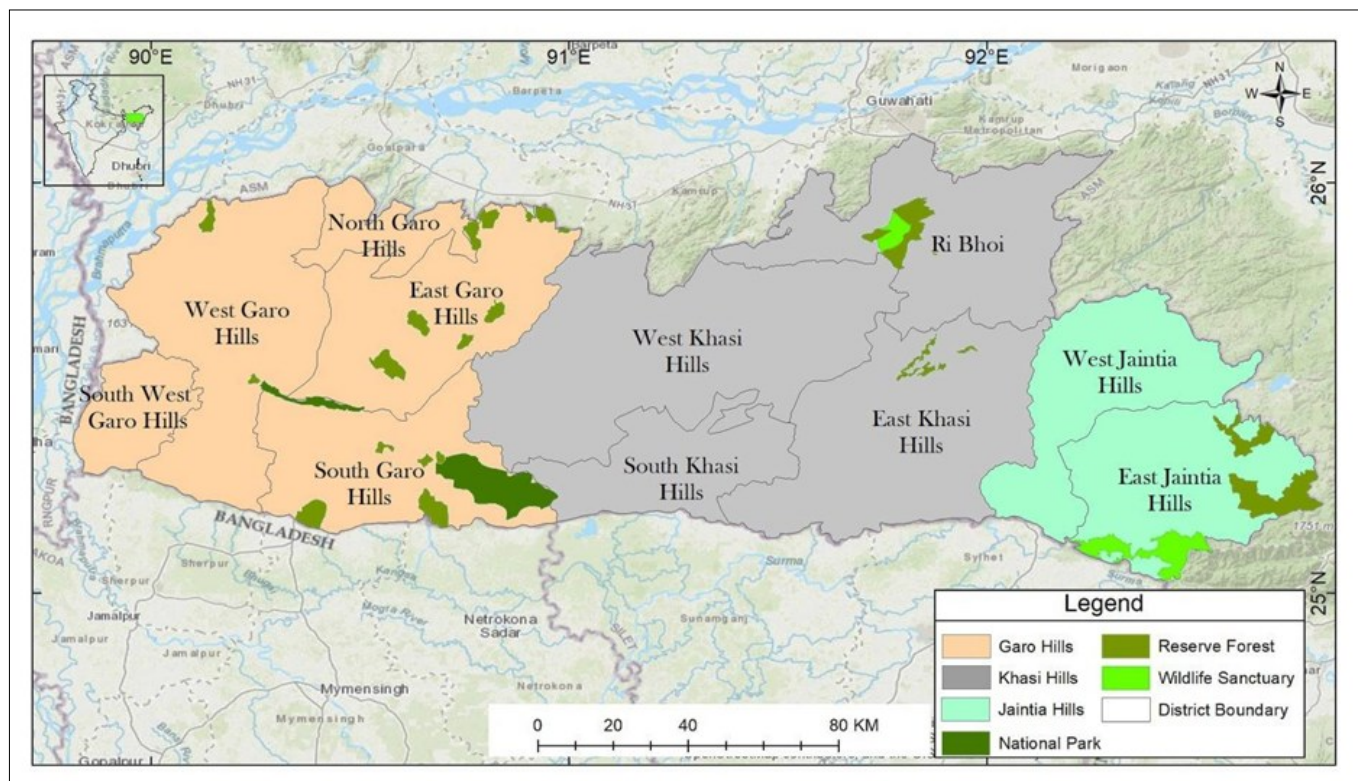


Fig. 2. Map of Meghalaya, India, showing the different hills where this study was conducted. (Source: Prepared by the authors using publicly available administrative boundary and protected forest datasets; the map is provided solely to indicate the location of the study area).

young (20–35 years old), middle (36–50 years old) and old (> 50 years old) were selected for this purpose. A total of 360 respondents were collected, of which 120 each were from Garo, Khasi and Jaintia Hills. Similarly, 120 samples each represented young, middle and old age groups. On the other hand, an equal number of samples (50 % sample) is represented by each gender.

The study was conducted using a mixed-methods approach for collecting both quantitative and qualitative data (25). Quantitative data were collected during interviews using structured (fixed-response / closed-ended questions) and open and semi-structured questions. Qualitative data were collected through informal discussions with the family members or participatory rural appraisal (26–33). For this, a standardised and structured questionnaire was prepared to ensure the reliability, generalisability and validity of the responses and semi-structured questionnaires were used to reduce bias in the responses of respondents. The respondents were selected randomly and the entire questionnaire was queried through ‘face-to-face’ communication with the respondents. Interviews were conducted in local languages (Garo, Jaintia and Khasi) with which all the respondents were familiar and local interpreters were also used for a better understanding of the question as well as the respondent statement (25). The data were later analysed based on the respondents' education, occupation, age, gender and regions of Meghalaya to find out which of the two parameters of the respondents influence the ethnobotanical importance of the pitcher plant.

Data analysis

The thematic coding approach was used in qualitative analysis, grouping the data into common categories or themes before analysis (31). Data was analysed using SPSS Version 25.0. Perceptions were related to gender, age and hill variables. A bivariate (chi-square test) and point-biserial correlation were employed at a $p \leq 0.05$ level to analyse the perception's significant differences. Quantitative indices [Fidelity level (FL) and Plant part value (PPV)] were computed.

Plant part value

The PPV displayed the significance of each employed part of the plant by the interviewee. The highest PPV is the most important part used by the informants. It is calculated using the following formula:

$$PPV = \frac{RU \text{ plant part}}{RU} \quad \text{Eq. (1)}$$

where RU plant part is the number of the reported uses per part of the plant and RU is the number of reported uses of all parts of the plant (34).

Fidelity level

The FL was applied to grasp the most essential plant species used for treating certain ailments. A higher FL value indicated that the usage of the plant for specific curative purposes is preferred more if respondents cited it repeatedly. It was computed with the following formula:

$$FL \% = \frac{NP}{N} \times 100 \quad \text{Eq. (2)}$$

where NP is the number of informants who stated the use of the plant for specific illnesses and N is the number of informants who recommended the plant for various ailments (35).

Results

Socio-economic profile of the respondents

A large percentage of respondents (40.56 %) had an education up to primary level, followed by secondary (27.78 %), higher secondary (20.83 %) and the remaining 10.83 % respondents were graduate or above level of education (Table 1). Education among the respondents varied significantly between the genders ($\chi^2 = 10.759$, $p \leq 0.05$). The finding revealed that females had a higher percentage (44.4 %) of primary education than male respondents (36.7 %), while a higher percentage of male respondents (16.1 %) had graduate and above education than the female respondents (5.6 %). However, both male and female respondents had almost equal percentages in secondary and higher secondary levels of education (Table 1). A significant difference in education was noted between the three hills of the state ($\chi^2 = 31.912$, $p \leq 0.05$). Education limited to only the primary level was observed among most of the respondents (55 %) in Jaintia Hills, while the number of respondents with higher secondary and graduate or above the level of education was highest in Garo Hills, followed by Khasi Hills and Jaintia Hills (Table 1).

Overall, most of the respondents (56.6 %) were agriculturists by occupation (Table 1). Only 8.5 % of the respondents were engaged in a job (both government and private). The occupation also varied statistically among different genders ($\chi^2 = 31.277$, $p \leq 0.05$) in the present study. Females (71.1 %) were more engaged in agriculture than males (42.8 %) in the study area. Although agriculture was the dominant occupation in all the regions of Meghalaya, it varied significantly ($\chi^2 = 14.867$, $p \leq 0.05$). Being lowest in all the sectors of occupations, the unemployed were highest in Jaintia Hills (35.8 %) as compared to Garo Hills (22.5 %) and Khasi Hills (18.3 %).

Table 1. Education standard and occupations of the respondents in Meghalaya, India

Education level	Age group			Gender		Hills		
	Young	Middle	Old	Male	Female	Garo	Jaintia	Khasi
Education standard								
Primary	15.0 % (n = 18)	25.8 % (n = 31)	80.8 % (n = 97)	36.7 % (n = 66)	44.4 % (n = 80)	25.8 % (n = 31)	55.0 % (n = 66)	40.8 % (n = 49)
Secondary	24.2 % (n = 29)	44.2 % (n = 53)	15.0 % (n = 18)	27.2 % (n = 49)	28.3 % (n = 51)	28.3 % (n = 34)	28.3 % (n = 34)	26.7 % (n = 32)
Higher secondary	39.2 % (n = 47)	20.0 % (n = 24)	3.3 % (n = 4)	20.0 % (n = 36)	21.7 % (n = 39)	26.7 % (n = 32)	12.5 % (n = 15)	23.3 % (n = 28)
Degree or more	21.7 % (n = 26)	10.0 % (n = 12)	0.8 % (n = 1)	16.1 % (n = 29)	5.6 % (n = 10)	19.2 % (n = 23)	4.2 % (n = 5)	9.2 % (n = 11)
Occupation								
Agriculture	22.5 % (n = 27)	60.8 % (n = 73)	87.5 % (n = 105)	42.8 % (n = 77)	71.1 % (n = 128)	55.8 % (n = 67)	53.3 % (n = 64)	61.7 % (n = 74)
Job and wage	10.8 % (n = 13)	13.3 % (n = 16)	1.7 % (n = 2)	10.0 % (n = 18)	7.2 % (n = 13)	12.5 % (n = 15)	5.0 % (n = 6)	8.3 % (n = 10)
Business	9.2 % (n = 11)	13.3 % (n = 16)	4.2 % (n = 5)	13.3 % (n = 24)	4.4 % (n = 8)	9.2 % (n = 11)	5.8 % (n = 7)	11.7 % (n = 14)
Unemployed	57.5 % (n = 69)	12.5 % (n = 15)	6.7 % (n = 8)	33.9 % (n = 61)	17.2 % (n = 31)	22.5 % (n = 27)	35.8 % (n = 43)	18.3 % (n = 22)

Usage as medicine

Although the medicinal value of the pitcher plant is traditionally known to them, only 22.5 % (n = 81) of the respondents had experience using it as medicine provided by their family members (Table 2). Age groups significantly influenced the use of pitcher plants ($\chi^2 = 36.416, p \leq 0.05$; Fisher's exact = 39.573, $p \leq 0.05$). Among the users, old age people used the most (38.3 %, n = 46) while younger people were the least (5.8 %, n = 7). The gender-based study showed that there was considerable variation in usage between the genders ($\chi^2 = 9.956, p \leq 0.05$). Males (29.4 %, n = 53) were comparatively more users of pitcher plants as medicine than females (15.6 %, n = 28). A significant difference ($\chi^2 = 23.035, p \leq 0.05$) was also observed between Garo, Jaintia and Khasi Hills for the use of pitcher plants as medicine. The people of Jaintia Hills (35.8 %, n = 43) were the maximum users of pitcher plants as medicine, followed by Garo Hills (21.7 %, n = 26) and the least by the folks of Khasi Hills (10.0 %, n = 12).

Ailments treated

The study found that the majority of the people (22.5 %, n = 81) use parts of the pitcher plant for treating eye-related disorders, followed by leprosy and skin problems (16.4 %, n = 59), kidney problems (13.9 %, n = 50), while usage for diabetes and gynecological problems was the least preferred (6.4 %, n = 23 each). There was a difference ($\chi^2 = 1.139E2, p \leq 0.05$) among the young, middle and old age groups in their views on the use of pitcher plants to treat various diseases. Both old (38.3 %, n = 46) and middle-aged groups (23.3 %, n = 28) mostly used the parts of the pitcher plant for treating eye-related disorders, while the young people (21.7 %, n = 26) used it for treating stomach disorders. The second most preferred treatment category among the older (32.5 %, n = 39) and middle-aged respondents (13.3 %, n = 16) was leprosy and other skin-related disorders, whereas the younger age group primarily preferred treatments for eye-related problems (5.8 %, n = 7).

The third area of preference for the treatment was kidney-related problems (Table 3). Older and middle-aged people relied most on the plant for the treatment of kidney-related problems. Females (15.6 %) were comparatively higher in using the plant for kidney treatment than males (12.2 %). Regionally, respondents from the Jaintia Hills (23.3 %) used the plants more than the other two regions of the state. About 30.7 % respondents used plants for the treatment of gastrointestinal disorders. Most of them were young (21.7 %), followed by middle-aged (7.5 %) and older (1.7 %). Gender-wise, females (12.8 %) contributed more to using the plant for gastrointestinal remedies than their male counterparts (7.8 %). Respondents from Garo Hills were using the plant for treating gastrointestinal disease more than the other regions of the state.

Like eye problems, older (15.8 %) and middle-aged (3.3 %) respondents were found using the plant for ear treatment more than the younger generation (0.8 %). Male (6.1 %) and female users (7.2 %) in this regard were almost the same. However, respondents from Jaintia Hills were more conscious of treating ear problems than the other two regions. For the treatment of diabetes, older (14.2 %) and middle-aged people (4.2 %) were using the plants more than the young people (0.8 %). Male respondents (7.8 %) were found to use more than female respondents (5 %). Jaintia people were more conscious in treating diabetes by using the pitcher plant than the Garo (5 %) and the Khasi Hills (3.3 %). Gynaecological problems were the least treated ailments. Here, older and middle-aged respondents were more likely to use the pitcher plant for the treatment than their younger counterparts. All the respondents who preferred to use the plants were female. Respondents from the Jaintia regions had more knowledge than the Garo (5.8 %) and the Khasi Hills (3.3 %). The voices from Garo, Jaintia and Khasi Hills on the use of pitcher plants for treating various diseases also varied significantly by the chi-square test ($\chi^2 = 52.252, p \leq 0.05$). A significant positive correlation was

Table 2. Knowledge of the respondents on the medicinal value of the pitcher plant and its uses in Meghalaya, India

	Age			Gender		Hills		
	Young	Middle	Old	Male	Female	Garo	Jaintia	Khasi
People's knowledge of pitcher plants as medicine								
Having knowledge	25.8 % (n = 31)	63.3 % (n = 76)	90.8 % (n = 109)	62.2 % (n = 112)	57.8 % (n = 104)	60.0 % (n = 72)	76.7 % (n = 92)	43.3 % (n = 52)
No knowledge	74.2 % (n = 89)	36.7 % (n = 44)	9.2 % (n = 11)	37.8 % (n = 68)	42.2 % (n = 76)	40.0 % (n = 48)	23.3 % (n = 28)	56.7 % (n = 68)
Usage of pitcher plant as medicine								
Used	5.8 % (n = 7)	23.3 % (n = 28)	38.3 % (n = 46)	29.4 % (n = 53)	15.6 % (n = 28)	21.7 % (n = 26)	35.8 % (n = 43)	10.0 % (n = 12)
Not used	94.2 % (n = 113)	76.7 % (n = 92)	61.7 % (n = 74)	70.6 % (n = 127)	84.4 % (n = 152)	78.3 % (n = 94)	64.2 % (n = 77)	90.0 % (n = 108)

Table 3. Respondent's voice on ailments treated by the usage of pitcher plant in Meghalaya, India

Diseases	Age			Gender		Hills		
	Young	Middle	Old	Male	Female	Garo	Jaintia	Khasi
Eye problems	5.8 % (n = 7)	23.3 % (n = 28)	38.3 % (n = 46)	29.4 % (n = 53)	15.6 % (n = 28)	19.2 % (n = 23)	38.3 % (n = 46)	10.0 % (n = 12)
Diabetes	0.8 % (n = 1)	4.2 % (n = 5)	14.2 % (n = 17)	7.8 % (n = 14)	5.0 % (n = 9)	5.0 % (n = 6)	10.8 % (n = 13)	3.3 % (n = 4)
Leprosy and skin problems	3.3 % (n = 4)	13.3 % (n = 16)	32.5 % (n = 39)	18.3 % (n = 33)	14.4 % (n = 26)	6.7 % (n = 8)	15.8 % (n = 19)	26.7 % (n = 32)
Stomach disorder	21.7 % (n = 26)	7.5 % (n = 9)	1.7 % (n = 2)	7.8 % (n = 14)	12.8 % (n = 23)	15.8 % (n = 19)	9.2 % (n = 11)	5.8 % (n = 7)
Ear problem	0.8 % (n = 1)	3.3 % (n = 4)	15.8 % (n = 19)	6.1 % (n = 11)	7.2 % (n = 13)	5.8 % (n = 7)	11.7 % (n = 14)	2.5 % (n = 3)
Gynecological problem	1.7 % (n = 2)	5.8 % (n = 7)	11.7 % (n = 14)	0 % (n = 0)	12.8 % (n = 23)	5.8 % (n = 7)	10.0 % (n = 12)	3.3 % (n = 4)
Kidney problems	2.5 % (n = 3)	10.0 % (n = 12)	29.2 % (n = 35)	12.2 % (n = 22)	15.6 % (n = 28)	13.3 % (n = 16)	23.3 % (n = 28)	5.0 % (n = 6)

illustrated between different age groups and ailments treated in this study ($rpb=0.568^*$).

Plant parts used as medicine

The study found that the pitcher plant fluid was mostly used (49.2 %, $n = 177$) as medicine as compared to other parts of the plant. Next to the fluid, the pitcher was widely utilised (37.5 %, $n = 135$) followed by root (21.7 %, $n = 78$), leaf (17.2 %, $n = 62$), stem (15.8 %, $n = 57$), whereas flower and seed (11.4 %, $n = 41$) were the least preferred plant parts. There was a significant difference in the use of different parts of the pitcher plant across age groups as revealed by the chi-square test ($\chi^2 = 81.600, p \leq 0.05$). Interestingly, it was found that most of the old and middle-aged people, irrespective of hills mostly (85.0 %, $n = 102$; 39.2 %, $n = 47$ respectively) employed fluid pitcher as medicine, while the young people used roots (37.5 %, $n = 45$) mostly as medicine (Table 4). Additionally, the young people used pitcher fluid (23.3 %, $n = 28$) as the second preferred component, as compared to the pitcher by the old (70.0 %, $n = 84$) and middle-aged people (28.3 %, $n = 34$).

The preferences of male and female respondents differed significantly with respect to the use of different parts of pitcher plants for medicinal purposes ($\chi^2 = 15.281, p \leq 0.05$). Irrespective of gender, the fluid was the most preferred plant part for medicinal use among both male (57.8 %, $n = 104$) and female respondents (40.6 %, $n = 73$), followed by the pitcher (male: 42.2 %, $n = 76$; female: 32.8 %, $n = 59$). Among males, the root was the third most preferred plant part (26.1 %, $n = 47$), whereas females preferred the leaf (20.6 %, $n = 37$). In contrast, the least preferred plant parts were the stem among males (13.3 %, $n = 24$) and the flower and seed among females (6.7 %, $n = 12$). Overall, the findings indicate that the fluid of the pitcher plant is the most preferred medicinal component, followed by the pitcher itself.

People's attitudes and knowledge about the species and its conservation importance

Table 4. Respondent's perception of parts of pitcher plant employed as medicine in Meghalaya, India

Plant parts	Age			Gender		Hills		
	Young	Middle	Old	Male	Female	Garos	Jaintia	Khasi
Fluid	23.3 % ($n = 28$)	39.2 % ($n = 47$)	85.0 % ($n = 102$)	57.8 % ($n = 104$)	40.6 % ($n = 73$)	44.2 % ($n = 53$)	78.3 % ($n = 94$)	25.0 % ($n = 30$)
Pitcher	14.2 % ($n = 17$)	28.3 % ($n = 34$)	70.0 % ($n = 84$)	42.2 % ($n = 76$)	32.8 % ($n = 59$)	35.0 % ($n = 42$)	55.8 % ($n = 67$)	21.7 % ($n = 26$)
Leaf	9.2 % ($n = 11$)	14.2 % ($n = 17$)	28.3 % ($n = 34$)	13.9 % ($n = 25$)	20.6 % ($n = 37$)	29.2 % ($n = 35$)	9.2 % ($n = 11$)	13.3 % ($n = 16$)
Root	37.5 % ($n = 45$)	11.7 % ($n = 14$)	15.8 % ($n = 19$)	26.1 % ($n = 47$)	17.2 % ($n = 31$)	22.5 % ($n = 27$)	26.7 % ($n = 32$)	15.8 % ($n = 19$)
Flower and seed	3.3 % ($n = 4$)	6.7 % ($n = 8$)	24.2 % ($n = 29$)	16.1 % ($n = 29$)	6.7 % ($n = 12$)	15.8 % ($n = 19$)	10.8 % ($n = 13$)	7.5 % ($n = 9$)
Stem	6.7 % ($n = 8$)	11.7 % ($n = 14$)	29.2 % ($n = 35$)	13.3 % ($n = 24$)	18.3 % ($n = 33$)	11.7 % ($n = 14$)	25.0 % ($n = 30$)	10.8 % ($n = 13$)

Table 5. Respondent's voice on the conservation of pitcher plant in Meghalaya, India

	Age			Gender		Hills		
	Young	Middle	Old	Male	Female	Garos	Jaintia	Khasi
Knowledge about the endemism								
Known	59.2 % ($n = 71$)	44.2 % ($n = 53$)	30.0 % ($n = 36$)	52.2 % ($n = 94$)	36.7 % ($n = 66$)	74.2 % ($n = 89$)	22.5 % ($n = 27$)	36.7 % ($n = 44$)
No knowledge	40.8 % ($n = 49$)	55.8 % ($n = 67$)	70.0 % ($n = 84$)	47.8 % ($n = 86$)	63.3 % ($n = 114$)	25.8 % ($n = 31$)	77.5 % ($n = 93$)	63.3 % ($n = 76$)
Reasons for the conservation of pitcher plant								
Medicinal value	13.3 % ($n = 16$)	46.7 % ($n = 56$)	60.0 % ($n = 72$)	45.1 % ($n = 83$)	34.7 % ($n = 61$)	35.8 % ($n = 43$)	55.0 % ($n = 66$)	29.2 % ($n = 35$)
Endemism	9.2 % ($n = 11$)	9.2 % ($n = 11$)	17.5 % ($n = 21$)	13.0 % ($n = 24$)	10.8 % ($n = 19$)	18.3 % ($n = 22$)	9.2 % ($n = 11$)	8.3 % ($n = 10$)
Both medicinal value and endemism	3.3 % ($n = 4$)	7.5 % ($n = 9$)	13.3 % ($n = 16$)	4.9 % ($n = 9$)	11.4 % ($n = 20$)	5.8 % ($n = 7$)	12.5 % ($n = 15$)	5.8 % ($n = 7$)
Not known	74.2 % ($n = 89$)	36.7 % ($n = 44$)	9.2 % ($n = 11$)	37.0 % ($n = 68$)	43.2 % ($n = 76$)	40.0 % ($n = 48$)	23.3 % ($n = 28$)	56.7 % ($n = 68$)
Proudness for having pitcher plant								
Pride species	35.0 % ($n = 42$)	52.5 % ($n = 63$)	70.0 % ($n = 84$)	56.1 % ($n = 101$)	48.9 % ($n = 88$)	70.0 % ($n = 84$)	35.0 % ($n = 42$)	52.5 % ($n = 63$)
No pride	43.3 % ($n = 52$)	36.7 % ($n = 44$)	20.0 % ($n = 24$)	25.6 % ($n = 46$)	41.1 % ($n = 74$)	20.8 % ($n = 25$)	39.2 % ($n = 47$)	40.0 % ($n = 48$)
Not known	21.7 % ($n = 26$)	10.8 % ($n = 13$)	10.0 % ($n = 12$)	18.3 % ($n = 33$)	18.3 % ($n = 18$)	9.2 % ($n = 11$)	25.8 % ($n = 31$)	7.5 % ($n = 9$)

About 44.4 % ($n = 160$) of the folks in the study area knew that pitcher plants are endemic to Meghalaya. However, 55.6 % ($n = 200$) of the respondents were unaware of this fact. The young, middle and old age groups ($\chi^2 = 20.678, p \leq 0.05$; Fisher's exact = 20.815, $p \leq 0.05$) informants differ significantly regarding the knowledge about the endemism of pitcher plants. The young age group, males, were more aware of this knowledge than their counterparts. There was also variation in knowledge levels regarding the pitcher plant's endemism across different hills ($\chi^2 = 69.278, p \leq 0.05$). The Garo people were found to be the most (74.2 %) familiar, followed by Khasi Hills (36.7 %) and the least familiar were Jaintia Hills (22.5 %). Again, more than half of the respondents (52.5 %, $n = 189$) were proud of the endemic status of the pitcher plant. These include mostly male and older respondents. Respondents shared that they were prouder (70.0 %, $n = 84$) of Garo Hills as compared to Khasi Hills (52.5 %, $n = 63$) and Jaintia Hills (35.0 %, $n = 42$) (Table 5).

People's views on the conservation of pitcher plants were distinct. About 40.0 % ($n = 144$) of the respondents favoured conserving the pitcher plant due to its medicinal properties, followed by 11.9 % ($n = 43$) for its endemism and 8.1 % ($n = 29$) for both medicinal value and endemism. However, the remaining 40.0 % ($n = 144$) showed no interest in the conservation of the pitcher plant. Interestingly, most of the people, irrespective of age class, voiced for the safeguarding of pitcher plants due to their medicinal properties rather than endemism (Table 5).

There was a distinct variation in the voice for the conservation of pitcher plants among different genders ($\chi^2 = 8.386, p \leq 0.05$). Male respondents (45.1 %, $n = 83$) showed more concern for the protection of pitcher plants as compared to females (34.7 %, $n = 61$) for their medicinal properties. The same trend was also observed, with most respondents supporting safeguarding the pitcher plant owing to its medicinal properties, irrespective of the hills in Meghalaya ($\chi^2 = 38.058, p \leq 0.05$) (Table 5).

Discussion

The present study assessed the ethnomedicinal properties of the pitcher plant, *N. khasiana*, along with their conservation perspectives through people's voices in the Garo, Jaintia and Khasi Hills of Meghalaya, India. The investigation of demographic features of an area, specifically the age, gender, educational level and job, is important to display the validity and representativeness of survey responses as well as to enable the impact of demographics on the studied parameters (36). A significant variation in educational level, irrespective of age, gender and study area, was observed in all the studied areas of Meghalaya. This variation reflects uneven socio-economic development and accessibility to educational infrastructure across regions, which in turn shapes knowledge systems and healthcare choices. Females exhibited a higher proportion of primary-level education, which may be attributed to limited access to higher educational institutions due to poor transportation and communication facilities in rural areas, as most higher education institutions are located in urban regions. But young generations are getting the facilities as communication has been much improved over time. The young generation also received more emphasis on education as compared to the middle and old age generations. This generational shift suggests a transition from traditional knowledge systems toward formal education, which may influence the declining transmission of ethnomedicinal knowledge. Higher education levels in Garo Hills may contribute to greater reliance on modern healthcare systems, thereby reducing dependence on traditional plant-based remedies. The education level of the Jaintia Hills people is mostly limited to the primary level and the region has received less attention in developmental processes than in the other two regions of the state. Hence, most people in Jaintia Hills are engaged in agricultural activities. The capital city of the state (Shillong) is situated in the Khasi Hills and a lot of people, therefore, are also involved in different types of business activities, which is not preferable to the other regions. Less educated people use herbal medicine due to poverty and easy availability, whereas well-educated people use it for its safety and effectiveness and hence Jaintia respondents use the plant more than Garo and Khasi people, which is coinciding with other studies (37–39).

The present study suggests that ethnomedicinal knowledge is experience-based and orally transmitted, making it more prevalent among older individuals and traditional practitioners. This might be due to modernisation, lack of interest among the young generation and less revenue earned by selling herbal medicine, which supports previous studies (38, 40–43). Contrarily, some studies reported that female respondents were more acquainted with the medicinal properties of the plants (44, 45).

The present work likely reflects the age-associated prevalence of ocular disorders, reinforcing the role of the plant in geriatric healthcare. It is obvious that young people do not suffer too much from eye-related problems and therefore, they don't need to use it. However, the preference of many respondents for eye treatment by the plant signifies its effectiveness in treating the problems. The kidney-related problems were also mostly observed by the old-aged people after eye and skin-related problems. Generally, the number of old people suffering eye-related problems in society is higher than skin or kidney problems. Regionally, the Jaintia people are ahead in treating any ailments that can be

related to their socio-economic and educational background (Table 1). The Jaintia people are mostly agriculturists, less educated and more remote from accessing modern medicine as compared to other regions. Therefore, their preference for treating all the ailments mentioned above was higher than in the other regions. The present study also suggests selective retention of traditional knowledge among youth, particularly for treating gastrointestinal disorders. Gastrointestinal disorders are a common health problem and their use for treatment by the young generation indicates their trust in the effectiveness of the plant for the treatment. It was less in the Garo Hills, where access to higher education and modern medicines is comparatively easier.

Traditional healers use the various parts of plants based on the type of disease and the characteristics of the plants. Pitcher fluid was found to be mostly used in the study, irrespective of gender and sample areas, followed by pitcher, roots, leaves, stem and flower and seeds; nevertheless, roots of the plant were used by most young people, considering their relative preference of treatment for diseases. The pitchers are exquisite and alluring, while the fluids are easy to obtain and use as they do not require any intricate method of preparation and are hence used dominantly. Roots and leaves have a bioactive compound in diverse concentrations, making them a potential part of indigenous medicines (46, 47).

The medicinal plants in the wild are declining sharply (48). Unfortunately, most of the inhabitants worldwide are heedless of this fact, while various *in vitro* and *ex vitro* conservation measures have already been employed. Additionally, the younger generations in most parts of the world are apathetic to the perpetuation of indigenous knowledge of medicinal plants (49). Hence, medicinal plants need urgent documentation and conservation (16). Researchers from the world, India, including Meghalaya, asserted that the people in their study area are oblivious to the conservation affairs of medicinal plants and their threat (15, 38, 50–53). In Meghalaya, the preamble of the Khasi Hills Autonomous District (Protection and Promotion of Khasi Traditional Medicine) Act, 2011, affirms that Khasi traditional medicine is accessible, affordable and efficacious and that it also offers opportunities for livelihoods and trade and assists in biodiversity conservation.

The success of conservation often depends upon the people's perception of the species. If the species is culturally associated with the local community, then it is automatically conserved by them. More than half of the respondents shared their proudest moment on the endemic species, which can be utilised for their successful conservation. The young age group, male members and Garo people are aware of their endemism, while the middle, old, female, Jaintia and Khasi people are a little obscure with this concept. Respondents belonging to the middle and old age group, along with the folks of Jaintia Hills, voiced that the pitcher plants should be conserved owing to their medicinal properties. However, most of the young age groups, from the Garo Hills and Khasi Hills area, abstain from any inkling on the conservation perspective of pitcher plants growing in Meghalaya. Henceforth, public awareness, stakeholder participation, incorporation of traditional cultural norms in conservation strategies and concrete pharmacological analysis through laboratory tests, along with proper documentation of indigenous knowledge, are required for the conservation of traditional knowledge of the pitcher plant (50).

Conclusion

The present study revealed the importance of pitcher plants in the treatment of various diseases in the rural lives of Meghalaya. The medicinal value of the plant is known to a large section of the people of Meghalaya, but the status of the plant as endemic is unknown to most of the elderly people due to the lack of education among them. The younger generation is apathetic to using the plant for the treatment of diseases, except for day-to-day health problems like gastrointestinal disorders. The young people, however, are proud of the endemic status of the pitcher plant and therefore vows for the conservation of the plant. The conservation of *Nepenthes khasiana* requires integration into state biodiversity action plans with strict policy implementation and its inclusion in community-managed sacred groves. Targeted awareness programs, particularly among rural youth, along with active community participation involving local healers and stakeholders, are essential to strengthen conservation efforts. The development of sustainable harvesting guidelines and promotion of ex-situ conservation measures, such as nursery raising and tissue culture, are necessary to ensure its long-term survival. Furthermore, support for pharmacological and toxicological research is crucial to validate its medicinal potential, while linking conservation initiatives with livelihood opportunities, such as eco-tourism, can enhance community engagement and sustainability.

Acknowledgements

The authors are thankful to the village heads and residents of various villages in Meghalaya, India. The local guides and language transcribers who accompanied the researchers during the study are highly acknowledged. The authors are also grateful to the University of Science and Technology Meghalaya (USTM).

Authors' contributions

AB and PS designed the project. AB, PS and SGM conducted the interviews. AB carried out the transcription, analyses and writing of the manuscript. PS provided feedback at every stage of writing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

- Adamec L, Matusikova I, Pavlovic A. Recent ecophysiological, biochemical and evolutionary insights into plant carnivory. *Ann Bot*. 2021;128:241–59. <https://doi.org/10.1093/aob/mcab071>
- Santapau H, Henry AN. A dictionary of the flowering plants in India. New Delhi: Publication and Information Directorate; 1976.
- Kamble MV, Hari Krishnan S, Balakumar P. *Utricularia caerulea* (Lentibulariaceae): a new record to flora of Andaman and Nicobar Islands. *Rheedea*. 2012;22:116–18. <https://doi.org/10.22244/rheedea.2012.22.02.12>
- Bhattacharya A, Momin SG, Sarkar P. New distribution records of the endemic pitcherplant, *Nepenthes khasiana* Hook f. and identification of threats in Meghalaya, India. *J Environ Biol*. 2024;45:1–7. <https://doi.org/10.22438/jeb/45/1/MRN-5172>
- Cross AT, Krueger TA, Gonella PM, Robinson AS, Fleischmann AS. Conservation of carnivorous plants in the age of extinction. *Glob Ecol Conserv*. 2020;24:e01272. <https://doi.org/10.1016/j.gecco.2020.e01272>
- Ved D, Saha D, Haridasan K, Ravikumar K. *Nepenthes khasiana*. IUCN Red List Threat Species. 2015;e.T48992883A49009685. <https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T48992883A49009685.en>
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The CITES appendices [Internet]. Geneva: CITES Secretariat; 2022. <https://cites.org/eng/app/index.php>
- Ziemer B. Exciting conservation news: the rare *Nepenthes* collection project. *Carniv Plant Newslett*. 2010;39:67. <https://doi.org/10.55360/cpn393.bz815>
- Bordoloi RPM. The pitcher plant *Nepenthes khasiana*. Guwahati (Assam): Sreeguru Press; 1977. p. 58.
- Momin KC, Mehra TS, Dobhal S, Momin BC, Gupta YC. Status of *Nepenthes khasiana* Hook f. (pitcher plant) in Meghalaya: a review. *J Pharmacogn Phytochem*. 2018;7:353–58.
- Devi SP, Kumaria S, Sharma PR, Khoyumthem P, Tandon P. *Nepenthes khasiana* Hook f., an endangered tropical pitcher plant of India. *Indian J Tradit Knowl*. 2019;18:68–75.
- Bhattacharya A, Verma AK, Rao S, Momin SG, Radhakrishnanand P, Sarkar P. Unlocking the phytochemicals in unopened pitcher fluids of *Nepenthes khasiana*: a GC-MS study. *Intell Pharm*. 2024;2:284–90. <https://doi.org/10.1016/j.ipha.2023.10.005>
- Bokatia D, Synelish SM, Rao CR. Conservation of pitcher plant. *Curr Sci*. 2012;102:381–382.
- Rana CS, Rana V, Bisht MPS. An unusual composition of the plant species towards zone of ablation (*Tipra glacier*), Garhwal Himalaya. *Curr Sci*. 2010;99:574–76.
- Hazarika TK, Marak S, Mandal D, Shukla AC. Underutilised and unexploited fruits of Indo-Burma hotspot, Meghalaya, north-east India: ethno-medicinal evaluation, socio-economic importance and conservation strategies. *Genet Resour Crop Evol*. 2016;63:289–304. <https://doi.org/10.1007/s10722-015-0248-0>
- Dixit S, Tiwari S. Investigation of anti-diabetic plants used among the ethnic communities of Kanpur division, India. *J Ethnopharmacol*. 2020;253:112639. <https://doi.org/10.1016/j.jep.2020.112639>
- Rao TA, Shanware PG, Tribedi GN. A note on the pitcher plant habitat in Assam. *Indian For*. 1969;95:611–13.
- Kumar YK, Haridasan S, Rao RR. Ethnobotanical notes on certain medicinal plants among some Garo people around Balphakram Sanctuary in Meghalaya. *Bull Bot Surv India*. 1980;22:161–65. <https://doi.org/10.20324/nelumbo/v22/1980/75417>
- Kharkongor P, Joseph J. Folklore medicobotany of rural Khasi and Jaintia tribes in Meghalaya. In: Jain SK, editor. *Glimpses of Indian ethnobotany*. New Delhi: Oxford and IBH; 1981. p. 115.
- Joseph J, Joseph KM. Insectivorous plants of Khasi and Jaintia Hills, Meghalaya, India: a preliminary survey. Kolkata: Botanical Survey of India; 1986.
- Behera KK, Sahoo S, Mohapatra PN. Medicinal plant resources for bioprospecting and drug development in the tribal-rich district of Orissa, India. *Ethnobot Leaflet*. 2007;11:106–12.
- Shil D, Mohanty JP, Das T, Bhuyan NR, Uriah T, Saleem TSM. Protective role of pitcher of *Nepenthes khasiana* Hook against dexamethasone-induced hyperlipidemia and insulin resistance in rats. *Int J Res Pharm Sci*. 2010;1:195–98.
- Sanglyne MW, Dirborne CM, Nongkynrih DH. Ethnomedicinal plants used by the tribal inhabitants of two of the wettest places on earth: an overview. *Int J Bot Stud*. 2021;6:125–34.

24. Dikshit KR, Dikshit JK. North-east India: land, people and economy. Dordrecht: Springer; 2014. <https://doi.org/10.1007/978-94-007-7055-3>
25. Ogra M. Attitudes toward resolution of human–wildlife conflict among forest-dependent agriculturalists near Rajaji National Park, India. *Hum Ecol.* 2009;37:161–77. <https://doi.org/10.1007/s10745-009-9222-9>
26. Badola R. Attitudes of local people towards conservation and alternatives to forest resources: a case study from the lower Himalayas. *Biodivers Conserv.* 1998;7:1245–59. <https://doi.org/10.1023/A:1008845510498>
27. Talukdar NR, Choudhury P. Attitudes and perceptions of the local people on human–elephant conflict in the Patharia Hills Reserve Forest of Assam, India. *Proc Zool Soc.* 2020;73:380–91. <https://doi.org/10.1007/s12595-020-00343-5>
28. Shibia MG. Determinants of attitudes and perceptions on resource use and management of Marsabit National Reserve, Kenya. *J Hum Ecol.* 2010;30:55–62. <https://doi.org/10.1080/09709274.2010.11906272>
29. Torri MC. Power, structure, gender relations and community-based conservation: the case study of the Sariska region, Rajasthan, India. *J Int Womens Stud.* 2010;11:1–18.
30. Ebua VB, Agwafo TE, Fonkwo SN. Attitude and perceptions as threats to wildlife conservation in Bakossi area, South West Cameroon. *Int J Biodivers Conserv.* 2011;3:631–36.
31. Bernard HR. Research methods in anthropology: qualitative and quantitative approaches. 5th ed. Lanham (MD): Altamira Press; 2011.
32. Bajracharya SB, Furley PA, Newton AC. Impacts of community-based conservation on local communities in the Annapurna Conservation Area, Nepal. *Biodivers Conserv.* 2006;15:2765–86. <https://doi.org/10.1007/s10531-005-1343-x>
33. Kalibo HW, Medley KE. Participatory resource mapping for adaptive collaborative management at Mt. Kasigau, Kenya. *Landsc Urban Plan.* 2007;82:145–58. <https://doi.org/10.1016/j.landurbplan.2007.02.005>
34. Orch H, Benkhniq O, Zidane L, Douira A. Treatment of urolithiasis: ethnobotanical study of plants used by the population bordering the forest of Izarène Lithiasis. *Ethnobot Res Appl.* 2020;19:1–15. <https://doi.org/10.32859/era.19.33.1-15>
35. Phillips OL. Some quantitative methods for analysing ethnobotanical knowledge. In: Alexiades MN, editor. Selected guidelines for ethnobotanical research: a field manual. New York: New York Botanical Garden; 1996. p. 171–97.
36. Lazar J, Preece J. Using electronic surveys to evaluate networked resources: from idea to implementation. In: McClure C, Bertot J, editors. Evaluating networked information services: techniques, policy and issues. Medford (NJ): Information Today; 2001. p. 137–54.
37. Rajalakshmi S, Vijayakumar S, Arulmozhi P. Ethnobotanical survey of medicinal plants in Thanjavur and its surrounding (Tamil Nadu, India). *Acta Ecol Sin.* 2019;39:380–97. <https://doi.org/10.1016/j.chnaes.2018.09.010>
38. Ojha SN, Tiwari D, Anand A, Sundriyal RC. Ethnomedicinal knowledge of a marginal hill community of Central Himalaya: diversity, usage pattern and conservation concerns. *J Ethnobiol Ethnomed.* 2020;16:29. <https://doi.org/10.1186/s13002-020-00381-5>
39. Mlilo S, Sibanda S. An ethnobotanical survey of the medicinal plants used in the treatment of cancer in some parts of Matebeleland, Zimbabwe. *S Afr J Bot.* 2022;146:401–408. <https://doi.org/10.1016/j.sajb.2021.11.022>
40. Kala CP, Dhyani PP, Sajwan BS. Developing the medicinal plants sector in northern India: challenges and opportunities. *J Ethnobiol Ethnomed.* 2006;2:32. <https://doi.org/10.1186/1746-4269-2-32>
41. Tefera BN, Kim YD. Ethnobotanical study of medicinal plants in the Hawassa Zuria District, Sidama zone, Southern Ethiopia. *J Ethnobiol Ethnomed.* 2019;15:25. <https://doi.org/10.1186/s13002-019-0302-7>
42. Zougagh S, Belghiti A, Rochd T, Zerdani L, Mouslim J. Medicinal and aromatic plants used in traditional treatment of oral pathology: an ethnobotanical survey in Casablanca, Morocco (North Africa). *Nat Prod Bioprospect.* 2019;9:35–48. <https://doi.org/10.1007/s13659-018-0194-6>
43. Eshete MA, Molla EL. Cultural significance of medicinal plants in healing human ailments among Guji semi-pastoralist people, Suro Barguda District, Ethiopia. *J Ethnobiol Ethnomed.* 2021;17:61. <https://doi.org/10.1186/s13002-021-00487-4>
44. Luitel DR, Rokaya MB, Munzbergova Z. Medicinal plants used by Tamang community in the Makawanpur district of central Nepal. *J Ethnobiol Ethnomed.* 2014;10:5. <https://doi.org/10.1186/1746-4269-10-5>
45. Randrianarivony TN, Ramarosandratana AV, Andriamihajarivo TH, Rakotoarivony F, Jeannoda VH, Randrianasolo A, et al. The most used medicinal plants by communities in Mahaboboka, Amboronabo, Mikoboka, southwestern Madagascar. *J Ethnobiol Ethnomed.* 2017;13:19. <https://doi.org/10.1186/s13002-017-0147-x>
46. Adia MM, Anywar G, Byamukama R, Kamatenesi-Mugisha M, Sekagya Y, Kakudidi EK. Medicinal plants used in malaria treatment by *Prometra herbalists* in Uganda. *J Ethnopharmacol.* 2014;155:580–88. <https://doi.org/10.1016/j.jep.2014.05.060>
47. Bouafia A, Laouini SE, Ahmed ASA, Soldatov AV, Algarni H, Chong KF, et al. Recent progress on silver nanoparticles: synthesis and electronic applications. *Nanomaterials.* 2021;11:2318. <https://doi.org/10.3390/nano11092318>
48. Njoroge GN, Kaibui IM, Njenga PK, Odhiambo PO. Utilisation of priority traditional medicinal plants and local people's knowledge on their conservation status in arid lands of Kenya (Mwingi District). *J Ethnobiol Ethnomed.* 2010;6:22. <https://doi.org/10.1186/1746-4269-6-22>
49. Tugume P, Kakudidi EK, Buyinza M, Namaalwa J, Kamatenesi M, Mucunguzi P, et al. Ethnobotanical survey of medicinal plant species used by communities around Mabira Central Forest Reserve, Uganda. *J Ethnobiol Ethnomed.* 2016;12:5. <https://doi.org/10.1186/s13002-015-0077-4>
50. Ssenku JE, Okurut SA, Namuli A, Kudamba A, Tugume P, Matovu P, et al. Medicinal plant use, conservation and the associated traditional knowledge in rural communities in Eastern Uganda. *Trop Med Health.* 2022;50:39. <https://doi.org/10.1186/s41182-022-00428-1>
51. Tsobou R, Mapongmetsem PM, van Damme P. Medicinal plants used for treating reproductive health care problems in Cameroon, Central Africa. *Econ Bot.* 2016;70:145–59. <https://doi.org/10.1007/s12231-016-9344-0>
52. Lu Z, Chen H, Lin C, Ou G, Li J, Xu W. Ethnobotany of medicinal plants used by the Yao people in Gongcheng County, Guangxi, China. *J Ethnobiol Ethnomed.* 2022;18:49. <https://doi.org/10.1186/s13002-022-00544-6>
53. Kumari P, Wani IA, Khan S, Verma S, Mushtaq S, Gulnaz A, et al. Modelling of *Valeriana wallichii* habitat suitability and niche dynamics in the Himalayan region under anticipated climate change. *Biology.* 2022;11:498. <https://doi.org/10.3390/biology11040498>

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