Heliyon 9 (2023) e15607

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

A multivariate and quantitative assessment of medicinal plants used by the indigenous Malayali tribes in the Javadhu hills of Tiruvannamalai district, Tamil Nadu, India

Rajendran Silambarasan [a], Shan Sasidharan [a,*], Hareendran Nair J [a], Nishanth Kumar S [a], Aravind R [a], Akhila S. Nair [a], K.T. Selavinayagam [b]

[a] *Department of R&D, Pankajakasthuri Herbal Research Foundation, Pankajakasthuri Ayurveda Medical College Campus, Trivandrum, Kerala, India*
[b] *Jantho Memorial Educational Foundation, Kallathikulam Village, Eluvanoor Post, Kamuthi Taluk, Ramanathapuram District, 623605, Tamil Nadu, India*

ARTICLE INFO

Keywords:
Ethnobotany
Malayali tribe
Ethnobotanical indices
Principle component analysis
Pheatmap

ABSTRACT

The study of medicinal plants with their traditional uses and related pharmacological studies has received more attention during the past several decades around the world. The Malayali tribes of the Javadhu Hills in the Eastern Ghats rely heavily on a system of traditional medicine for healthcare. A qualitative ethnographic method with a semi-structured questionnaire was used to interview 52 people across 11 localities in the Javadhu Hills. In the data analysis, descriptive statistics such as Use reports (UR), frequency of citations (FC), relative frequency of citations (RFC), informant agreement ratio (IAR), fidelity level (FL), and informant consensus factor (FIC) were studied. In the current investigation, 146 species from 52 families and 108 genera were discovered to treat 79 diseases. Leguminosae and Apocynaceae were the dominant families (12 species each). The most frequently used life form was the herb and the plant part were the leaf. The majority were being harvested from natural resources. Most medicines were taken orally. The most frequently cited species are *Moringa oleifera* and *Syzygium cumini*. The illnesses were divided into 21 categories. The majority of the plants mentioned are utilised to increase human immunity and health. The principal ailment (general health) was revealed by two-way cluster analysis and PCA. The species *Litsea decanensis, Phoebe paniculata, Commiphora caudata, etc.*, were new records for the Javadhu hills according to a comparison between the current study and previous local and regional research. Documenting novel ethnomedicinal species and their therapeutic applications will encourage more phytochemical and pharmacological research and may even result in the creation of new medications. Furthermore, the study's significant novelty is that principle component analysis and two-way cluster analysis clearly revealed that the species that are used to treat various diseases, as well as species that are closely associated with treating specific ailment categories, are distinct. Significantly, species recorded in this study rely on maintaining and improving general body health of humans.

* Corresponding author.
E-mail address: drshansasidharan@gmail.com (S. Sasidharan).

https://doi.org/10.1016/j.heliyon.2023.e15607
Received 10 January 2023; Received in revised form 12 April 2023; Accepted 17 April 2023
Available online 18 April 2023
2405-8440/

1. Introduction

Research on ethnobotany and traditional knowledge of peoples was often significant and instructive, with a focus on compiling a list of plants, their native names, and their local benefits [1]. Due to the concepts, techniques, and beliefs that may be found in many cultural backgrounds, traditional medicine is used to prevent, treat, and diagnose physical and mental illness as well as to maintain health [2]. Aside from that, it is disappearing globally. In order to safeguard the rights of local people in the age of globalization, traditional knowledge documentation is crucial [3]. The results of recent ethnobotanical research help to preserve traditional knowledge of medicinal plants [4] and accelerate the discovery of new drugs because the biodiversity of natural plant resources in many places provides quick, affordable, and abundant alternatives for local healthcare [5]. A crucial step in preserving traditional plant knowledge is recognizing plant taxa and determining which people in a community possess it (such as the usage of therapeutic herbs). As a result, the significance of human-plant interactions has grown in terms of safeguarding biodiversity. In actuality, this has given rise to more quantitative approaches that concentrate on the many processes that shape conventional knowledge [6].

Traditional medicine is used by about 80% of people worldwide. The governments of 170 of the 194 World Health Organization (WHO) member states recently requested support from the WHO in gathering the necessary data and evidence about traditional medicine practices and products. WHO and the Government of India consequently reached an agreement to launch the WHO Global Centre for Traditional Medicine. With the use of cutting-edge science and technology, this worldwide information center for traditional medicine hopes to advance both human and environmental health. It is sponsored by a $250 million investment by the Government of India. A good example of the crucial importance of biodiversity conservation and sustainability is the fact that 40% of currently available approved pharmaceutical medications are made from natural resources. For instance, the contraceptive pill was based on the tubers of wild yam plants, while treatments for child cancer were based on rose periwinkle. Aspirin was also developed as a result of traditional medicines made from willow bark [7]. A review of ancient Chinese medical texts served as the foundation for the Nobel Prize-winning artemisinin malaria research [8].

India is also a very diverse nation in terms of its cultures, languages, religions, and ethnic groups. As a result, "Tribals" may be found in practically all of India's States. According to the 2001 census, there were 84.51 million tribal people in India, or 8.14% of the overall population, and they occupied 15% of the total land area. Significantly, tribal people employ 3900 plant species for food, of which 145 species are used for roots and tubers, 521 species are used for leafy vegetables, 101 species are used for bulbs and flowers, and 647 species are used for fruits [9]. Through substantial institutional efforts, these communities are actively attempting to maintain their rich traditions. The Malayali tribe is one of the most significant and substantial designated ethnic groups in Tamil Nadu. Such mountains as Kollimalai, Shervaroysmalai, Pachamalais, Kalrayans, Javadhumalai, Pudurnadumalai and Yelagirimalai are located in the Eastern Ghats of Tamil Nadu. 2,09,040 Malayalis were counted in the census in 1981 belonging to the religion Hindu. The tribes are not uncivilized and comprise farmers, woodsmen, and shepherds [10].

Siddha, one of India's earliest traditional medicinal systems, began approximately 5000 BC in South India. Siddha was also the mother medicine of the prehistoric Tamilians of peninsular South India. The ancient Siddha system lists 4448 ailments induced by a three-humor imbalance (Vali, Azhal, and Aiyam) [11,12]. The Siddha system is remarkable because it is viewed as a scientific representation of Siddhar intuitions (Ancient scholars). According to Siddha literature, eighteen Siddhars who lived in southern India at various eras presented their own treatment plans for a variety of illnesses. These treatments are presently accessible in printed books and palm-leaf manuscripts. Even though Siddha is one of the oldest indigenous medical systems, it must be preserved and developed going forward [13].

Even though ethnobotanical studies have been carried out in India since the country's republican period, researchers from India have recently highlighted the significance of the traditional usage of medicinal plants, particularly in mountainous areas. In recent decades, their number has greatly expanded [14–24] and the amount of work needed to conserve this treasure, which is decreasing with time, is nevertheless considerable. Particularly, Siddha healers and Siddha medicine adherents have no comprehensive information on the therapeutic herbs they utilise. However, a little research has documented the therapeutic plants utilised by tribes using the Siddha system of medicine in India and its nearby countries [25–28].

Tiruvannamalai is a holy location with three distinct mountains: Parvadhamalai, Arunachalamalai, and Javadhumalai. Among the mountains/hills of Tiruvannamalai Javadhu is one of Tamil Nadu's most important and biggest Eastern Ghat areas. Additionally, the Malayali tribes that reside there follow the previously stated siddhars' medical practices and food habits. Javadhu Hill is home to a diversity of habitats and medicinal plants. Although there have been a few studies that have documented the Malayali tribes' usage of medicinal plants [9], no in-depth ethnobotanical research on the Malayali tribes of the Javadhu hills in the Tiruvannamalai district have been conducted. Notably, no evidence pertaining to Siddha medicine has ever reported in this region.

We gathered ethnobotanical knowledge in the Javadhu Hills for this investigation. We focused on understanding more about and updating the taxonomy of the medicinal plants already present in the Javadhu Hills, recording the techniques of preparation and use of these plants, and demonstrating how the locals already comprehend and apply their ethnobotanical knowledge. These findings will address the knowledge gap regarding the ethnobotanical know-how and medicinal flora in the Javadhu highlands and offer references for the conservation, exploitation, and use of wild traditional medicinal plants.

1.1. Aim of the present study

1 Documentation of medicinal plants used by the ethnic Malayali tribe communities in different areas of Javadhu hills
2 Find the plant collection methods based on season and availability.
3 Techniques used by the Malayali tribes for the development and application of medicine.

4 To study the relationship between the medicinal plants and disease categories using statistical methods.
5 To study the richness, diversity of medicinal plants and its uses at different environments.
6 Document the novel medicinal plants used for the treatment of human illness.

2. Materials and methods

2.1. Study environment

In Tamil Nadu, the Javadhu hills, which are a part of the Eastern Ghats, possess a characteristic geographic environment with a wide variety of physical features and extensive stretches with a wide spectrum of rich forest resources (floristic composition). The Javadhu hill range is made up of hilly terrain that stretches from the north to the south, reaching a maximum length of 64 km and a maximum width of 25 km, and is distributed among the taluks of Polur, Tiruppattur, Chengam, Vaniyambadi, and Vellore. The Javadhu hill complex along with Pudurnadu hills spread out between 12^0 02″ 4 ‘and 12^0 05″ 5′ of northern latitude and 78°35″03′ and 78° 85″56’ of eastern longitude at the average height of 2300 feet, covering an area of 2405 sq.km. The reserve forest covers a total of 2, 26, 782.96 ha in the Javadhu and Pudurnadu hill ranges. The minimum temperature is 11.7 °C in January and the maximum

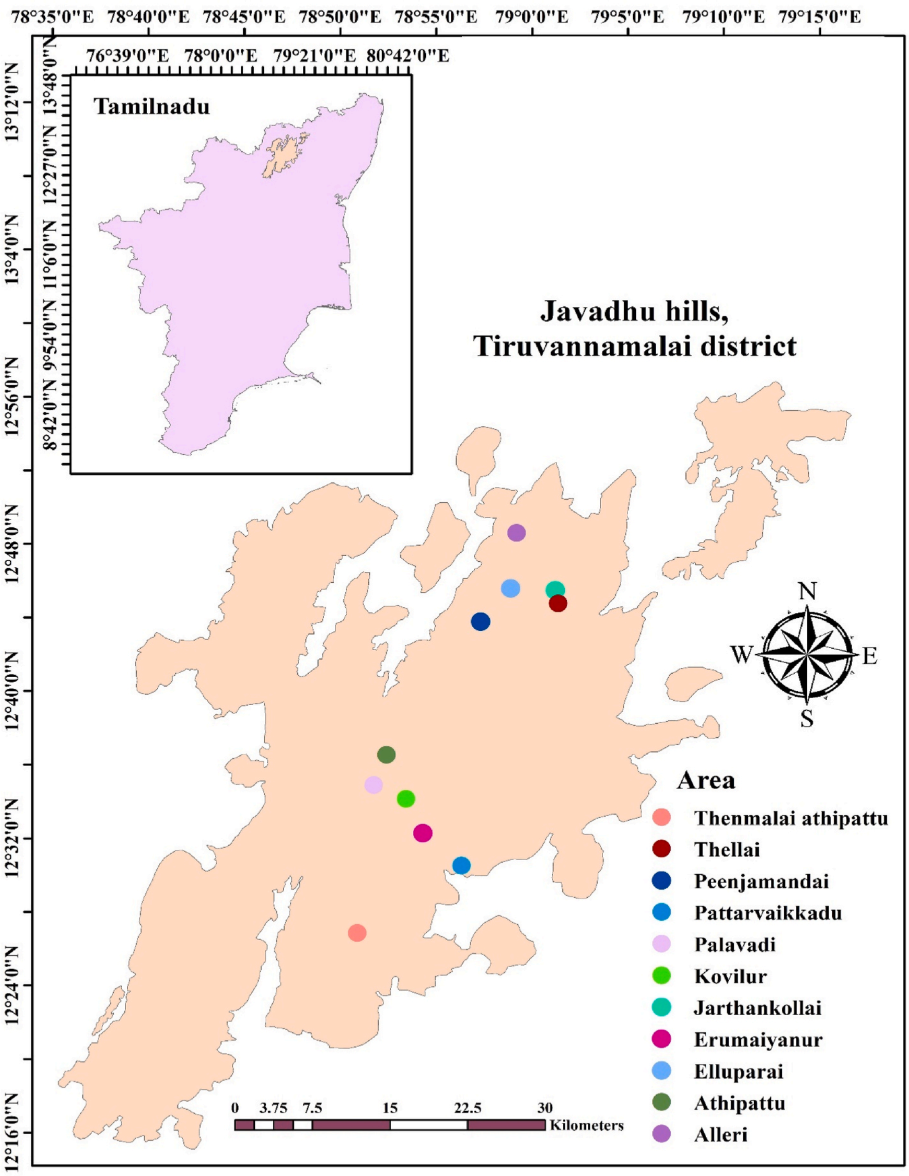

Fig. 1. Study area map, Javadhu hills, Tiruvannamalai district, Tamil Nadu.

temperature rises to 44.4 °C in May. The average rainfall is about 886 mm. Ethnobotanical data were collected according to the methodology suggested earlier [29]. The hill ranges of Javadhu have extensive lofty peaks and several river valleys and are endowed with a broad range of ecological habitats giving rise to a varied and rich forest resource and thus assume significance for conservation

Fig. 2. Medicinal plant species and their habitats in the Javadhu hills. a–i: Medicinal plant used by the Malayali tribes, j: Malayali tribe collect the plant for their food, k&l: study sites.

strategies. Many remnant patches of semi-evergreen forests and dry mixed deciduous forests are found throughout the southern portion of the hills. These habitats serve as sources of medicinal plants and contain rare, endangered, and endemic plant species, which simultaneously provide important resources to the hill populations. Javadhu Hills' vegetation dramatically changes with the elevation gradient (400–1150 m). The foothills are covered in scrub vegetation, mixed deciduous forests may be found between 400 and 600 m above the level, and wet evergreen forests could be found between 600 and 1150 m above sea level.

Eleven villages in the Javadhu Hills participated in this study (Kovilur, Paalavadi, Jarthankollai, Thenmalai athipattu, Peenjamandai, Alleri, Erumaiyanur, Ellupparai, Pattarvaikkadu, Thellai and Athipattu) (Fig. 1). As stated in the village forest management plan by regulations, the communities adapt to the forest and maintain access to the forest. The local Malayali tribal population was surveyed, interviewed, and had discussions to get the ethnobotanical data. Malayali tribes and other peoples with knowledge of medicinal plants, including both men and women who depended on plants as sources of medicine for either self-medication or treating others, were interviewed in a selective manner. The nomenclature of the plant species used for identification and verification of the plants was determined using two sources: The Flora of Presidency of Madras [30] and an excursion flora of central Tamil Nadu [31]. Data about folk medicinal plants lists their botanical names first, then their family names and common names.

2.2. Data collection

Interviews with local traditional healers who have firsthand experience regarding medicinal plants were conducted in 11 villages within the study area between April 2022 and November 2022. Twenty field visits were conducted in the study area over the course duration, totaling 113 days spent with the area's traditional healers. The selection of informants is based on the availability of knowledgeable people in each region. They were asked to collect specimens of plants they were familiar with or to display the plant species on site. These informants knew how to utilise the plants for medicine, either because they were experienced traditional healers themselves or because healing was a family tradition. People in this area have a wealth of information about medicinal plants that is founded on hundreds of years' worth of beliefs and observations. This information has been passed from generation to generation verbally from one generation to the next. However, it appears that it is fading from contemporary culture since fewer young people want to continue this practice. A detailed questionnaire during the interview was shown in Supplementary t. 1.

2.2.1. Plant collection and identification

The identified ethnomedicinal plants were collected in triplicate and kept for herbarium specimen preparation using accepted practices. The morphological, floral, and fruiting characteristics that were noticed during the field trips were used to identify the plant materials (Fig. 2 (a-i showed the plant photos, j-l showed the study environment photos)). 'The Flora of Tamil Nadu Carnatic' [32] and 'The Flora of Presidency of Madras' [30] were used to identify the binomials of preserved herbarium specimens. The naming of plants and families was in accordance with Angiosperm Phylogeny Group III (2009). In accordance with the common database's "plant list," we also determined the scientific names of plant species [33]**.** For future use, the identified plant specimens were labelled on herbarium sheets and placed in the Pankajakasthuri Herbal Research Foundation herbarium at Kattakada in Thiruvananthapuram, Kerala, India.

2.2.2. Ethics statement and consent to participate

The Independent Ethics Committee of Pankajakasthuri Herbal Research Foundation Trivandrum, Kerala, India approved this work. We obtained oral informed consent in each case before beginning data collection, first at the site level and then individually before each interview. Informants were also instructed that the research's objectives were academic rather than commercial. Participants gave verbal informed consent to participate in this study, and they had the option to withdraw their information at any time. Finally, informants agreed to the concept and agreed that their names and personal information would be published.

2.3. Ethnomedicinal data analysis

In MS Excel 2010, information related to collected ethnomedicinal plants was organized and analysed for descriptive statistical patterns, including use value (UV), family use value (FUV), informant consensus factor (ICF), fidelity level (FL), frequency of citation (FC), relative frequency citation (RFC), and informants agreement ratio (IAR). Using the abovementioned statistical equations, the informants of the study area were analysed about their knowledge of medicinal plants that are used to cure various types of illnesses.

2.4. Ailment categories

All reported illnesses were divided into 15 categories (Supplementary t. 2) based on the information provided by the local and traditional healers gastro-intestinal ailments (GIA), dermatological infections/diseases (DID), respiratory systems dis-eases (RSD), genito-urinary ailments (GUA), fever (FVR), skeleto-muscular system disorders (SMSD), poisonous bites (PB), circulatory system/cardiovascular diseases (CSCD), endocrinal disorders (ED), liver problems (LP), dental care (DC), hair care (HC), ear, nose, throat problems (ENT), cooling agents (CA) and general health (GH). Based on the body systems that were treated, many diseases were grouped under one disease category.

2.5. Data analysis

The information gathered was arranged into use reports (one interviewee's statement of one plant's use) in a spreadsheet with therapeutic uses. The descriptive statistics, such as the Use Value (UV), the Fidelity Level (FL), the Frequency of Citation (FC) and the Relative Frequency of Citation (RFC), the Family Use Value (FUV), the Informants Agreement Ratio (IAR), were calculated for each species, and the Informant Consensus Factor (ICF) was determined per therapeutic category, were used to compare the knowledge of cattle drowers, jaints, temple keepers.

2.5.1. Use value

The UV assesses a plant's significance to a particular population [34].

$$UV = \frac{\text{Number of uses mentioned by Informants (Ui)}}{\text{Number of Informants Interviewed (N)}}$$

where U is the number of uses mentioned by informants i, and N the total number of informants interviewed.

2.5.2. Frequency citation (FC)

Using the formula, the FC of the plant species being used was assessed:

$$FC = \frac{\text{The number of times a particular species was mentioned}}{\text{Total number of times that all species were mentioned}} \times 100$$

2.5.3. Relative frequency citation (RFC)

The relative frequency citation (RFC) index was done [35] by using the following formula:

$$RFC = \frac{\text{Frequency of citation}}{\text{Number of Informants}} \ (0 < RFC < 1)$$

This index is calculated by dividing the total number of informants in the survey by the number of informants who mentioned a useful species FC or frequency of citation (N). RFC values range from 0 (when no one mentions a plant as being beneficial) to 1. (when all the informants mention it as useful). RFC index, which does not consider use category into account (UR or use-report is a single record for use of a plant mentioned by an individual).

2.5.4. Medicinal Informant Agreement Ratio

Medicinal Informant Agreement Ratio (Med. IARs) has been proposed by Trotter and Logan [36] as follows:

$$IAR = \frac{Nr - Na}{Nr - 1}$$

whereby Nr is the total number of medicinal responses registered for species s and Na is the number of ailments or health conditions that are treated with this species.

The IARs of a medicinal species range from 0 (where the number of health issues treated equals the number of medicinal responses) to 1 (where everyone agrees that the species should only be used for a specific health condition) [37]. Compared to the use value (UV), which does not accurately reflect the consensus of the informants, this method takes into consideration this parameter [38].

2.5.5. Fidelity level

Fidelity level (FL) Fidelity level (FL) index was calculated by using the following formula as described by Friedman et al. [39] to determine the most preferred species used in the treatment of a particular ailment as more than one plant species are used in the treatment in the same category:

$$FL = \frac{Np}{N} \times 100$$

where N p is the number of informants citing the use of the plant for a particular illness and N is the total number of informants citing the species for any illness. High FL value indicates high frequency of use of the plant species for treating a particular ailment category by the informants of the study area.

2.5.6. Informant consensus factor

The ethnobotanical information was analysed and presented using the Informant consensus factor (FIC). The Trotter and Logan [36] method was used to determine the FIC value, which is a measure of the level of agreement about the usage of specific species of medicinal plants for treating specific diseases;

$$ICF = \frac{Nur - Nt}{Nr - 1}$$

where Nur = the number of use reports from informants for a particular plant use category and Nt = number of taxa or species that use the category for all informants. ICF scores range from zero to 1, with 1 representing the greatest level of informant consensus or demonstrating that informants share traditional knowledge about using medicinal plants and/or use a clearly defined selection criterion in the community [40].

2.6. Statistics

Datasets related to demographics and ethnobotany were gathered and submitted to univariate and multivariate analysis. The one sample *t*-test (P = 0.05) was calculated to compare the differences in the RFC, FC, number of disease categories, number of ailment

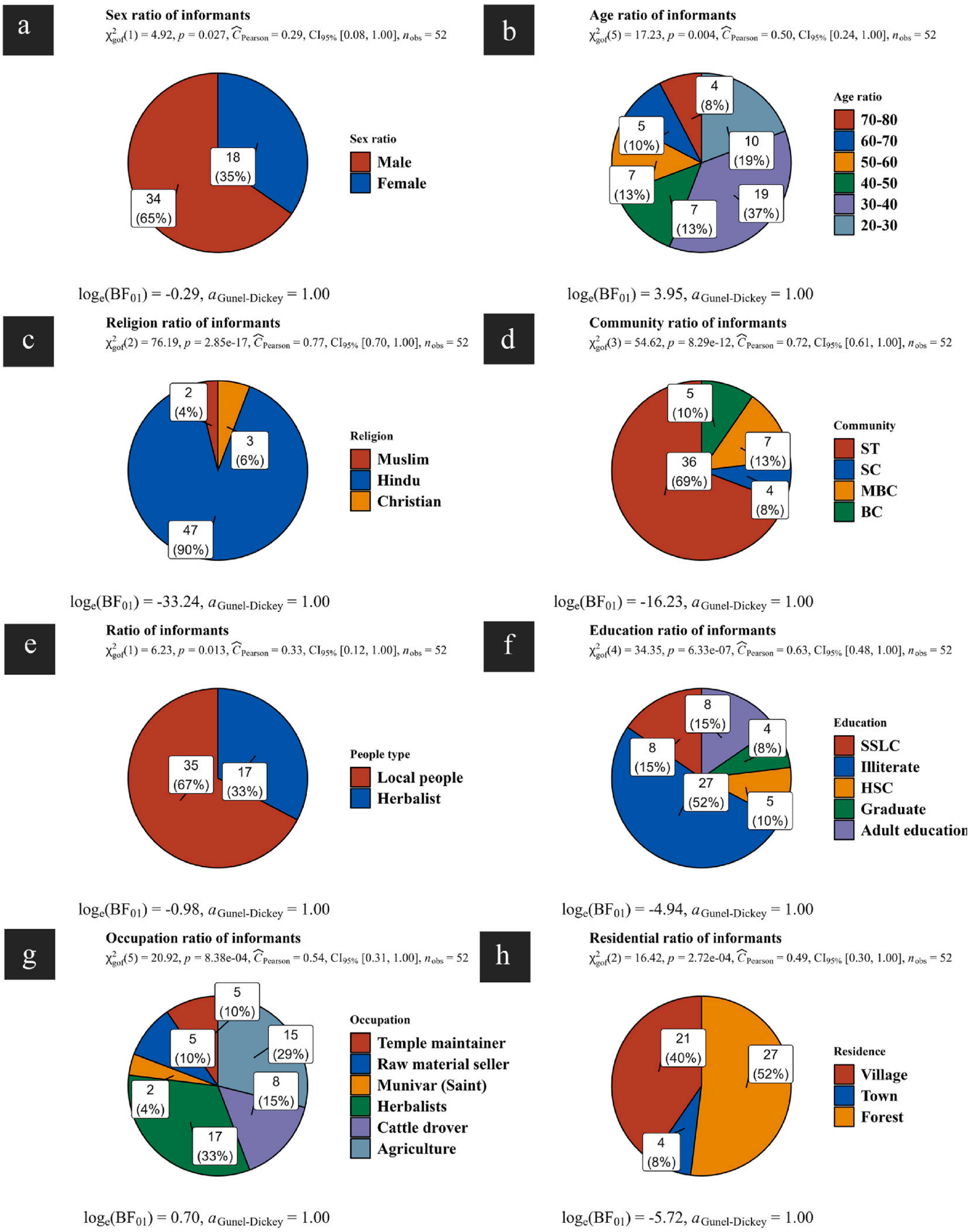

Fig. 3. Overall demographic profile of informants in Jawadhu hills.

categories, and use value given by informants. The ggstatsplot module uses the chi-square goodness of fit index analysis to separate the demographic profile data. The library ggcor examined the document of species and performed the Pearson correlation test to the disease and ailment categories to search for significant relationships. A was used to examine how information about medicinal plants is shared among different study environments according to lifeform and family. To investigate the variations in the informants' conventional healthcare knowledge in terms of disease category, ailment category, and fundamental descriptive outcomes, the total variance within the dataset was calculated using the R language platform. Significantly, Principle component analysis was the multivariate analysis techniques used in this study [41]. Moreover, the rarefaction cuve was computed using the iNEXT library to determine the richness and diversity of medicinal plant species, as well as an abundance-based two-way cluster analysis, was developed to investigate the relationship between illness category and species (R software version 4.0.1).

3. Results and discussion

3.1. Characteristics of informants

The survey involved interviewing 52 traditional Malayali tribes from the Javadhu hills in Tiruvannamalai, India, as well as other herbalists. The information gathered regarding the characteristics of the tribes is summarised in Supplementary T. 3. The ratio of male to female practitioners interviewed was significantly different, with male practitioners being the majority (34, 65.4%), while female practitioners made up just 34.6% (18 people) (P = 2.85e-17, Chi-square GOF = 76.19) (Fig. 3a). Males are overwhelmingly dominant and in charge of treating health issues in both humans and animals, which has been demonstrated by numerous ethnobotanical researchers, as in the case of the present study [42]. The greatest age group among the traditional healers who were interviewed was between the ages of 30 and 40 (36.5%; 19 people), followed by 20–30 (19.2%; 10 people), 40 to 50 (13.5%), and between the ages of 50 and 60 (13.5%) (Fig. 3b). The age group of 60–70 and 70 to 80 had the lowest percentage (9.6% (5–4)). At the 1% level, the Chi-square goodness of fit test revealed a significant difference between the age groups (P = 0.004). The majority of the interviewees were between the ages of 20 and 60, while the number of participants between the ages of 60 and 80 was very low. This statement was conflicted with the study undertaken in Punjab, Pakistan [42], but it was consistent with studies conducted in the Pechiparai Hills [43]. and the Chunati Wildlife Sanctuary [44].

Schedule tribal communities (69.2%) and Hindu people (90.4%) made up the majority of the population. The goodness of fit test also revealed that there were significant variations between the categories of Religion and Community (P = 2.85e-17 and P = 8.29e-12, respectively) (Fig. 3c and d). Local peoples are the most dominant respondent (67%), then the herbalist (33%). At the 1% level, the Chi-square test revealed a significant difference (P = 0.013) (Fig. 3e). Education displays a significant difference at the 1% level (P = 6.33e-17) once again, similar to the previous category (Age group), with the majority of the population being illiterate (52%; 27 persons) (Fig. 3f). Approximately 15.4% of the population (18 persons for both) have finished their primary school, and 15.4% have finished their adult education. Four of the members are only graduate students. As a result, the native population had poor educational credentials. The majority of Tamil Nadu's tribes and traditional healers had venerated the Hindu goddess from ancient times, and their educational standards were quite low [20,26].

Herbalists were the most common occupation among respondents (32.7%), followed by cattle herders, temple caretakers, Munivars (Saints), and raw material sellers (28.8%, 15.4%, 9.6%, 3.8%, and 9.6%, respectively). At the 1% level, the Chi-square test revealed a significant difference (P = 8.384–4) (Fig. 3g) between the occupation categories. In addition, interviewees preferred residing in a forest environment (52%), followed by a village (21%) and a city (8%); the difference in preference was statistically significant (P = 2.72e-4) (Fig. 3h). The primary livelihood of the indigenous tribal people (Malayalis) in Tamil Nadu was agriculture [45]. Although the present study found that the traditional healer was the primary source of income for the indigenous tribal people (Malayalis) of Javadhu hills, Tiruvannamalai, Tamil Nadu, this was already recognized by Prabhu et al. [46] in the Kalrayan Hills in the Viluppuram district. Most notably, as shown by our study, Malayali tribal communities prefer the environments of deep forests for their survival [47].

3.2. Diversity of medicinal plants in Javadhu hills

The results obtained from the surveys (Botanical name, plant family, specimen code, Habitat code, Occurrence code, habit, part used, preparation methods, local use, use value, Med IARs value, ICF) are denoted in the Supplementary t. 4.

The Javadhu hills included a total of 146 species that belonged to 108 genera and 52 families. Gymnosperms and pteridophytes made up 1.4% and 6.2% of all species, respectively, whereas the majority of species (92.5%) were angiosperms (Supplementary t. 5). According to plant habit, trees made up 21 families, 41 genera, and 53 species, whereas herbs made up 18 families, 23 genera, and 31 species, and climbers made up 15 families, 24 genera, and 31 species. Shrubs are made up of 8 families, 15 genera, and 15 species. Ferns are made up of 6 families, 9 genera, and 10 species. The other lifeforms, such as liana, gymnosperms, and epiphytes, are extremely rare (1–5 in number) (Supplementary t. 5&6). As in our work, other investigations have recently documented medicinal plants from various phyla due to their medical value [48].

The families with the highest species richness were Leguminosae and Apocynaceae (13 species, 8.9% each), Rutaceae (9 species, 6.2%), Solanaceae (7 species, 4.8%), Lamiaceae (6 species, 4.1%), and Lauraceae and menispermaceae (5 species, 3.4%). The remaining families contain 1-4 species, 10 families (Combretaceae, Compositae, Dioscoreaceae, Euphorbiaceae, Malvaceae, Moraceae, Phyllanthaceae, Pteridaceae, Rhamnaceae and Rubiaceae) contribute 4 species (4 species in each family), likewise, 3 families contributed 3 species (3 species in each family), seven families contributed 2 species, 25 families contributed single species (Supplementary t. 7). Due to their greatest availability and distributional range, many tribes in India [46,49–51] as well as adjacent countries have already reported that the frequent usage of Leguminosae members [52].

At the 1% level, there is a significant difference in the habitat proportion of the plants that have been observed ($\chi^2_{gof}(22) = 274.3$; p = 1.91e-45) (Fig. 4). In this region, the majority of the species that have been observed are widespread in all habitats (45 species, 31%). These are followed by 12 species (18%) that grow in tropical dry deciduous forests, 10 species (7%) that reside in shrubby areas, and 9 species (6%) that reside in evergreen forests. There are only a few species that can survive in the remaining ecosystems (1–8 species (1–5%)). Significantly, some plant species, like *C. caudata, C. epigaeus, C. fenestratum* and *C. peltata*, are grown in a specific habitat, but others, like *T. procumbens, A. precatorius, Cardiospermum* spp.*, C. quadrangularis, Citrus* spp.*,* etc., are often found in all tropical environments (www.indiabiodiversity.org). At a 1% level, the availability proportion of plants likewise differs significantly ($\chi^2_{gof}(6) = 190.67$; p = 1.91e-45) (Fig. 5). The availability of the most medicinal plant species was widespread (68 species, or 47%), followed by 45 species in the forest environment. Although the availability proportion of 16 species was quite uncommon due to its limited distribution, the remaining categories only have a few species. Examples include *P. dicoccos, C. swietenia, C. fenestratum, C. epigaeus,* etc., whose distributional range was constrained as a result of overexploitation and reproductive failure, among other factors [57,58].

Angiosperms (134, 91.8%) comprised the majority of the ethnomedicinal plants in this study, followed by ferns (10, 6.8%), and gymnosperms (2, 1.4%) (Supplementary t. 5). Due to their distributional range and exponential abundance, flowering plants (Angiosperms) have a greater rate of ethnobotanical medicinal use than the other plant groups [43]. As such, the most common lifeform was a tree (53), followed by herbs (31), climbers (31), shrubs (15), pteridophytes (10), liana (3), gymnosperm (2), and epiphytes (1). Traditional or conventional medicine encompasses the use of plants and plant products as therapeutics [53]**.** Recent ethnobotanical studies in India and surrounding countries revealed that the lifeform herb was the most frequently used lifeform [20,42] (Supplementary t. 6). However, the current study reported that the lifeform tree was the most frequently used lifeform because of its year-round presence, which is consistent with the findings of Kareti et al. [49]. While leaves (78 species, 28%) are the most frequently used plant part, followed by fruit (29 species, 11%), aerial part and rhizome (26 species, 9% each), seeds (20 species, 7%), stembark (18 species, 7%), stem (11 species, 4%), and root (10 species, 4%) (Fig. 6). Only a very small percentage of species (1–9 species) contain any remaining plant parts. The proportion between various plant parts varied significantly, according to the Chi-square test (P = 9.39e-84). These findings have also been acknowledged by a number of authors in various Tamil Nadu regions of India [17,18,20,21,43,54] as well as in many allied countries [55].

There were considerable variations between the preparation techniques utilised by the Malayali tribe community in the Javadhu Hills to generate ethnomedicine ($\chi^2_{gof} = 561.56$; p = 3.54e-106) (Fig. 7). Interestingly, the decoction was the most frequently used preparation method (87 species, 31%), followed by paste, juice (29 species, 10%), curry (26 species, 9%), chutney and powder (14 species, 5% each), and other preparation techniques are only utilised in a very small number of species. Similarly, numerous studies showed that decoction was the method most commonly used to treat a variety of illnesses that affect humans [56]. The current investigation also identified four different forms of administration procedures. Particularly, oral administration (227 species, 80%) was more common than topical (48 species (17%), chewing (5species (2%)), and brushing (2 species (1%)) (Fig. 8). Due to its adequate

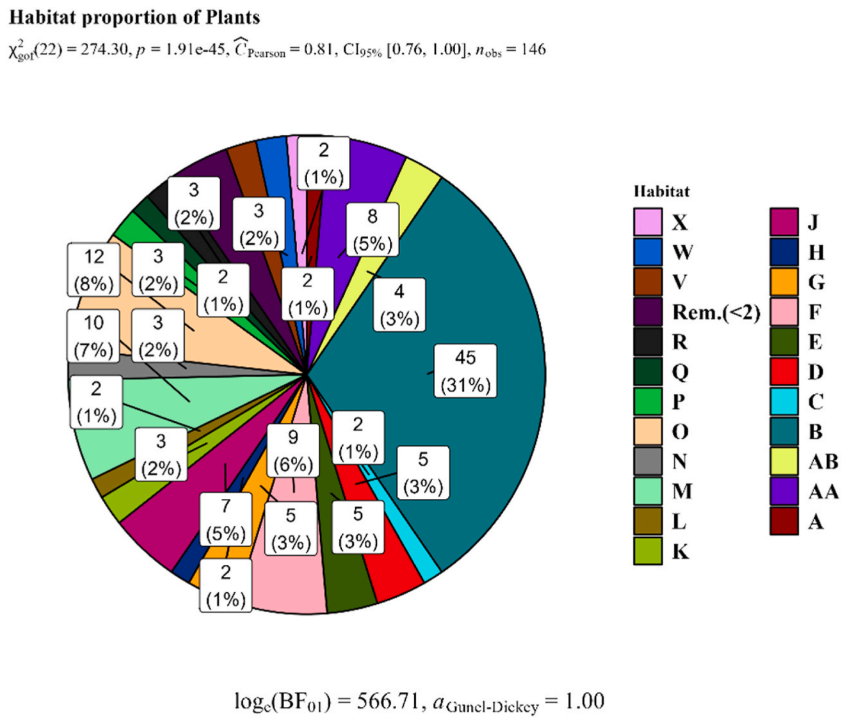

Fig. 4. Percentage of habitat proportion of the total number of plant species informed as used for ethnomedicinal purposes.

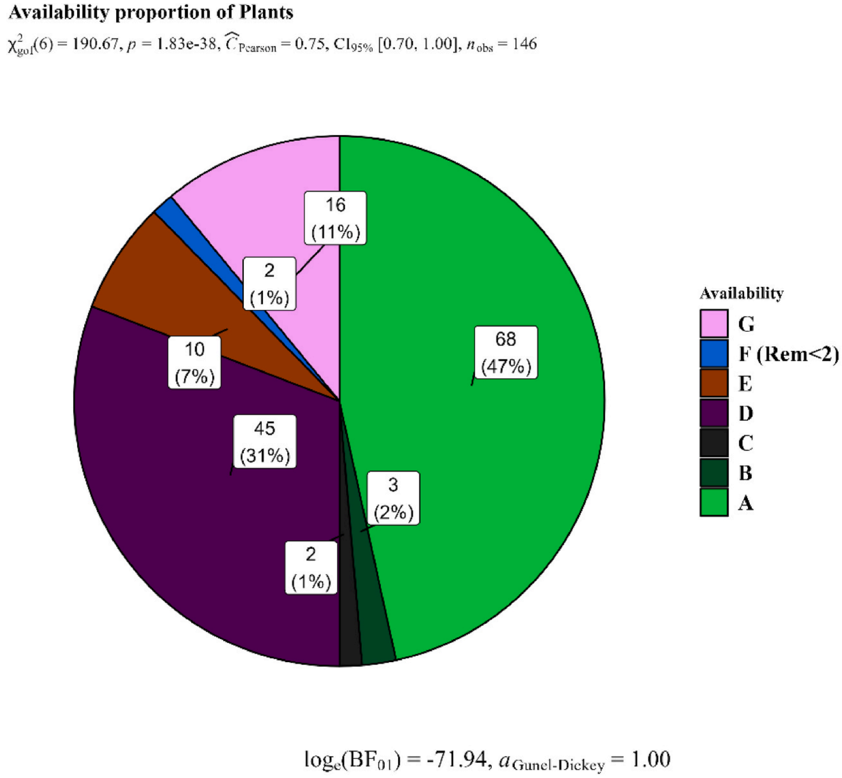

Fig. 5. Percentage of availability proportion of the total number of plant species informed as used for medicine.

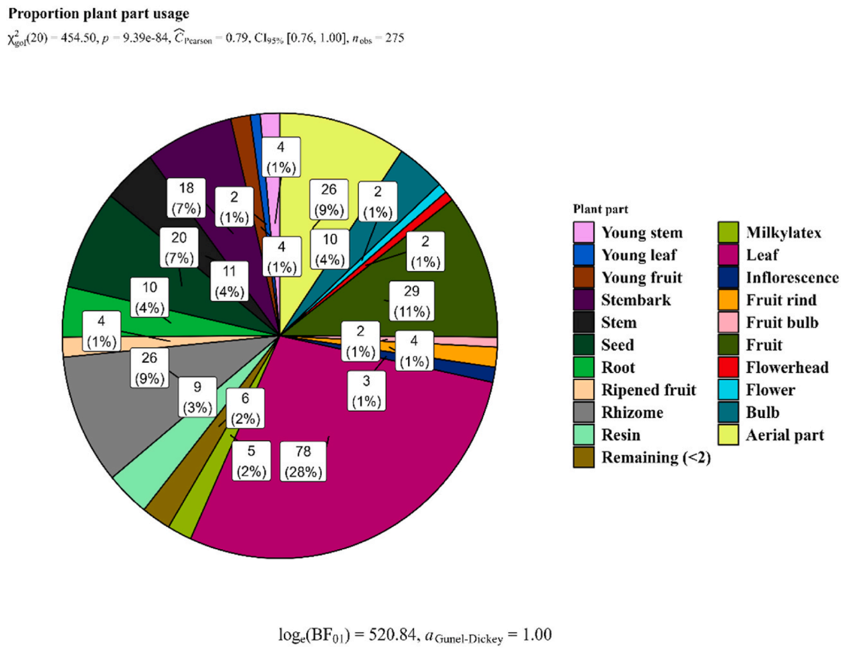

Fig. 6. Percentage of different plant parts used in the Javadhu hills region.

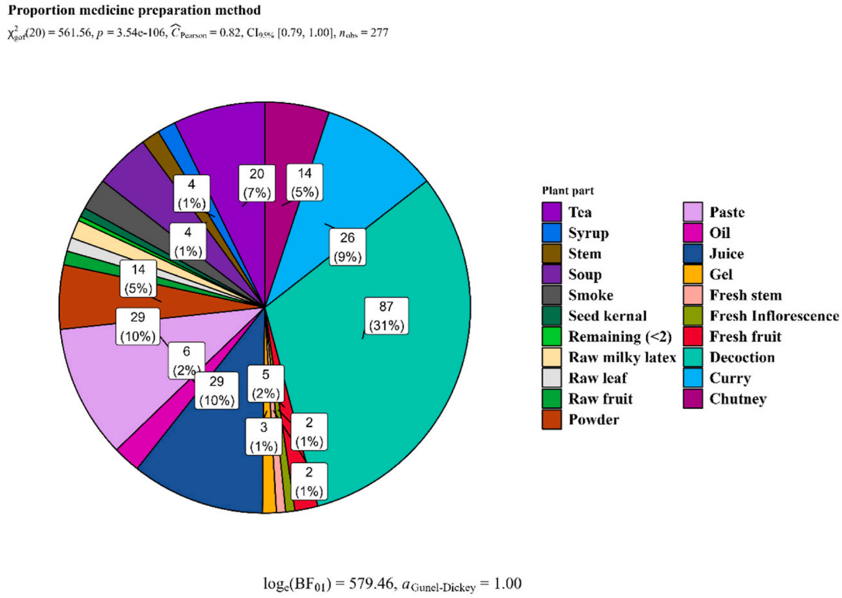

Fig. 7. Percentage of form of medicine used in the Javadhu hills region.

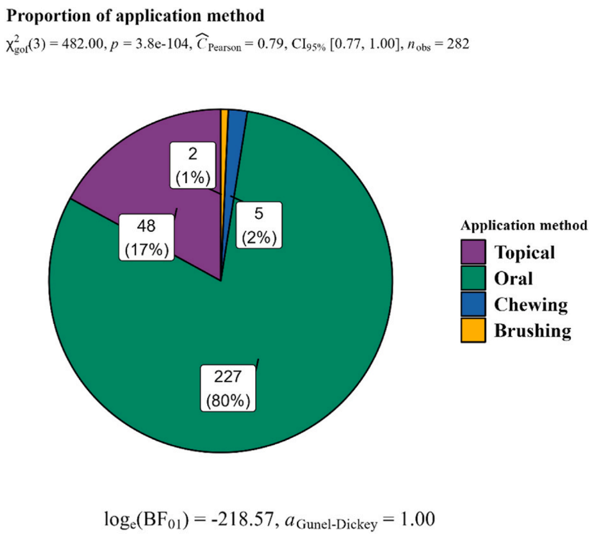

Fig. 8. Percentage of various application mode applied in the Javadhu hills region.

variation, there was a significant difference in the administration modes (χ^2_{gof} = 482; p = 3.8e-104). Oral administration was frequently used in Malayali tribe communities, according to earlier ethnobotanical investigations [20,56].

3.3. Frequency of citation

The frequency of citations demonstrated the sociocultural significance of medicinal plants in determining their therapeutic effectiveness [59]. In this study, *Azadirachta indica, Cardiospermum halicacapum,* and *Tridax procumbens* are the three species most frequently cited (52 FC each), along with *Aristolochia indica, Moringa oleifera* (51 FC), *Dioscorea pentaphylla* (47 FC), *Cinnamomum verum, Myristica fragrans, Ocimum tenuiflorum, and Ocimum americanum* (45 FC each). The *Gnetum ula* (8 FCs), *Sapium insigne* (8 FCs), and *Decalepis hamiltonii* (8 FCs) species had the least frequency citations (9 FCs). The remaining species receive citations only occasionally (11–44 FCs). *Azadirachta indica* was determined to have the highest citation frequency, according to several ethnobotanical researches [60,61].

3.4. Relative frequency citation

Comparing the quantitative results of the ethnobotanical study can help us acquire a better understanding of the culture and traditions surrounding the use of plants by a particular ethnic group in a specific area. Supplementary t. 4 shows that among the species investigated, 3.4% (or around 4 species) had a relative frequency of citation of one (RFC = 1). This demonstrates that the vast majority of respondents in the study area agreed that these species were the most often utilised therapeutic plants. *Dioscorea pentaphylla, Ocimum tenuiflorum, Myristica fragrans, Cinnamomum verum,* and *Ocimum americanum* were the species with the most citations (0.9). *Asplenium yoshinagae, Callicarpa tomentosa, Vanda tessellate, Coscinium fenestratum, Cycas beddomei, Phoebe paniculate, Schefflera* sp, *Decalepis hamiltonii, Gnetum ula,* and *Sapium insigne* had the fewest citations (0.2), suggesting that they have the least medicinal importance. The one-sample *t*-test findings indicated that there was a significant variance in the RFC of plants (P = 0.0001). researchers in Pakistan's Neelum Valley, Toli Peer National Park, and Tanawal area have already reported on the importance of Dioscorea sp [62,63].

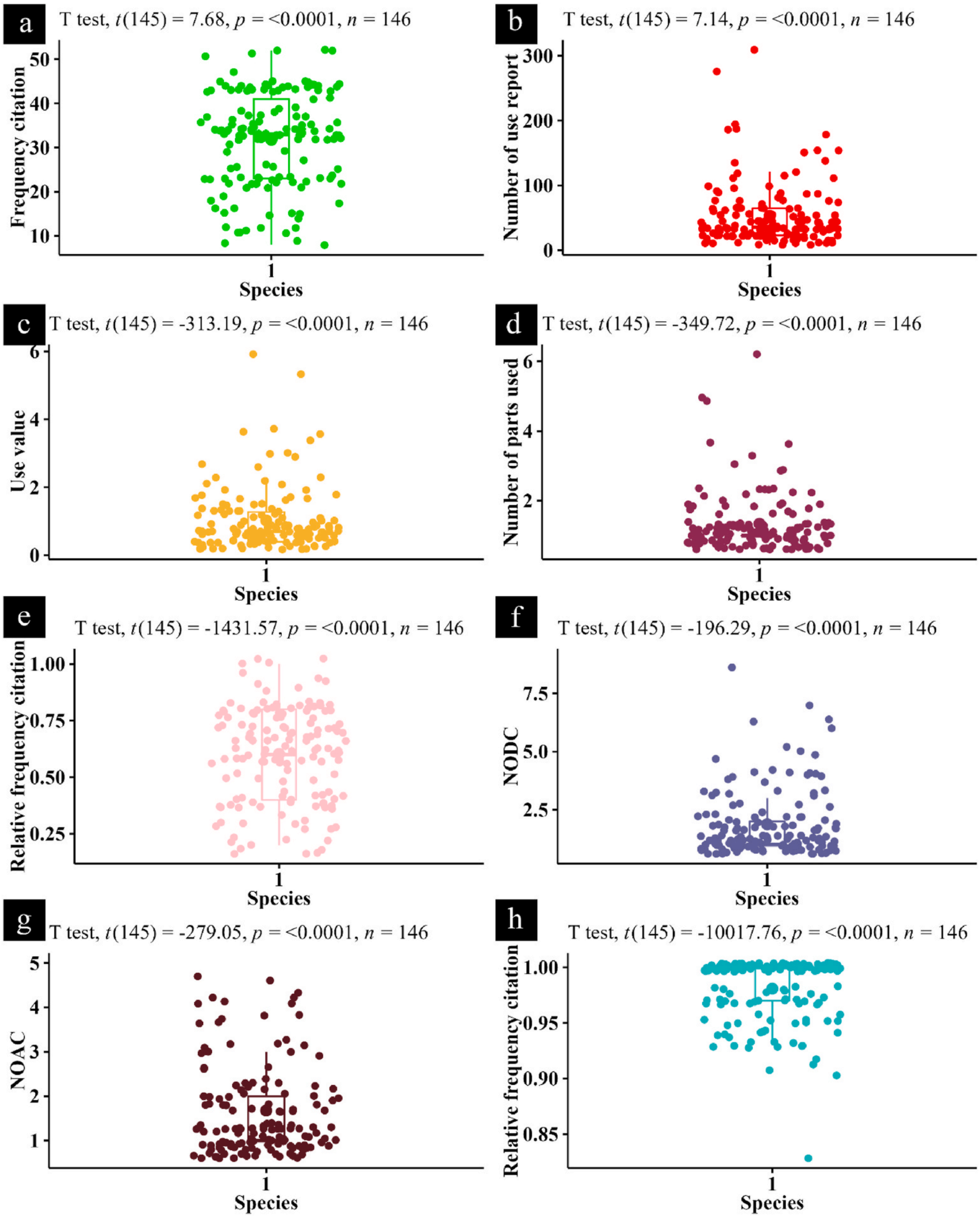

Fig. 9. One sample *t*-test on all the ethnobotanical indices derived from the individual plant species. a) Frequency citation of species, b)Number of used report of each species, c)Use value of each species, d) Number of part used in each species, e)RFC of each species, f)NODC of each species, g) NOAC of each species, h) RFC based on disease category.

3.5. Use report and use value

Different plant parts are used locally for medicinal purposes. On various plant components, 7793 URs were reported. In the Javadhu hill tribes, leaves make up the majority of the indigenous medicines (2355 URs, or 30.2% of 78 species), followed by fruit (1304 URs,/16.7%/29 species), aerial parts (1011 URs,/12.97%/26 species), rhizomes (727 URs,/9.3%/26 species), and seed (634 URs/8.1%/20 species). Less than 500 URs are available for the remaining parts. Frequent use of leaves has already been recorded in the Malayali tribe in the various Eastern Ghats regions [20,46]. In addition, the places inhabited by the Kani tribes (KMTR) also align with the present study [18]. *Ocimum tenuiflorum* had the highest number of citations (309) among the reported species, followed by *Curcuma longa* (276), *Ocimum basilicum* (194), *Azadirachta indica* (186), *Ficus racemosa* (178), *Andrographis paniculata* (156), *Ficus benghalensis* (156), and *Ficus religiosa* (156). (151 URs). While the fewest number of URs were obtained for species like *Gnetum ula* (8URs), *Sapium insigne* (8URs), *Decalepis hamiltonii* (9URs), *Schefflera* sp (11URs), *Phoebe paniculata* (11URs), *Coscinium fenestratum* (11URs), *Cycas beddomei* (11URs), *Vanda tessellata* (12URs), etc. The *t*-test reveals a significant difference between use reports for various plants (*t*-test value = 7.14; P = 0.0001). Similar to the use report, *Ocimum tenuiflorum* has a UV rating of 5.9. The majority of Malayali tribes utilise this plant to treat a variety of illnesses, especially cancer, the common cold, and cough. Aside from these, other plants with high use values include *Curcuma longa* (5.7), *Ocimum basilicum* (3.7), *Moringa oleifera* (3.6), and *Azadirachta indica* (3.6). As a result of their reporting by a few informants, 10 species had the lowest UV (0.2) values. Additionally, the use value across the plants showed a significant variance at a 1% level (P = 0.0001).

Due to their active biomolecules, noteworthy species including *O. sanctum, C. longa, M. oleifera*, and *O. basilicum* are the primary commercial plant species used for food and medicine in India [64,65]. In addition, recent studies have demonstrated the significance of *Ocimum tenuiflorum* in India and its nearby countries from an ethnobotanical perspective [18,54,66,67]. The UV of a taxon will differ depending on the availability of a certain plant in an area, how it is used, and the informant's experience. High UV species may experience significant anthropogenic stress, which might make them rare in their native habitats. The plants with the lowest potential uses are not entirely unimportant because this may mean that traditional knowledge about these plants is in danger of not being handed down and may even be slowly vanishing.

The one sample *t*-test showed the significant difference between species. For instance, Fig. 9a showed the significant difference on frequency citation related to related to disease category ($P < 0.0001$). Fig. 9b, showed the significant difference between the use report of species ($P < 0.0001$). Fig. 9c showed the significant difference on use value of species. Number of part usage on each species was also noticed a significant variation (Fig. 9d) $P < 0.0001$. Fig. 9e showed RFC of species also differed significantly ($P < 0.0001$). As like this, NODC and NOAC of species also noticed appropriate variance (Fig. 9f and g). Moreover, RFC related to species related to disease category (Fig. 9h) also noticed a significant difference ($P < 0.0001$).

3.6. Informant agreement ratio

On plant usage, there was a 0.1–1 range in the informant agreement ratio. In the current investigation, the plants with the highest IAR values were those that all of the informants recommended for treating the same ailment, particularly when treating a single disease. Significantly, the maximum IAR-value 1 was noticed for the species such as *Tridax procumbens* L. (Wound healing), *Cinnamomum verum* J.Presl (Improves body health), *Ocimum americanum* L. (Insect repellent), *Acacia concinna* (Willd.) DC. (Hair growth), *Actiniopteris radiata* (Sw.) Link (Bone setting), *Cocculus hirsutus* (L.), W.Theob. (Leprosy), Piper nigrum L. (Throat infection), Citrus hystrix DC. (Body refreshment), *Ficus microcarpa* L.f (Fungal infection on head), *Hemidesmus indicus* (L.). R. Br. (Body refreshment), *Ruta graveolens* L. (Snakebite), *Toddalia asiatica* (L.) Lam. (Stomach pain), *Memecylon umbellatum* Burm. f. (Diabetes), *Sapindus mukorossi* Gaertn. (Hair growth), *Dalbergia* sp (Stomach pain), etc., (56.4%) (Supplementary t. 4). The remaining species' IAR range ranged between 0.83 and 99 (43.6%). An ethnobotanical investigation revealed that a plant with a high IAR among easily available plants was important for maintaining knowledge of its use in therapeutic formulations [20,25].

3.7. Family use value

The Meliaceae was the most frequently used family with the highest FUV (3.6 with 3.6 UV, Single species) followed by Zingiberaceae (3.3 with 6.3 UV, 2 species), Acanthaceae (3 with 3 UV, 1 species), Moringaceae (2.6 with 5.2 UV, 2 species), Moraceae (2.5 with 10.1 UV, 4 species), Nelumbonaceae and Vitaceae (2.3, UV 2.3, 1 species) (Supplementary t. 6), Anacardiaceae, Myrtaceae (2.1 with 2.1 UV, 1 species), Lamiaceae (2 with 12.1UV, 6 species), remaining are with 0.1–1.8 FUV (Supplementary t. 7). Our findings suggest that a significant number of species are not necessarily present in the study area to represent the families with high FUV. It was established that the local community prefers to utilise specific plant families over others, which depends on the use-value of families. Similar outcomes from a recent ethnobotanical experiment have been published [68].

3.8. Fidelity level

Different ailments have been treated with plants, either on their own or in combination. Higher FL value plants were used more frequently than lower FL value plants. In the present study 84 species of plants were recorded with 100% fidelity level for different type of illness category (Supplementary t. 4). According to informants, the plant species with the highest FL are those that are most commonly used to treat a particular illness category [39] and plants that are used repeatedly are more likely to be biologically active [36]. Thus, plants with the greatest FL may have strong therapeutic potential for a specific disease [18]. The plants with the highest FL

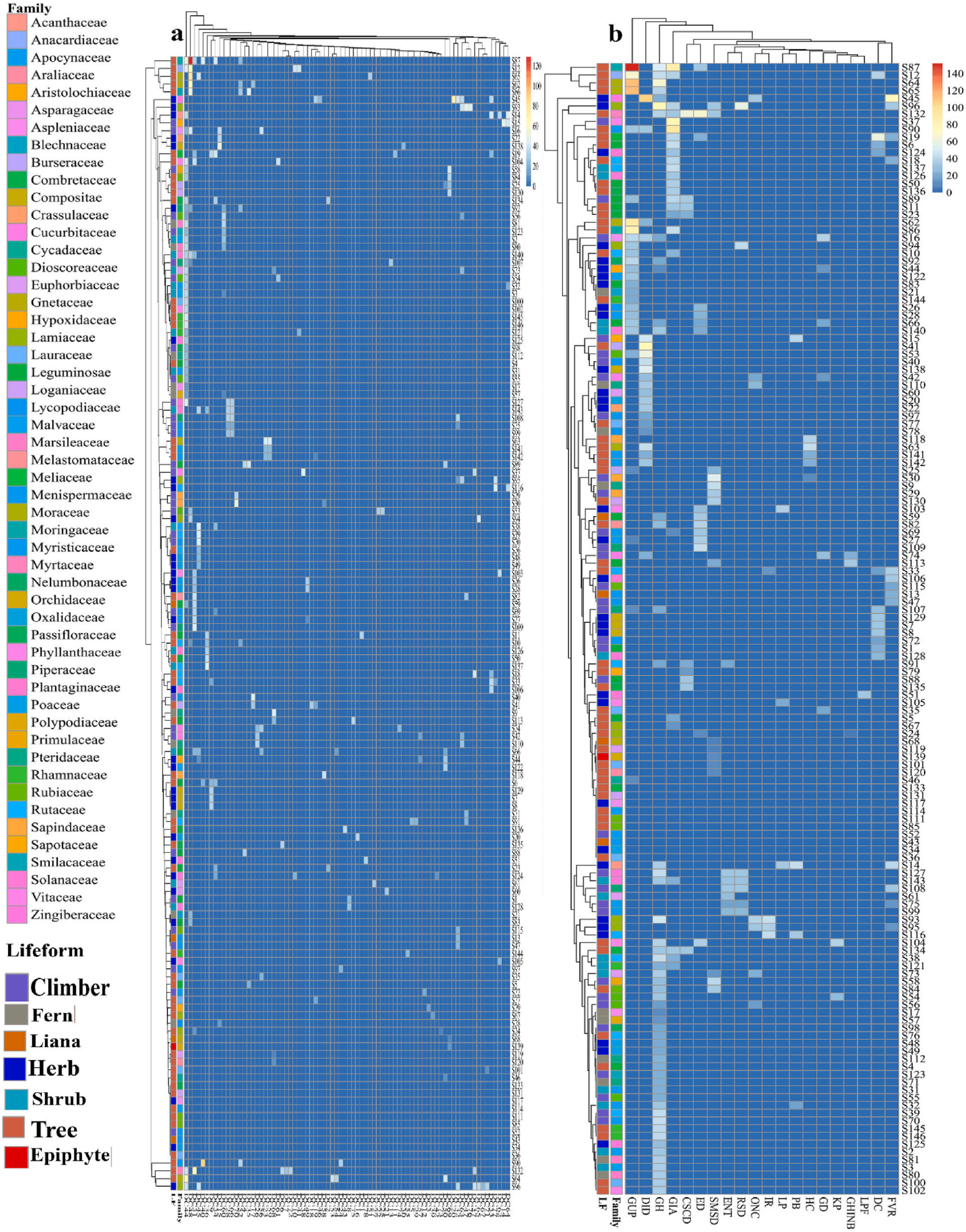

Fig. 10. Two-way cluster analysis based on use report of plants used for to treat a) disease category and b) ailment category in Javadhu hills.

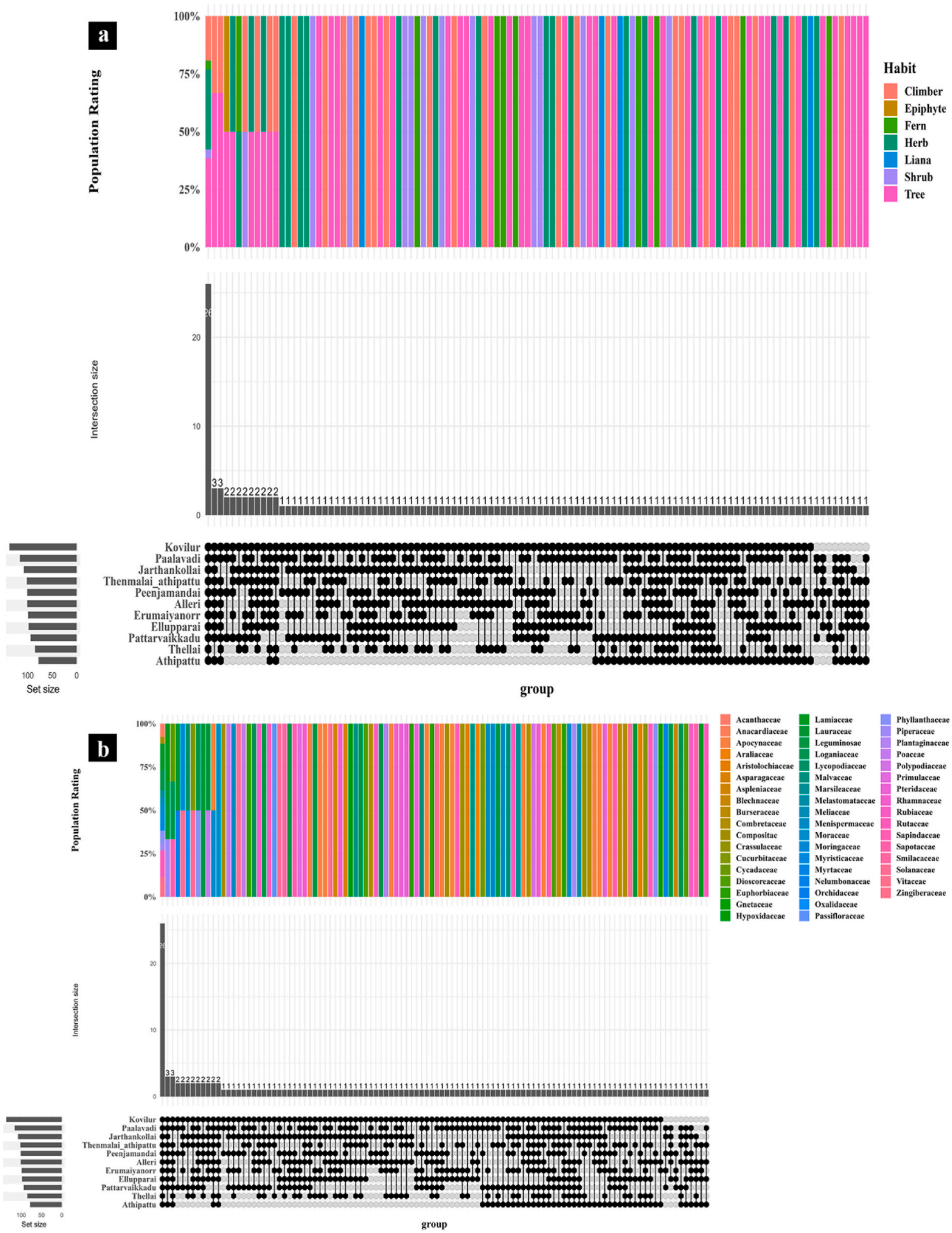

Fig. 11. Complexupset intersection plot showed the sharing of species at a different area of Javadhu hills based on a) Habit and b) Family.

values were also claimed to possess a number of pharmacological properties that had been independently verified by science. Some important plants with the highest FL in the study were *T. procumbens* (DID), *C. verum* (GH), *O. americanum* (IR), *A. concinna* (HG), *A. radiata* (SMSD), *C. hirsuitus* (DID), *Piper nigrum* (ENT), *F. microcarpa* (DID), *H. indicus* (GH), *T. asiatica* (GIA), etc., On the other hand, the plant with the lowest FL suggests that these plants were less popular species for treating particular illnesses. In contrast, one of the well-reported plants in the research (*O. sanctum, C. longa,* and *M. oleifera*) has been extensively used to treat many different types of ailments and has actually obtained very low FL values. Abe and Ohtani [69] (*M. oleifera*); Xavier et al. [54] (*O. tenuiflorum*) were utilised for a broad variety of diseases by the locals in the Philippines and the tribal community in Kerala, with varying low FL values similar to those found in the current study.

3.9. Informant consensus factor

According to the study findings, the Galactogenic problem was the most prevalent in the study area with an ICF value of 1, followed by Kidney problem (0.985), Respiratory System Disorder (0.983), Insect repellent, Genito urinary problem (Each with 0.979), Dental Care Dermatological infections and Disorder (0.977), Poisonous bite, Ear, Nose and Throat infections (Each with 0.976), Gastrointestinal ailments (0.973), Circulatory system/Cardiovascular disease (0.972), Dental care, Endocrinal disorder (Each with 0.971), Fever (0.970), Oncology (0.968), Liver problem, General health in a newborn baby (Each with 0.968), General health (0.966), Gynecological disorder, Skeleton Muscular system disorder (Each with 0.964), Hemorrhoids (0.960) and Haircare (0.957) (Supplementary t. 8). All of the disease categories reported in the Malayali tribe's habitat region (Palamalai) were consistent with the present findings, and the majority of the disease categories in the current study were documented with the highest ICF [20].

3.10. Relationship between species and disease category

The 146 species' 78 ethnobotanical applications were analysed in two-way clusters, and the results revealed 4 main clusters (Fig. 10) between illness categories and plant species. A heat map displaying the frequency of plant use reports. Additionally, it demonstrates a distinct division between disease groups and species. Three distinct clusters can be seen on the dendrogram of disease categories, with cluster 1 having the maximum use reports and the other two having intermediate use reports (Fig. 10a). Due to the

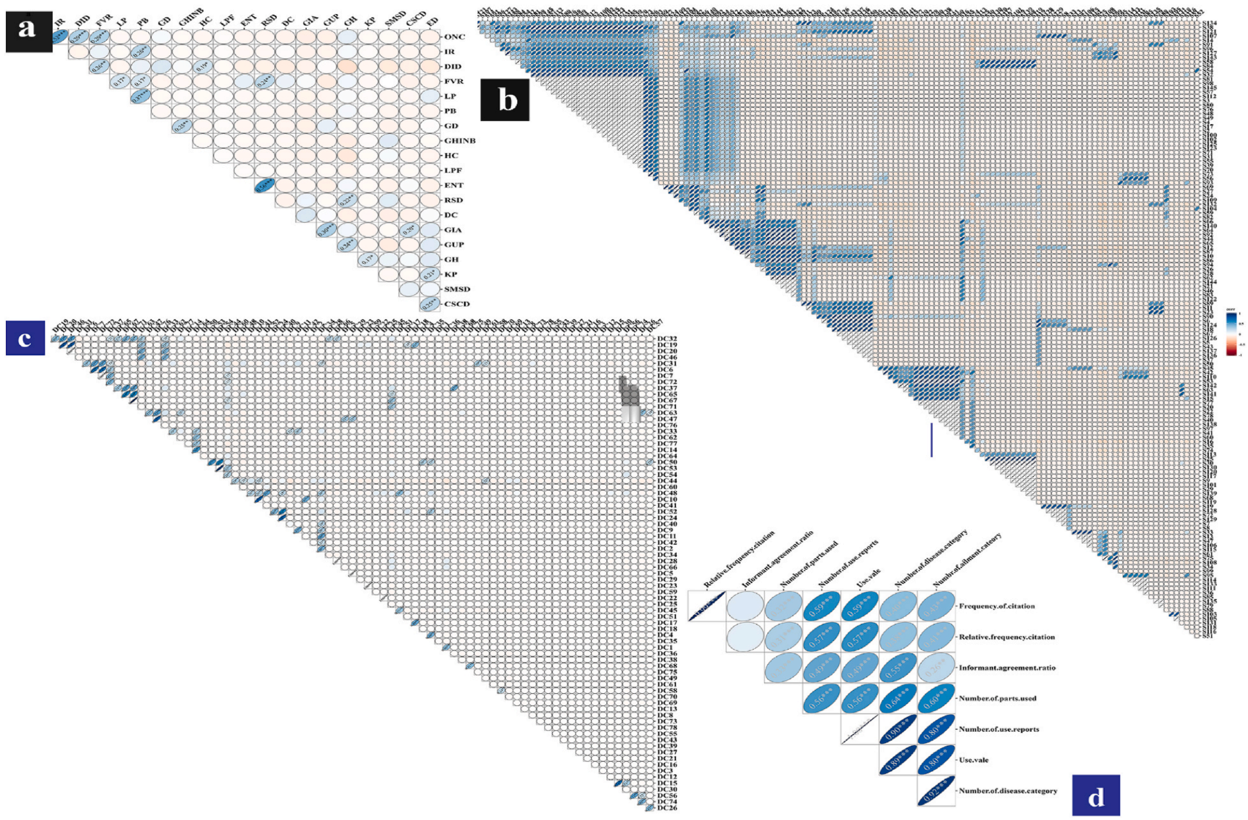

Fig. 12. Pearson correlation showed a significant relationship between a) species, b) Ailment category, c) Disease category and d) Ethnobotanical indices. (Dark blue indicates maximum positive correlation and light blue indicated minimum positive correlation; red color indicates negative correlation).

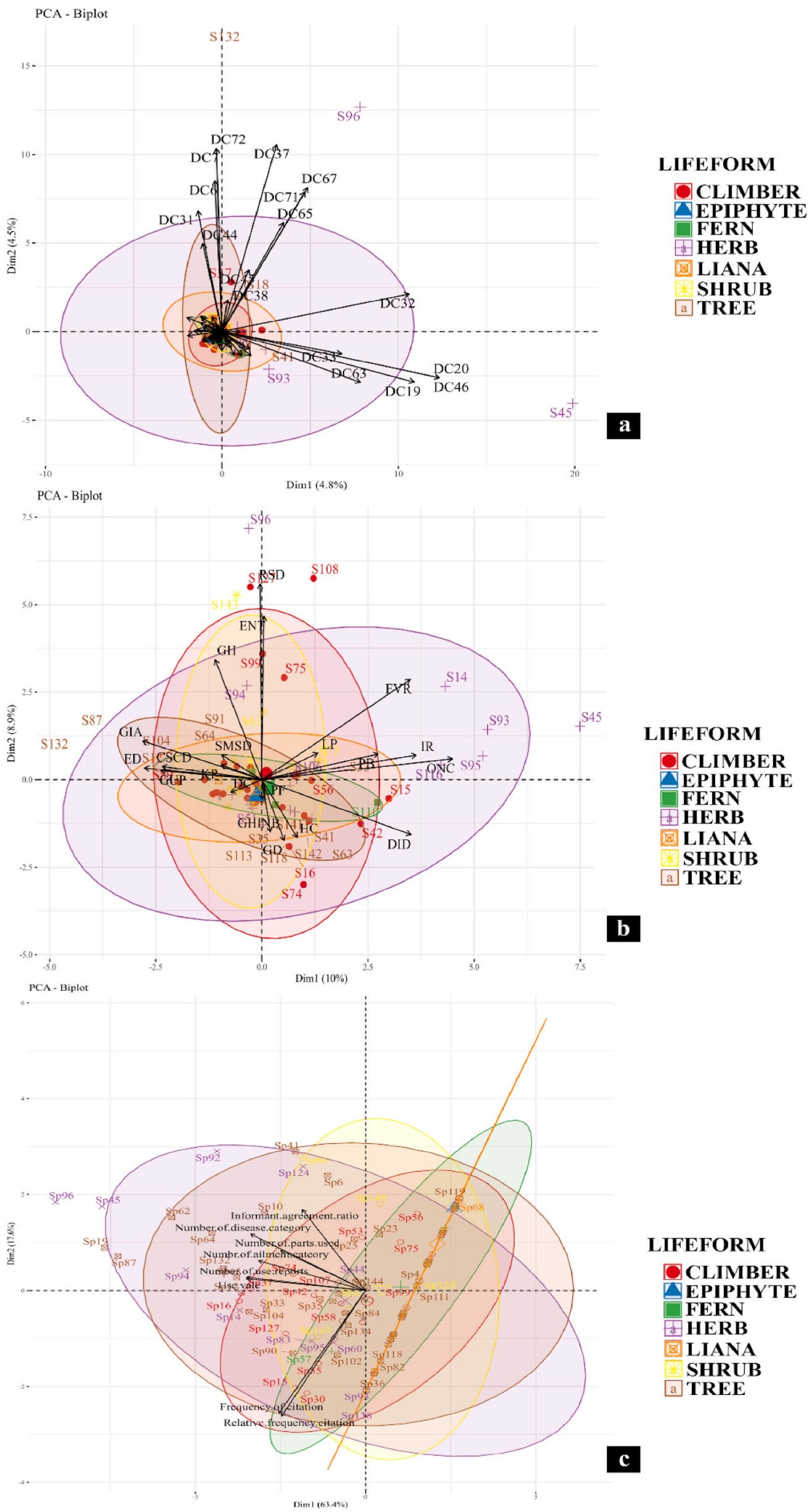

Fig. 13. Principle component analysis showed the variation between a) Disease category, b) Ailment category and c) Ethnobotanical indices. (Library ggplots, FactoMineR and factoextra, corrplot are used for the PCA biplot analysis in R siftware Ver. 4.0.1).

existence of the greatest number of use reports, illness categories including DC44, DC48, DC 31, and DC45 were specifically discovered to have a close relationship. Significantly, a maximum use report for the DC 48 was noted, and it is used for species like Sp. 87, Sp. 12, Sp. 65, Sp. 62, and Sp. 86. On the left side, you can see different colored blocks that represent the lifeform and the species' family. The top annotation was the category for ailments. According to a dendrogram based on species, there are four distinct groups, with Sp. 87, 12, 65, 62, and 86 being grouped together with reports of maximum use, Sp. 90, 132, 64, and 96 are grouped together with reports of minimum use, and the remaining species are grouped together with reports of moderate use and those species being reported for the treatment of specific diseases. The same findings from the above-mentioned two-way cluster analysis dependent on the DC were also found (Fig. 10b). For example, three distinct row annotation clusters were found, in which Sp87, Sp12, Sp64, Sp65, Sp45, Sp96, Sp132, Sp37, and Sp10 were grouped together due to their maximum use reports as well as their similarity to lifeforms and families. Additionally, the plants in the third cluster are mostly used to support human immunity and overall physical health. The association between the various DCs was also shown by column annotation. For instance, GUP, DID, GH, and GIA were recognized with the highest use reports and are treated by the majority of plants. Numerous studies have been conducted recently that use two-way cluster analysis, like in the case of the present study, to illustrate the association between DC, AC, location, and individual UR of plant species [70,71].

3.11. Distribution and interconnection of medicinal plants

The usage of medicinal plants varied in different environments of the Javadhu hills due to their distribution, availability, and people's knowledge. There were 116 intersection groups total, with one group recording 26 species across all environments, two groups recording 3 species (one group shared all the areas except Thellai, and another group shared all the areas except Jarthankollai), 9 groups recording 2 species, and the remaining groups having a single species but with varying intersections. At the top of the intersecting group, a bar chart depicting the proportion of each group's Lifeform (Fig. 11a) and Family (Fig. 11b) (Based on Species) was displayed. Numerous kinds of research in the neighboring countries [42,72–74] have already reported the overlapping of species between areas, tribes, and time. Their findings also partially agreed with our study.

3.12. Correlation on ethnobotanical indices and use report on disease, ailment and species

Maximum and moderate association with a significant difference was found between the categories of illnesses for ENT and RSD (0.56), ONC and IR (0.52), LP and PB (0.37), ONC and DID (0.29), and ONC and FVR (0.29) (Fig. 12a). Additionally, Fig. 12b showed a linear relationship between the use reports of different species, where the dark blue color expresses the highest correlation and the light blue color has the lowest correlation. Whereas the light brown color represents the representation of a negative correlation, the right end of the figure in particular exhibited the maximum correlation with significant differences as a group. The positive correlation indicates both the value of using plants and the cultural relevance of each species. Positive combinations prepare the door for future ethnobotanical and ethnomedical applications. The other disease categories refused to exhibit any correlation or statistically significant difference. In terms of disease categories, DC71 vs. 67 (0.95***), DC 54 vs. 53 (91***), DC20 vs. 19 (0.78***), DC46 vs. 20 (0.78***), and DC41 vs. 10 (0.77***) were observed to have the highest correlations with significant differences, while only a few disease categories had moderate to low correlation (Fig. 12c). The remaining disease categories revealed neither correlation nor significant difference. IAR, RFC, UR, and UV, which are ethnobotanical indices, were shown to be significantly correlated at 0.01 (Fig. 12d). A strong positive correlation was present between RFC and FC ($r = 0.99$***), followed by Number of Ailment Category (NOAC) and Number of Disease Categories NODC ($r = 0.92$***), NODC Vs UR (0.90***), NODC Vs UV (0.89***), NOAC Vs UR (0.80***), NOAC Vs UV (0.80***), while a variable number of parts usage moderately correlated with the neighboring variables, likewise number of use report, was moderately correlated with the ethnobotanical indices such as RFC, IAR and FC. Additionally, the substantial differences in the ethnobotanical indices have a little relationship with the IAR and number of parts used (FC, RFC). Significantly, no negative association between the indices was found. In order to determine the linear relationship between the ethnobotanical indices, Sharafatmandrad and Mashizi [75] and Cao et al. [76] applied the correlation test; furthermore, their results were somewhat consistent with those of the present study.

3.13. Principle component analysis on ethnobotanical indices and use report on disease, ailment and species

The Malayali indigenous people used plants in the present study to cure several illness and ailment categories with a noticeable variation (Fig. 13a and b). Groupings between diseases and plant species were found by multivariate analysis. Principle component analysis based on disease category explained nearly 18.9% of the variation (Fig. 13b). FVR, GH, SMSD, RSP, ONC, and GIA are highly contributed variables in the first axis (10%), and highly contributed variables in the second axis (8.9%) include SMSD, CSCD, ED, GIA, GH, DID, and ONC. The contribution of plants to the remaining disease categories is insufficient. Additionally, the herbaceous lifeform was commonly used in the treatment of all health problems. One lifeform may have been utilised to treat a number of human health issues since the categories of different lifeforms overlapped. Particularly, species like S45 (*Curcuama longa*), S96 (*Ocimum sanctum*), S87 (*Moringa oleifera*), and S132 (*Syzygium cumini*) are discovered in the same position due to its diverse usage. A disease category-dependent PCA analysis revealed a total variance of 9.3%, with illness categories 46, 20, 37, 19, 32, 7, and 72 contributing significantly to the variance (Fig. 13a). Plant species like S132, S96, and S45 were also highly representative owing to their use reports. Herbaceous species, which overlap with other lifeforms, were also the most often used lifeform in this area to cure a wide range of ailments. The 63.4% variation at the first axis was shown via a PCA analysis using ethnobotanical indices (Fig. 13c). Use report, use value, the number of disease categories and the number of ailments are the major contributors in the present investigation. The values of the ethnobotanical indices for the species 96, 45, 19, 87, and 62 were similar. All of the life forms in this example overlapped one another, indicating that their values are greater or similar to those of others. The Malayali tribes in the nearby areas (Palamalai) have already documented these findings, for example, they have mentioned the different uses of *Moringa oleifera, Syzygium cumini,* and *Ocimum sanctum* [20]. In addition, a number of researchers, used this principle component analysis to establish the connection between the use of species, area, ethnobotanical indices, etc., and their findings coincide with us [77,78]. For instance, in the case of the present study, Kaur et al. [79] reported that the herb lifeform was the most prevalent one.

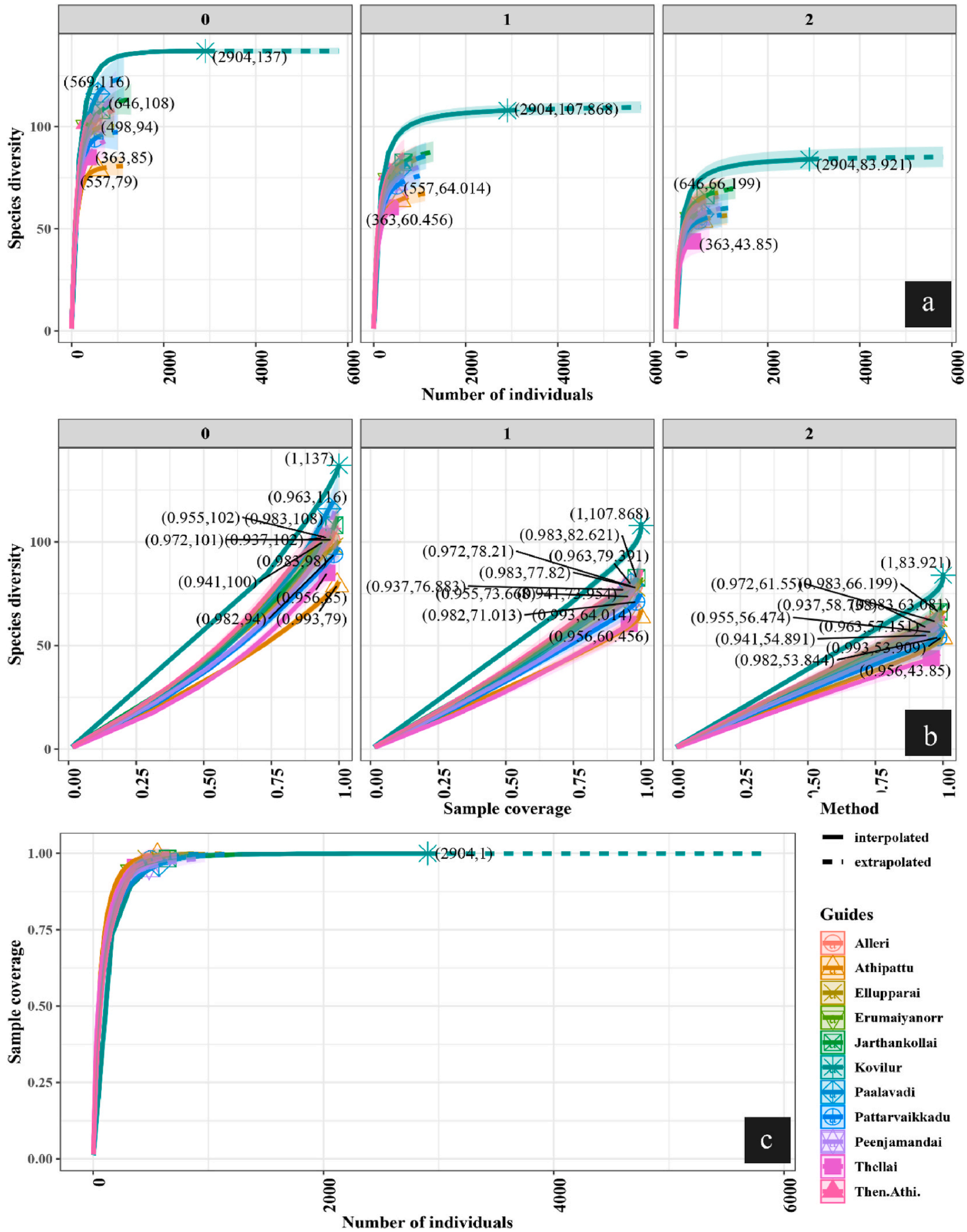

Fig. 14. Medicinal plant diversity indices (Citation based). a) (q = 0 (Species richness), q = 1 (Shannon diversity), q = 2 (Simpson diversity), b) sample coverage based on species diversity, c) sample coverage based on number of individuals, at different areas of Javadhu hills.

3.14. Ethnobotanical diversity and distribution

Medicinal plant diversity indices and sample coverage at different areas in Javadhu hills are shown in Fig. 14. The rarefaction curve revealed that the Kovilur region had the highest level of species richness, while the Athipattu region had the lowest (Fig. 14a). The existence of traditional healers, tribes and different types of environments increased the richness and diversity indices of medicinal plants. Furthermore, when compared to species richness, the Shannon and Simpson diversity ranges diverged little. With more sampling sites, there was a significant increase in coverage (Fig. 14b). Following extrapolation, species coverage became asymptotic (Fig. 14c). A number of recent studies have used the rarefaction curve to assess the species richness, diversity, and coverage in India and adjacent nations [80–82].

3.15. Novelty of the study

Some of the ethnobotanical applications revealed in our study had never been documented from the region, such as the usage of the stem bark of *C. swietenia* and *S. potatorum* to cure snake bites and the tubers of *Dioscorea* spp. for treating body weakness and piles. A. cocculus stem decoction was used to cure fever, especially during the rainy season. *C. caudata* stembark paste was used to treat Vitiligo, leprosy, and scabies. The milky latex of *Ficus microcarpa* was used to cure a fungal infection on the head. The leaf of *L. deccanensis* was used to treat scabies. *B. sensitivum* leaves were used to treat fungal diseases on the skin. *C. strictum* fruit rind was used to treat male fertility problems in humans. Furthermore, the stembark of *N. crenulata* was utilised to treat cardiac problems. *P. santalinus* resin was utilised to boost newborn babies' memory and brain activity. *Manilkara hexandra, P. acerifolium,* and *Sapium insigne* stembark were employed for bone setting. *P. dicoccos* leaf was used to cure cancer.

3.16. Medicinal plants with toxic effects

Malayali tribe of Javadhu hills use *Abrus precatorius, Aristolochia indica, Androgrqaphis paniculate, Strychnos nux-vomica, Phyllanthes emblica, Myristica fragrans, Mucuna atropurpurea, Moringa concanensis, Ficus microcarpa, Dioscorea* spp., and *Jatropha gossypifolia* say that these plants should be used conservatively. *Abrus precatorius* is poisonous because it contains abrine, which enters cells and prevents the creation of new proteins in cells [83]. When used in excess, *A. paniculata* has certain negative effects including nausea, vomiting, and discomfort in the abdomen [84]. *Aristolochia indica* has been proved to be a powerful carcinogen, kidney toxin [85] and nephrotoxicant [86]. It has also been reported to decrease fertility, develop gastrointestinal difficulties, and cause skin itching problems [87]. Phytomolecule Myristin, a compound found in *Myristica fragrans*, is known to induce liver problems in humans. In addition, eating excessive amounts of nutmeg seeds has been linked to delirium, tachycardia, dry mouth, impaired vision, psychoactive hallucinations, and face flushing [88]. Due to the presence of L-Dope content, regular consumption of *Mucuna Sp.* seeds might increase oxidative DNA damage and be hazardous to tissues affected by neurological disorders [89].Continuous consumption of *Dioscorea* spp., and excessive consumption of *M. concanensis* leaf lead to difficulties with stomach aches, however there is no scientific evidence of this plant's toxicity. Tribal peoples in India and Nepal rely heavily on the foods of the *Dioscorea* spp. However, due to the presence of phytomolecules such Diosbulbins A and B, these wild tubers are unpleasant to eat, have a bitter taste, cause inflammation, and occasionally exhibit toxicity [90]. The seeds of *J. Gossypifolia* are high in toxalbumins, which harm other cell types and agglutinate and hemolyze erythrocytes. They also contain a lipoid resin complex, which can irritate the skin. General gastrointestinal problems make up the symptomatology (abdominal pain, nausea, vomiting, and diarrhea). Additionally, the clinical course may result in issues with the heart, the brain, or the kidneys [91]. Few interviewees, including traditional healers and members of tribes, identified these species as being harmful to human health. Those who did provided general information on how these plants' use affected people and animals, but they were unaware of the exact types of harmful substances found in plants, their rates of action, or how they specifically affected people.

3.17. Conservation status of the plants

IUCN Red List categories place three species in the threat categories of Vulnerable (*Chloroxylon swietenia* and *Psydrax dicoccos*) and Endangered (*Decalepis hamildonii*, *Pterocarpus santalinus*), however many other species are found in this category geographically. Significantly, *Dioscorea* spp., *Aristolochia indica, Andrographis paniculata, Vanda tessellata, Asparagus racemosus, Biophytum sensitivum, Canarium strictum, Caralluma* spp., *Corallocarpus epigaeus, Kedrosdis foetidessima, Coscinium fenestratum, Anamirta cocculus, Smilax zeylanica, Lycopodiella cernua, etc.*, have extremely low or rare abundance and distribution. By speaking with the informants in Javadhu Hills, numerous elements that were thought to be the greatest risks to medicinal plants were noted. Deforestation, agricultural development, overgrazing, fire, and drought were cited as the main causes. It was found that virtually little was being done in the community to preserve therapeutic plants. Despite the minimum effort, some traditional practitioners have begun to conserve and cultivate medicinal plants in their own gardens. Traditional healers in the Thoppampatti, Dindigul region created a home garden of medicinal plants for their own usage [67].

4. Conclusion

The conservation and use of indigenous plants depend heavily on ethnobotanical knowledge. However, plant resources and their popular and traditional applications in many geographical regions and by people from various cultural backgrounds are documented in the current scenario. Therefore, the current study demonstrated that traditional therapy methods utilizing medicinal plants are still widely used in the Javadhu Hills study areas, reinforcing the necessity of documenting traditional ethnomedicinal knowledge before this rich resource is lost. According to our knowledge, this is the first quantitative ethnomedical investigation that identifies UR, UV, FC, RFC, ICF, IAR, and FL in the study area. There are 146 plant species that have been prescribed to treat 79 different illness categories, according to sources in the Javadhu Hills. The most often chosen plant species were *Syzygium cumini*, Moringa oleifera, *Curcuma longa,* and *Ocimum tenuiflorum*. The novelty of the present study documents new ethnomedicinal species with their therapeutic uses, which may lead to the invention of novel therapeutic and may serve as novel bioresources for phytochemical and pharmacological studies, particularly *C. swietenia* used for the snake bite, *C. epigaeus* for female White discharge, *Mucuna atropurpurea* for enhancing brain strength, and a vulnerable species *P. dicoccos* which has been claimed to have anticancer effects by the knowledgeable traditional healers. Moreover, the multivariate and correlation studies revealed that species are used to treat ailment categories and their significant relationships. Most significantly, people are taking medicine as food in their daily livelihood for the maintenance and improving their body health to sustain various environments as well as situations. Due to a lack of proper records management and a focus on the use of modern medications, knowledge of traditional medicinal plants, their dosage levels, diseases treated, toxicity levels, and other factors are currently seriously deteriorating. The present study's datasets were investigated by applying multivariate analysis in order to establish a connection between ethnobotanical indices and medicinal plants as well as illness categories and medicinal plants. Also described are the species diversity, coverage, and vulnerability level of therapeutic plants. In order to effectively manage plant resources for their biodiversity and to identify medicinal plants with novel plant metabolites for treating newly emerging diseases, which is urgently needed, conservation organizations can use the information provided by the current inventory.

Author contribution statement

Shan Sasidharan, Hareendran Nair J: Conceived and designed the experiments; Analysed and interpreted the data.

Rajendran Silambarasan, K.T. Selavinayagam: Performed the experiments; Wrote the paper; Contributed reagents, materials, analysis tools or data.

Nishanth Kumar S: Analysed and interpreted the data; Wrote the paper.

Aravind R, Akhila S Nair- Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supplementary material/referenced in article.

Funding statement

This work was supported by funds under SHRI scheme from the Department of Science and Technology of India (Ref. No: DST/TDT/SHRI -25/2021).

Additional information

No additional information is available for this paper.

Declaration of interest's statement

The authors declare no conflict of interest.

Acknowledgements

The authors are grateful to all the informants who took part in the study and voluntarily shared their friendship and knowledge with us. The authors are grateful to the DST-SHRI (DST/TDT/SHRl-25/2021) for providing financial assistant in this project. We specially express our thanks to the management of Pankajakasthuri Herbal Research Foundation, Kattakada, Trivandrum, Kerala for providing them necessary facilities and support to carry out this work.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e15607.

References

[1] O.G. Gaoue, M.A. Coe, M. Bond, G. Hart, B.C. Seyler, H. McMillen, Theories and major hypotheses in ethnobotany, Econ. Bot. 71 (3) (2017) 269–287.
[2] C.T. Che, V. George, T.P. Ijinu, P. Pushpangadan, K. Andrae-Marobela, Traditional medicine, in: Pharmacognosy, Academic Press, 2017, pp. 15–30.

[3] C.R. Ramirez, Ethnobotany and the loss of traditional knowledge in the 21st century, Ethnobot. Res. Appl. 5 (2007) 245–247.
[4] G. Mattalia, R. Sõukand, P. Corvo, A. Pieroni, We became rich and we lost everything": ethnobotany of remote mountain villages of Abruzzo and Molise, Central Italy. Hum. Ecol. 49 (2) (2021) 217–224.
[5] V. Kathambi, F.M. Mutie, P.C. Rono, N. Wei, J.N. Munyao, P. Kamau, R.W. Gituru, G.W. Hu, Q.F. Wang, Traditional knowledge, use and conservation of plants by the communities of Tharaka-Nithi County, Kenya, Plant divers 42 (6) (2020) 479–487.
[6] S.M. Haq, E.S. Calixto, I. Rashid, A.A. Khuroo, Human-driven disturbances change the vegetation characteristics of temperate forest stands: a case study from Pir Panchal mountain range in Kashmir Himalaya, Trees. For. People. 6 (2021), 100134.
[7] M. Rahimi, G. Charmi, K. Matyjaszewski, X. Banquy, J. Pietrasik, Recent developments in natural and synthetic polymeric drug delivery systems used for the treatment of osteoarthritis, Acta Biomater. 123 (2021) 31–50.
[8] X.Z. Su, L.H. Miller, The Discovery of Artemisinin and the Nobel Prize in Physiology or Medicine, 2015.
[9] B. Sadasivaiah, T. Pullaiah, Ethnic food plants and ethnic food preparation in eastern Ghats and adjacent deccan region, Ethnobotany of India (2016) 151–234.
[10] B. Bahadur, R. Sultana, K.V. Krishnamurthy, S.J. Adams, Ethnic tribal diversity of eastern Ghats and adjacent deccan region, Ethnobotany of India 1 (2016) 45–72.
[11] S. Gairolan, J. Sharma, Y.S. Bedi, A cross – cultural analysis of Jammu, Kashmir and Ladakh (India) medicinal plant use, J. Ethnopharmacol. 155 (2014) 925–986.
[12] M. Kannan, P. Sathiyarajeswaran, D. Sasikumar, A. Geetha, M. Mohanapriya, N.P. Vinod, P. Manickam, K. Kanakavalli, P. Parthibhan, M.P. Kumar, R. Kannan, Safety and efficacy of a siddha medicine fixed regimen for the treatment of asymptomatic and mild COVID-19 patients, J. Ayurveda Integr. Med. (2022), 100589.
[13] D. Karmegam, M. Prakash, N. Karikalan, B. Mappillairajan, Development of database structure and indexing for siddha medicine system–A platform for siddha literature analytics, Dialogues Health 1 (2022), 100008.
[14] S.P. Jain, H.S. Puri, Ethnomedicinal plants of Jaunsar-Bawar hills, Uttar Pradesh, India, J. Ethnopharmacol. 12 (1984) 213–222.
[15] N. Nagaraju, K.N. Rao, A survey of plant crude drugs of Rayalaseema, Andhra Pradesh, India, J. Ethnopharmacol. 29 (1990) 137–158.
[16] S.S. Katewa, B.L. Chaudhary, A. Jain, Folk herbal medicines from tribal area of Rajasthan, India, J. Ethnopharmacol. 92 (2004) 41–46.
[17] M. Ayyanar, S. Ignacimuthu, Traditional knowledge of Kani tribals in kouthalai of tirunelveli hills, Tamil Nadu, India, J. Ethnopharmacol. 102 (2005) 246–255.
[18] M. Ayyanar, S. Ignacimuthu, Ethnobotanical survey of medicinal plants commonly used by Kani tribals in Tirunelveli hills of Western Ghats, India, J. Ethnopharmacol. 134 (2011) 851–864.
[19] M. Chellappandian, S. Mutheeswaran, P. Pandikumar, V. Duraipandiyan, S. Ignacimuthu, Quantitative ethnobotany of traditional Siddha medicinal practitioners from Radhapuram taluk of Tirunelveli district, Tamilnadu, India, J. Ethnopharmacol. 143 (2012) 540–547.
[20] R. Silambarasan, M. Ayyanar, An ethnobotanical study of medicinal plants in Palamalai region of Eastern Ghats, India, J. Ethnopharmacol. 172 (2015) 162–178.
[21] J. Sureshkumar, R. Silambarasan, M. Ayyanar, An ethnopharmacological analysis of medicinal plants used by the Adiyan community in Wayanad district of Kerala, India, Eur. J. Integr. Med. (2017) 60–73.
[22] R. Silambarasan, J. Sureshkumar, J. Krupa, S. Amalraj, M. Ayyanar, Traditional herbal medicines practiced by the ethnic people in Sathyamangalam forests of Western Ghats, India, Eur. J. Integr. Med. 16 (2017) 61–72.
[23] S.R. Kareti, R.H. Haran, V.S. Rajpoot, Diversity of ethnomedicinal plants among tribal communities in anuppur district, Madhya Pradesh, Central India, J. Herbs, Spices, Med. Plants (2022) 1–23.
[24] P. Vino, A. Maruthupandian, S. Murugesh, M. Viji, C. Santhosh, P. Murugan, Ethnomedicinal plants of kalakad mundanthurai tiger reserve forest: an appraisal, The Phytochemical and Pharmacological Aspects of Ethnomedicinal Plants (2021) 51–141.
[25] S. Mutheeswaran, P. Pandikumar, M. Chellappandian, S. Ignacimuthu, Documentation and quantitative analysis of the local knowledge on medicinal plants among traditional Siddha healers in Virudhunagar district of Tamil Nadu, India, J. Ethnopharmacol. 137 (1) (2011) 523–533.
[26] P. Pandikumar, M. Chellappandian, S. Mutheeswaran, S. Ignacimuthu, Consensus of local knowledge on medicinal plants among traditional healers in Mayiladumparai block of Theni District, Tamil Nadu, India, J. Ethnopharmacol. 134 (2) (2011) 354–362.
[27] S. Mutheeswaran, P. Pandikumar, M. Chellappandian, S. Ignacimuthu, V. Duraipandiyan, M. Logamanian, Consensus analysis of sastric formulations used by non-institutionally trained siddha medical practitioners of Virudhunagar and Tirunelveli districts of Tamil Nadu, India, J. Ethnopharmacol. 153 (1) (2014) 290–296.
[28] S.V. Sathasivampillai, P.R. Rajamanoharan, M. Munday, M. Heinrich, Plants used to treat diabetes in Sri Lankan Siddha Medicine–An ethnopharmacological review of historical and modern sources, J. Ethnopharmacol. 198 (2017) 531–599.
[29] C.M. Cotton, Understanding traditional plant use and management: indigenous perceptions of the natural world, in: Chapter 9. Ethnobotany: Principles and Applications, John Wiley & Sons Ltd, Chichester, Inglaterra, 1996.
[30] J.S. Gamble, The Flora of the Presidency of Madras, Adlard&son. Ltd. London, London, 1935.
[31] K.M. Matthew, An Excursion Flora of Central Tamilnadu, Oxford and IBH Publishing Co., New Delhi, 1991.
[32] K.M. Matthew, The Flora of the Tamilnadu Carnatic, the Rapinat Herbarium St. Joseph's College, Tiruchirapalli, Tamil Nadu, 1983.
[33] http://www.theplantlist.org/, 2020.
[34] W. Sujarwo, G. Caneva, Using quantitative indices to evaluate the cultural importance of food and nutraceutical plants: comparative data from the island of Bali (Indonesia), J. Cult. Herit. 18 (2016) 342–348.
[35] Z. Tardio, M. Pardo-de Santayana, Cultural importance indices: a comparative analysis based on the useful wild plants of southern Cantabria (Northern Spain), Econ. Bot. 62 (2008) 24–39.
[36] R.T. Trotter, M.H. Logan, Informant consensus: a new approach for identifying potentially effective medicinal plants, in: N.L. Etkin (Ed.), Plants in Indigenous Medicine and Diet, Behavioural Approaches, Redgrave Publishing Company, Bredford Hills, New York, 1986, pp. 91–112.
[37] E. Thomas, I. Vandebroek, S. Sanca, P. Van Damme, Cultural significance of medicinal plant families and species among Quechua farmers in Apillapampa, Bolivia, J. Ethnopharmacol. 122 (2009) 60–67.
[38] N.F. Bakwaye, C. Termote, K. Kibungu, P. Van Damme, Identification et importance locale des plantesmédicinalesutilisesans la région de Mbanza-Ngungu, Républiquedémocratique du Congo, Bois For. Trop. 316 (2013) 63–77.
[39] J. Friedman, Z. Yaniv, A. Dafni, D. Palewitch, A preliminary classification of the healing potential of medicinal plants, based on the rational analysis of an ethnopharmacological field survey among Bedouins in Negev Desert, Israel, J. Ethnopharmacol. 16 (1986) 275–287.
[40] M. Heinrich, A. Ankli, B. Frei, C. Weimann, O. Sticher, Medicinal plants in Mexico: healers' consensus and cultural importance, Soc. Sci. Med. 47 (11) (1998) 1859–1871.
[41] R Core Team. R, A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, 2020. https://www.R-project.org/.
[42] M.S. Iqbal, K.S. Ahmad, M.A. Ali, M. Akbar, A. Mehmood, F. Nawaz, S.A. Hussain, N. Arshad, S. Munir, H. Arshad, K. Shahbaz, An ethnobotanical study of wetland flora of Head Maralla Punjab Pakistan, PLoS One 16 (10) (2021), e0258167.
[43] S. Sukumaran, R.M. Sujin, V.S. Geetha, S. Jeeva, Ethnobotanical study of medicinal plants used by the Kani tribes of Pechiparai hills, western Ghats, India, Acta Ecol. Sin. 41 (5) (2021) 365–376.
[44] M. Rahman, B. Roy, G.M. Chowdhury, A. Hasan, M. Saimun, S. Reza, Medicinal plant sources and traditional healthcare practices of forest-dependent communities in and around Chunati Wildlife Sanctuary in southeastern Bangladesh, Environ. Sustain. (2022) 1–35.
[45] R.P. Samy, M.M. Thwin, P. Gopalakrishnakone, S. Ignacimuthu, Ethnobotanical survey of folk plants for the treatment of snakebites in Southern part of Tamilnadu, India, J. Ethnopharmacol. 115 (2) (2008) 302–312.
[46] S. Prabhu, S. Vijayakumar, J.M. Yabesh, K. Ravichandran, B. Sakthivel, Documentation and quantitative analysis of the local knowledge on medicinal plants in Kalrayan hills of Villupuram district, Tamil Nadu, India, J. Ethnopharmacol. 157 (2014) 7–20.
[47] T. Ravishankar, Ethnobotany of dharmapuri and north arcot districts in Tamil Nadu, South India, Biodiversity 8 (1) (2007) 12–20.

[48] H. Singh, T. Husain, P. Agnihotri, P.C. Pande, S. Khatoon, An ethnobotanical study of medicinal plants used in sacred groves of Kumaon Himalaya, Uttarakhand, India, J. Ethnopharmacol. 154 (1) (2014) 98–108.
[49] S.R. Kareti, R.H. Haran, V.S. Rajpoot, Diversity of ethnomedicinal plants among tribal communities in anuppur district, Madhya Pradesh, Central India, J. Herbs, Spices, Med. Plants (2022) 1–23.
[50] S.R. Kareti, V.S. Rajpoot, Ethnobotanical survey of folk medicinal plants used in tribal villages of Amarkantak region of Central India, Plant Biosyst. 156 (4) (2022) 1019–1038.
[51] J.M. Yabesh, S. Prabhu, S. Vijayakumar, An ethnobotanical study of medicinal plants used by traditional healers in silent valley of Kerala, India, J. Ethnopharmacol. 154 (3) (2014) 774–789.
[52] S. Khuankaew, K. Srithi, P. Tiansawat, A. Jampeetong, A. Inta, P. Wang, Ethnobotanical study of medicinal plants used by Tai Yai in Northern Thailand, J. Ethnopharmacol. 151 (2) (2014) 829–838.
[53] H.A. Jan, S. Wali, L. Ahmad, S. Jan, N. Ahmad, N. Ullah, Ethnomedicinal survey of medicinal plants of Chinglai valley, Buner district, Pakistan, Eur. J. Integr. Med. 13 (2017) 64–74.
[54] T.F. Xavier, M. Kannan, L. Lija, A. Auxillia, A.K.F. Rose, Ethnobotanical study of Kani tribes in thoduhills of Kerala, South India, J. Ethnopharmacol. 152 (1) (2014) 78–90.
[55] I.O. Lawal, B.O. Rafiu, J.E. Ale, O.E. Majebi, A.O. Aremu, Ethnobotanical survey of local flora used for medicinal purposes among indigenous people in five areas in lagos state, Nigeria, Plants 11 (5) (2022) 633.
[56] S. Prabhu, S. Vijayakumar, J.M. Yabesh, R. Prakashbabu, R. Murugan, An ethnobotanical study of medicinal plants used in pachamalai hills of Tamil Nadu, India, J. Herb. Med. 25 (2021), 100400.
[57] www.iucn.org, 2021.
[58] J.P. Narayan, Ex situ conservation of the rare and threatened medicinal climber *Corallocarpus epigaeus* Rottler through in vitro regeneration method, Biotechnol. J. Int. 9 (2016) 1–10.
[59] A.K. Khajuria, R.K. Manhas, H. Kumar, N.S. Bisht, Ethnobotanical study of traditionally used medicinal plants of Pauri district of Uttarakhand, India, J. Ethnopharmacol. 276 (2021), 114204.
[60] A.D. Ali, L.D. Ior, G.A. Dogo, J.I. Joshua, J.S. Gushit, Ethnobotanical survey of plants used as biopesticides by indigenous people of plateau state, Nigeria, Diversity 14 (10) (2022) 851.
[61] H. Khanum, M. Ishtiaq, K.H. Bhatti, I. Hussain, M. Azeem, M. Maqbool, T. Hussain, W. Mushtaq, S. Thind, R. Bashir, M. Muzamil, Ethnobotanical and conservation studies of tree flora of Shiwalik mountainous range of District Bhimber Azad Jammu and Kashmir, Pakistan, PLoS One 17 (2) (2022), e0262338.
[62] K.S. Ahmad, A. Hamid, F. Nawaz, M. Hameed, F. Ahmad, J. Deng, N. Akhtar, A. Wazarat, S. Mahroof, Ethnopharmacological studies of indigenous plants in Kel village, Neelum valley, Azad Kashmir, Pakistan, J. Ethnobiol. Ethnomed. 13 (1) (2017) 1–16.
[63] M.S. Amjad, M.F. Qaseem, I. Ahmad, S.U. Khan, S.K. Chaudhari, N. Zahid-Malik, H. Shaheen, A.M. Khan, Descriptive study of plant resources in the context of the ethnomedicinal relevance of indigenous flora: a case study from Toli peer National Park, Azad Jammu and Kashmir, Pakistan, PLoS One 12 (7) (2017), e0180917.
[64] D. Singh, P.K. Chaudhuri, A review on phytochemical and pharmacological properties of Holy basil (*Ocimum sanctum* L.), Ind. Crop. Prod. 118 (2018) 367–382.
[65] T.B.C. Laldingliani, N.M. Thangjam, R. Zomuanawma, L. Bawitlung, A. Pal, A. Kumar, Ethnomedicinal study of medicinal plants used by Mizo tribes in Champhai district of Mizoram, India, J. Ethnobiol. Ethnomed. 18 (1) (2022) 1–29.
[66] M.K. Islam, S. Saha, I. Mahmud, K. Mohamad, K. Awang, S.J. Uddin, M.M. Rahman, J.A. Shilpi, An ethnobotanical study of medicinal plants used by tribal and native people of Madhupur forest area, Bangladesh, J. Ethnopharmacol. 151 (2) (2014) 921–930.
[67] B. Sivasankari, M. Anandharaj, P. Gunasekaran, An ethnobotanical study of indigenous knowledge on medicinal plants used by the village peoples of Thoppampatti, Dindigul district, Tamilnadu, India, J. Ethnopharmacol. 153 (2) (2014) 408–423.
[68] M. Bouafia, F. Amamou, M. Gherib, M. Benaissa, R. Azzi, S. Nemmiche, Ethnobotanical and ethnomedicinal analysis of wild medicinal plants traditionally used in Naâma, southwest Algeria, Vegetos 34 (3) (2021) 654–662.
[69] R. Abe, K. Ohtani, An ethnobotanical study of medicinal plants and traditional therapies on Batan Island, the Philippines, J. Ethnopharmacol. 145 (2) (2013) 554–565.
[70] A. Gras, O. Hidalgo, U. D'Ambrosio, M. Parada, T. Garnatje, J. Valles, The role of botanical families in medicinal ethnobotany: a phylogenetic perspective, Plants 10 (1) (2021) 163.
[71] R. Yao, M. Heinrich, J. Wei, P. Xiao, Cross-cultural ethnobotanical assembly as a new tool for understanding medicinal and culinary values–the genus lycium as A case study, Front. Pharmacol. (2021) 12.
[72] L. Pawera, V. Verner, C. Termote, I. Sodombekov, A. Kandakov, N. Karabaev, Z. Polesny, Medical ethnobotany of herbal practitioners in the Turkestan Range, southwestern Kyrgyzstan, Acta Soc. Bot. Pol. (2016).
[73] M. Kujawska, N.I. Hilgert, H.A. Keller, G. Gil, Medicinal plant diversity and inter-cultural interactions between indigenous guarani, criollos and polish migrants in the subtropics of Argentina, PLoS One 12 (1) (2017), e0169373.
[74] R. Soukand, R. Kalle, A. Pieroni, Homogenisation of biocultural diversity: plant ethnomedicine and its diachronic change in Setomaa and Voromaa, Estonia, in the last century, Biology 11 (2) (2022) 192.
[75] M. Sharafatmandrad, A. KhosraviMashizi, Ethnopharmacological study of native medicinal plants and the impact of pastoralism on their loss in arid to semiarid ecosystems of southeastern Iran, Sci. Rep. 10 (1) (2020) 1–18.
[76] Y. Cao, R. Li, S. Zhou, L. Song, R. Quan, H. Hu, Ethnobotanical study on wild edible plants used by three trans-boundary ethnic groups in Jiangcheng County, Pu'er, Southwest China, J. Ethnobiol. Ethnomed. 16 (1) (2020) 1–23.
[77] A.Y. Mir, U. Yaqoob, M. Hassan, F. Bashir, S.B. Zanit, S.M. Haq, R.W. Bussmann, Ethnopharmacology and phenology of high-altitude medicinal plants in Kashmir, Northern Himalaya, Ethnobot. Res. Appl. 22 (2021) 1–15.
[78] S.M. Haq, E.S. Calixto, I. Rashid, A.A. Khuroo, Human-driven disturbances change the vegetation characteristics of temperate forest stands: a case study from Pir Panchal mountain range in Kashmir Himalaya, Trees. For. People. 6 (2021), 100134.
[79] J. Kaur, R. Kaur, A.K. Nagpal, Traditional use of ethnomedicinal plants among people of Kapurthala District, Punjab, India, Phcog. Mag. 16 (68) (2020) 69.
[80] B. Dangwal, S.K. Rana, V.S. Negi, I.D. Bhatt, Forest restoration enhances plant diversity and carbon stock in the sub-tropical forests of western Himalaya, Trees For. People. 7 (2022), 100201.
[81] J. Muvengwi, A. Kwenda, M. Mbiba, T. Mpindu, The role of urban schools in biodiversity conservation across an urban landscape, Urb. For. Urb. Green. 43 (2019), 126370.
[82] F. Cordero, J. Gálvez, E.Rodríguez-Valenzuela Arenas, Does access to natural environments explain differences in the use of wild plants between rural and urban populations? Bot. Sci. 99 (1) (2021) 104–123.
[83] K.J. Dickers, S.M. Bradberry, P. Rice, G.D. Griffiths, J.A. Vale, Abrin poisoning, Toxicol. Rev. 22 (3) (2021) 137–142.
[84] X.Y. Hu, R.H. Wu, M. Logue, C. Blondel, L.Y.W. Lai, B. Stuart, A. Flower, Y.T. Fei, M. Moore, J. Shepherd, J.P. Liu, *Andrographis paniculata* (ChuānXīnLián) for symptomatic relief of acute respiratory tract infections in adults and children: a systematic review and meta-analysis, PLoS One 12 (8) (2017), 0181780.
[85] J.P. Cosyns, Aristolochic acid and 'Chinese herbs nephropathy': a review of the evidence today, Drug Saf. 26 (1) (2003) 33–48.
[86] M. Heinrich, J. Chan, S. Wanke, C. Neinhuis, M.S.J. Simmonds, Local uses of Aristolochia species and content of nephrotoxic aristolochic acid 1 and 2 — a global assessment based on bibliographic sources, J. Ethnopharmacol. 25 (2009) 108–144.
[87] J. Michl, H.M. Jennings, G.C. Kite, M.J. Ingrouille, M.S. Simmonds, M. Heinrich, Is aristolochic acid nephropathy a widespread problem in developing countries?: a case study of *Aristolochia indica* L. in Bangladesh using an ethnobotanical–phytochemical approach, J. Ethnopharmacol. 149 (1) (2013) 235–244.
[88] N.A.A. Rahman, A. Fazilah, M.E. Effarizah, Toxicity of nutmeg (myristicin): a review, Int. J. Adv. Sci. Eng. Inf. Technol. 5 (3) (2015) 61–64.

[89] L.R. Lampariello, A. Cortelazzo, R. Guerranti, C. Sticozzi, G. Valacchi, The magic velvet bean of *Mucuna pruriens*, J. Tradit. Complement. Med. 2 (4) (2012) 331–339.

[90] M.R. Bhandari, J. Kawabata, Bitterness and toxicity in wild yam (*Dioscorea spp.*) tubers of Nepal, Plant Foods Hum. Nutr. (Dordr.) 60 (3) (2005) 129–135.

[91] J. Felix-Silva, R.B. Giordani, A.A.D. Silva, S.M. Zucolotto, M.D.F. Fernandes-Pedrosa, *Jatropha gossypiifolia* L. (Euphorbiaceae): a review of traditional uses, phytochemistry, pharmacology, and toxicology of this medicinal plant, Evid. Based Complement. Altern. Med. (2014).