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POPULATION ASSESSMENT, INDIGENOUS USES, AND THREAT STATUS OF ORCHIDS IN BAN OAK (*QUERCUS OBLONGATA* D.DON) FORESTS OF HIMACHAL PRADESH, NORTHWESTERN HIMALAYA

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Abstract

The orchids are highly evolved group of flowering plants known for their immense beauty and utility and are still under active state of speciation. Ban Oak (*Quercus oblongata* D.Don) forests are rich in orchid resource and exhibit incredible range of diversity in shape, size, and colour of their flowers. They are important aesthetically, medicinally, and also regarded as ecological indicators. Present study has been conducted in the Ban Oak forests of Himachal Pradesh to assess the distribution pattern and indigenous practices of terrestrial orchids. Rapid sampling was done for qualitative analysis and 22 orchids of 18 genera have been found to grow in the Ban Oak forests. The species were analysed for nativity, endemism, indigenous uses, and threat categories. Amongst the species, 1 species was endemic and 7 species were near endemic; 17 and 5 species were native and non-natives respectively, to the Indian Himalayan Region. Four species were used against bronchial, orthopaedic, and urinary disorders, 5 species against cardiovascular and gastroenterological disorders, 2 species against dermatological disorders, 8 against influenza like illness, 3 against immunological, sexual, and neurological disorders, and 1 against mental disorders. But, unfortunately, rapid decline of orchid populations was noticed due to massive anthropogenic pressure causing habitat degradation. Monitoring of habitats, mapping of populations of orchid species, and awareness among the local inhabitants and officials of the Forest Department and conservation are suggested.

Introduction

SINCE THE Vedic ages, orchids are famous to mankind (Ninawe and Swapna, 2017) and are nature's most extravagant group of flowering plants distributed throughout the world except the icy Antarctica and hot deserts. They are known for their beauty and utility. Their major diversity occurs in the tropical and sub-tropical regions (Hossain, 2011). Orchids are considered as indicator species of habitat disturbances and are eminent for their attractive and long lasting flowers (Devi *et al*., 2018). Apart from their ornamental significance, they find extensive usefulness in the traditional systems of medicine (Pangtey *et al.,* 1991; Samant, 2002, 2009). Though a few orchids are grown primarily as ornamentals, many are used as herbal medicines, food, and other cultural value by many different cultures and tribes in the different parts of world (Khasim and Rao, 1999; Kumari and Pathak, 2020; Pathak *et al.,* 2010). Orchids have miraculous curative properties and have been used as a source of medicine for ages to treat different diseases and ailments including bronchial, cardiovascular, dermatological, gastroenterological, influenza like illness (ILI), immunological, mental, neurological, orthopaedic, sexual and urinary disorders *etc.* Besides, many orchidaceous preparations are used as emetic, purgative, aphrodisiac, vermifuge, bronchodilator, sex stimulator, contraceptive, cooling agent, and remedies in scorpion sting and snake bite. A wide range of chemical compounds like alkaloids, bibenzyl derivatives, flavonoids, phenanthrenes, and terpenoids have been isolated from the orchids. A comprehensive account of chemical constituents and biological activities is presented and a critical appraisal of the ethnopharmacological issues is included in view of the many recent findings of importance of orchids. Studies on orchid diversity, their medicinal importance and conservation have been carried out in NorthWestern Himalaya by various workers (Barman *et al*., 2016; Balkrishna *et al*., 2020; Bhandari *et al*., 2018; Bhatti *et al*., 2107; Deva and Naithani, 1986; Devi *et al*., 2018; Kumar *et al*., 2016, 2018, 2019; Kumari and Pathak, 2020; Lal and Pathak, 2020; Pathak *et al*., 2010, 2017; Prakash *et al*., 2018; Prakash and Pathak, 2019; Samant, 2002, 2009; Shapoo *et al*., 2020; Sharma *et al*., 2015; Sharma *et al*., 2017; Singh and Sharma, 2006; Singh *et al*., 2019; Thakur and Pathak, 2020; Vasundhra *et al*., 2019; Verma *et al*., 2013; Vij *et al*., 1983, 2013). However, there are no such studies carried out throughout NorthWestern Himalaya specifically on the orchid diversity of Ban Oak (*Quercus oblongata* D.Don) forests. Therefore, this study is the first attempt to assess the diversity of orchids in Ban Oak forests of Himachal Pradesh. The present study has been

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conducted to: i) assess the diversity of orchids in the Ban Oak forests of Himachal Pradesh; ii) assess the indigenous uses and pharmacological potential of orchids; iii) assess the orchid diversity for nativity and endemism and threat categories; and iv) suggest conservation measures.

Material and Methods

Study Area

The State Himachal Pradesh (30°22'40" to 33°12'40" North latitudes and 75°47'55" to 79°04'20" East longitudes) covers the parts of Trans and NorthWestern Himalayas. It is bounded by Tibet in the East, Jammu and Kashmir (U.T.) in the North, Uttarakhand in the SouthEast, Haryana in the South, and Punjab in the West. Physiographically, it is divided in three conspicuous zones, namely outer Himalayas or the Shivaliks, inner Himalayas or mid mountain, and the greater Himalayas or Alpine zones (Fig. 1). Known for its healthy climate, it experiences considerable deviations in the distribution of rainfall and temperature due to varying aspects and altitude, precipitation declines from East to West and South to North. The study area is well known for diverse habitats, large altitudinal range, climatic conditions, and rich biodiversity. It is inhabited by a number of villages in all the accessible aspects and habitats and is mainly dominated by sub-tropical, temperate, and sub-alpine broad leaved and coniferous forests, alpine scrubs, and alpine herbaceous vegetation. Winter experiences severe cold and main precipitation is in the form of snow in the temperate, sub-alpine, and alpine zones. Rains are mostly confined to summer and rainy seasons. The inhabitants are largely dependent on natural resources for their sustenance. Due to various anthropogenic activities and sensitivity of the area for various risks and hazards, and climate, the most components of biodiversity in the area are under tremendous pressure.

Selection of Sites and Habitats

The sites were selected and surveys were conducted on each and every accessible aspects along an altitudinal gradient in the Ban Oak forests of Himachal Pradesh. Extensive surveys were conducted for the qualitative and quantitative assessment of orchids. The habitats were identified based on physical characters and dominance of the vegetation. Plots having closed canopy with high percentage of humus and moisture were considered as moist habitats, whereas low per cent of the same as dry habitats. The plots having >50% boulders of the ground cover were classified as bouldery habitats. The plots near Nallah or Khad or river were considered as riverine. The sites which had ≥60% rocks were considered as rocky habitats and those facing high anthropogenic pressures were classified as degraded habitats.

Surveys, Sampling, Identification, and Analysis of Data

Rapid floristic surveys and standard ecological method (quadrat methods) were followed to assess the orchid diversity. The rapid sampling of the species was done

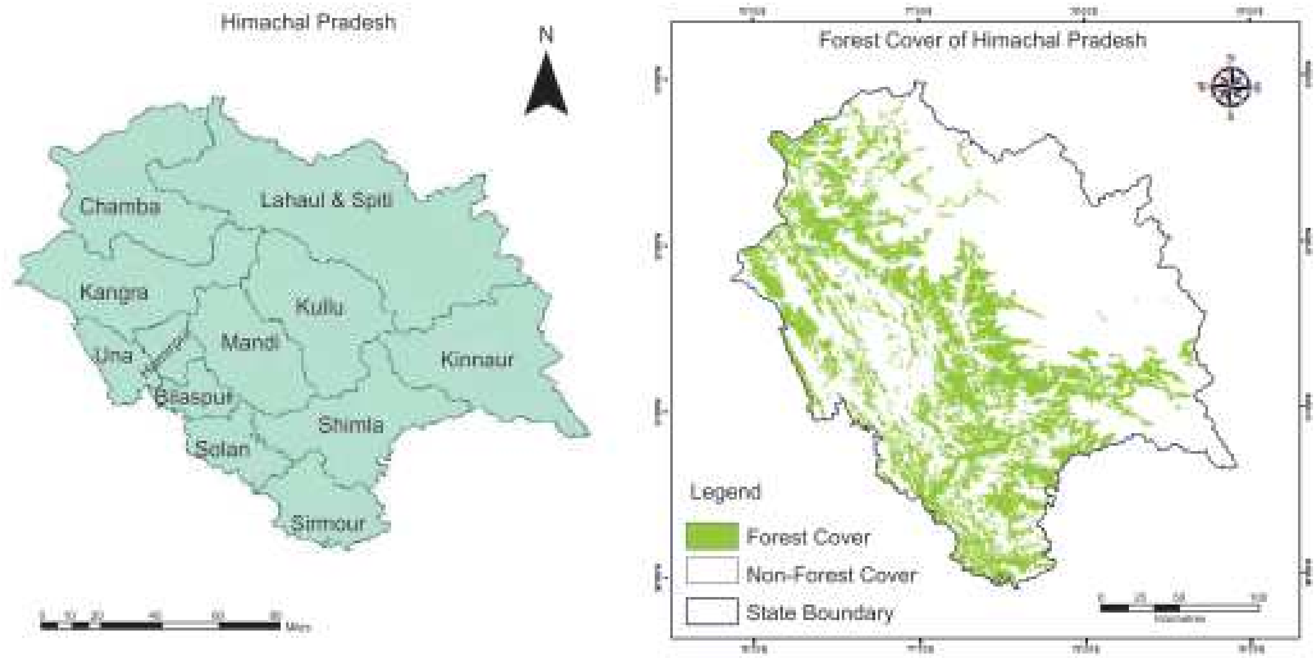


Fig. 1. Map of the study area.

and the samples of each species were collected for proper identification. Information regarding habitat(s) and altitude *etc.* was recorded. The species were identified with the help of flora and literature (Deva and Naithani, 1986; Dhaliwal and Sharma, 1999; Pangtey *et al.*, 1991; Samant, 1993). The field surveys and samplings were conducted in the selected sites along an altitudinal gradient. In each site, a plot of 50×50 m was laid and within this plot, 20 quadrats of 1×1 m were laid randomly. The data were analyzed for density. For the assessment of economically important biodiversity, local Vaidhyas and knowledgeable persons of the area were interviewed, irrespective of their age or gender. Species were analyzed for nativity and endemism. The nativity of the species was identified following Samant (1999), Samant and Dhar (1997), and Samant *et al.* (1998, 2000). Endemism of the species was identified based on distribution of the species (Dhar and Samant, 1993; Samant, 1999; Samant and Dhar, 1997; Samant *et al.*, 1996a, b, 1998, 2000). Species confined to the IHR were considered as endemic and those with a distribution extending up to neighbouring countries *i.e.* Himalayan region of Afghanistan, Pakistan, Baluchistan, Tibet, Nepal, Bhutan, and adjacent states of the IHR were considered as near endemic (Samant *et al.*, 1998). The threat categorization of the species was done based on the cumulative values of habitat preference, population size, distribution range, anthropogenic pressures including use values, extraction trends, nativity, endemism *etc.*, and following Rana and Samant (2010), Samant and Pal (2003), Samant *et al.* (1998), and Ved *et al.* (2003). Categorization of these species as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) *etc.* has also been done following Rana and Samant (2010). Phytochemical or active compounds of the orchids were identified and characterized following the literatures of Arora *et al.* (2019), D'Auria *et al.* (2021), Hossain (2011), Liu *et al.* (2013), Mishra and Saklani (2012), Sedai (2015), Sharma *et al.* (2011), Singh *et al.* (2017), Tran *et al.* (2019), Virk *et al.* (2020), and Wu *et al.* (2020).

Assessment of Physico-chemical Properties

Soil samples were collected from each studied site within each plot of 50 × 50 m (15-20 cm depth). Five soil samples, 4 from the corners and 1 from the centre of each plot were collected, pooled, and mixed properly to make a composite sample. The air-dried soil samples were assessed for further tests and analysis. Soil pH was measured using a pH meter in 1:5 mixture of soil and distilled water, moisture content was recorded as % difference in fresh and dry soil weight, % organic Carbon, and organic matter were analysed as described by Walkley and Black method (Walkley and Black, 1934), available Nitrogen by Kjeldahl method (Subbiah and Asiijah, 1956), available Phosphorus by Olsen's extraction method (Olsen *et al.,* 1954) and available Potassium by flame photometer (Jackson, 1958).

Numerical and Statistical Analysis

All numerical analysis was done in MS-Excel. Bray and Curtis cluster analysis was placed to identify the similarities of orchid species with soil parameters and Principle Component Analysis using PAST software.

Results

Diversity and Distribution

Total 22 species representing 17 genera (*i.e. Brachycorythis, Calanthe, Cephalanthera, Crepidium, Cymbidium, Cypripedium, Epipactis, Galeola, Goodyera, Habenaria, Herminium, Liparis, Neottia, Nervilia, Platanthera, Satyrium,* and *Spiranthes*) were recorded from the Ban Oak forests. Amongst genera, *Habenaria* (3 species) and *Platanthera, Goodyera,* and *Calanthe* (2 species, each) were dominant. These orchid species were found in diverse habitats *i.e.* shady moist, moist, dry *etc.* Orchids were recorded from the sub-tropical to temperate zones. Maximum diversity of orchids was found in temperate zone of the study sites.

Density

Density of *Brachycorythis obcordata* ranged from 0.21-1.01 Ind m^{-2}, *Calanthe plantaginea,* 0.37-1.55 Ind m^{-2}, *C. tricarinata,* 0.57-2.05 Ind m^{-2}, *Cephalanthera longifolia,* 0.31-1.09 Ind m^{-2}, *Crepidium acuminatum,* 0.19-0.52 Ind m^{-2}, *Cymbidium macrorhizon,* 0.23-1.58 Ind m^{-2}, *Cypripedium cordigerum*, 0.28-0.92 Ind m^{-2}, *Epipactis helleborine,* 0.24-0.53 Ind m^{-2}, *Galeola lindleyana,* 0.17-0.49 Ind m^{-2}, *Goodyera biflora,* 0.52-1.10 Ind m^{-2}, *G. repens,* 0.21-0.69 Ind m^{-2}, *Habenaria intermedia,* 0.11-0.37 Ind m^{-2}, *H. pectinata,* 0.25-0.64 Ind m^{-2}, *H. plantaginea,* 0.29-0.89 Ind m^{-2}, *Herminium lanceum,* 0.25-0.63 Ind m^{-2}, *Liparis odorata*, 0.19-1.01 Ind m^{-2}, *Neottia listeroides,* 0.58-1.28 Ind m^{-2}, *Nervilia concolor,* 0.27-0.88 Ind m^{-2}, *Platanthera edgeworthii,* 0.15-0.76 Ind m^{-2}, *P. latilabris,* 0.13-0.81 Ind m^{-2}, *Satyrium nepalense,* 0.25-1.01 Ind m^{-2}, and *Spiranthes sinensis,* 0.55-1.09 Ind m^{-2} (Fig. 2).

Nativity, Endemism, and Threat Categorization

17 species were native; 5 species were non-natives; 7 species (*i.e. Calanthe plantaginea, Cypripedium cordigerum, Goodyera biflora, Liparis odorata,*

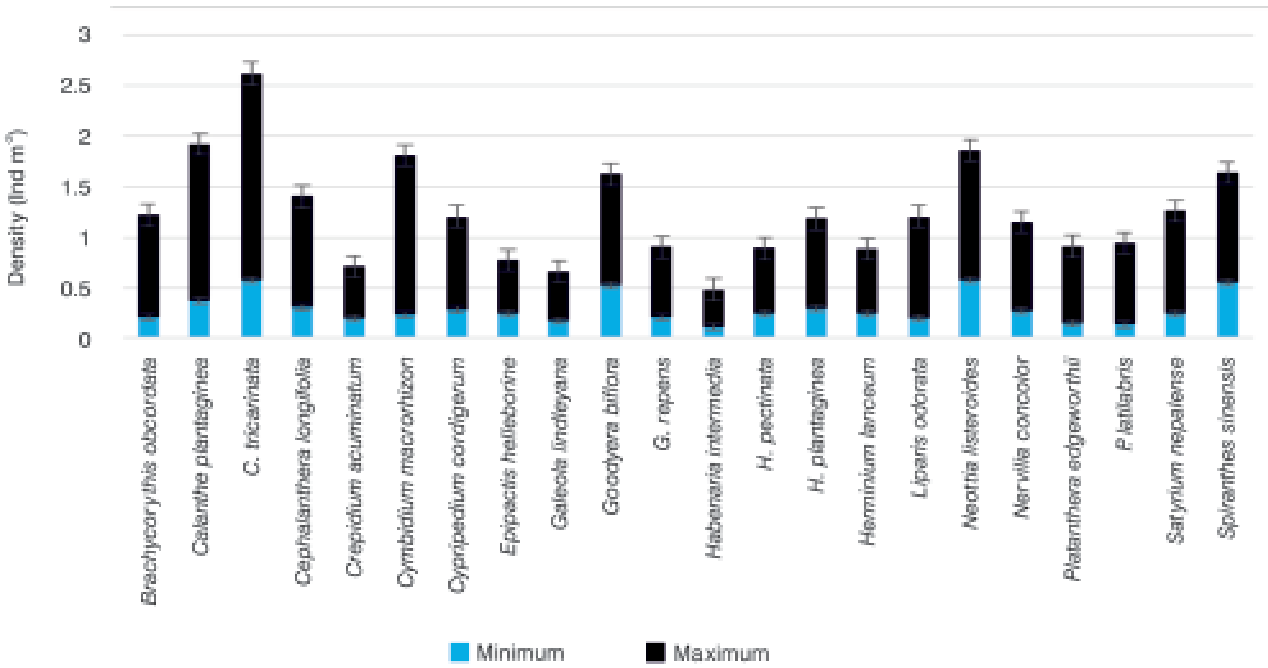


Fig. 2. Species wise density.

Platanthera edgeworthii, Platanthera latilabris, and *Satyrium nepalense*) were near endemic and; 1 species, *Habenaria intermedia,* was endemic to the Indian Himalayas (Table 1 and Fig. 3).

Analysis of threat categorization revealed 1 species *i.e. Crepidium acuminatum* as Critically Endangered (CR); *Habenaria intermedia* as Endangered (EN); 2 species, *Goodyera biflora* and *Platanthera edgeworthii*, Vulnerable (VN); 10 species *i.e. Cypripedium cordigerum, Epipactis helleborine, Galeola lindleyana, Goodyera repens, Habenaria pectinata, H. plantaginea, Herminium lanceum, Neottia listeroides, Satyrium nepalense,* and *Spiranthes sinensis* as Near Threatened (NT), and rest were Least concern (Table 1 and Fig. 4).

Altitudinal Range and Site Representation

Maximum species (15) were found in the altitudinal zone 1500-1800 m amsl, 12 species in 1801-2200 m amsl, and 10 species in 2201-2500 m amsl. *Calanthe tricarinata* was recorded in maximum sites (16 sites), followed by *Neottia listeroides* (14 sites), *Habenaria intermedia* (13 sites), *Crepidium acuminatum* and *Platanthera edgeworthii* (12 sites each), *Habenaria pectinata*, *Satyrium nepalense* (10 sites each), *Brachycorythis obcordata*, *Platanthera latilabris* and *Spiranthes sinensis* (9 sites each), *Cephalanthera longifolia* and *Nervilia concolor* (8 sites each), *Calanthe plantaginea* and *Epipactis helleborine* (7 sites each), *Galeola lindleyana* and *Herminium lanceum* (6 sites each), *Cymbidium macrorhizon* and *Habenaria plantaginea* (5 sites each), *Goodyera repens* (4 sites), *Goodyera biflora* and *Liparis odorata* (3 sites each) and *Cypripedium cordigerum* (2 sites) (Fig. 5).

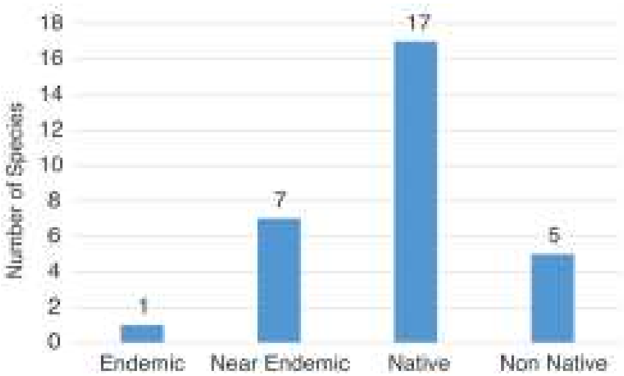


Fig. 3. Nativity of the species.

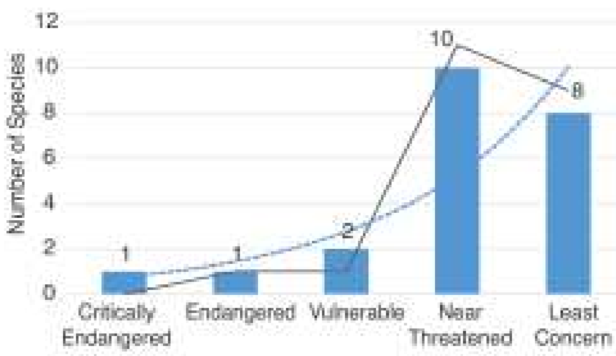


Fig. 4. Threat categorization of the species.

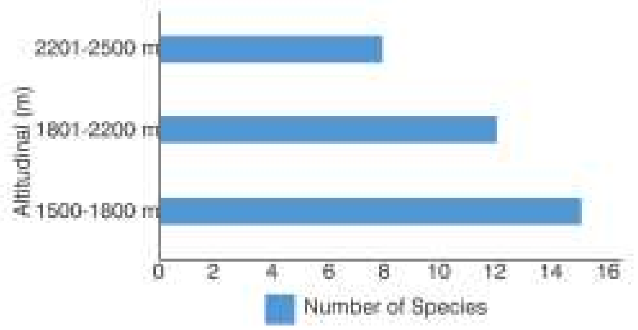


Fig. 5. Altitudinal distribution of the species.

Indigenous Uses

The percentage distribution of different plant parts used for the preparation of ethnomedicine is represented by Fig. 6. Use of below ground plant parts (80.16%) was higher than that of above ground plant parts (19.84%). Tubers from 9 plant species were used to prepare medicine, followed by leaves, rhizomes and roots (6 species each), aerial parts, pseudobulbs, and whole plants (3 species each) and bulb (1 species). Paste and powder were found to be most popular way to prepare medicine. Maximum medication was oral (87.14%), followed by topical (1.87%). In some cases, some species were used both orally and topically (10.99%).

Four species were used against bronchial, orthopaedic and urinary disorders, 5 species against cardiovascular and gastroenterological disorders, 2 species against dermatological disorders, 8 against Influenza like illness disorders, 3 against immunological, sexual and neurological disorders and 1 against mental disorders. Other details are given in Table 1 and Fig. 7.

Physico-Chemical Properties of Soil

Physico-chemical properties of soil collected from the representative orchid habitats indicated wide variations

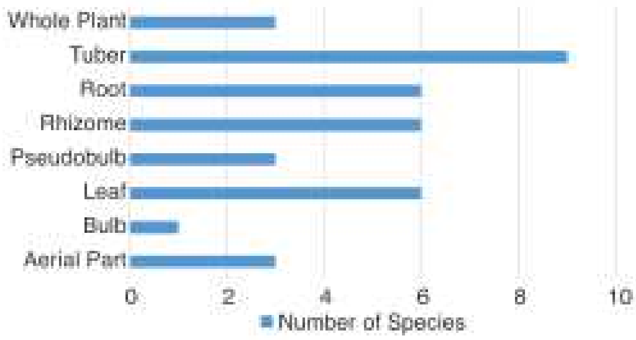


Fig. 6. Part(s) of medicinally important orchids used as ethnomedicine.

in soils with respect to their pH, moisture, Nitrogen, Phosphorus, Potassium, and Carbon contents (Table 2). Generally, pH was found minimum for *Habenaria plantaginea* (5.3) and maximum for *Cypripedium cordigerum* (7.4); moisture content minimum for *Habenaria plantaginea* (15.12%) and maximum for *Calanthe tricarinata* (55.56%); Nitrogen found minimum for *Habenaria plantaginea* (0.17%) and maximum for *Calanthe tricarinata* (0.71%); Phosphorous found minimum for *Brachycorythis obcordata* (3.01 $Kgha^{-1}$) and maximum for *Cypripedium cordigerum* (24.15 $Kgha^{-1}$); Potassium found minimum for *Habenaria plantaginea* (81 $Kgha^{-1}$) and maximum for *Cypripedium cordigerum* (245 $Kgha^{-1}$) and organic Carbon found minimum for *Brachycorythis obcordata* (0.75%) and maximum for *Calanthe tricarinata* (7.12%). Other details of soil parameters are presented in Table 2.

Bray and Curtis cluster analysis was placed to identify the similarities of 22 orchid species with soil parameters. The results showed two clusters of similar attributes. Both clusters had 11 orchid species, each. Cluster 1 had *Crepidium acuminatum, Cypripedium cordigerum, Galeola lindleyana,*

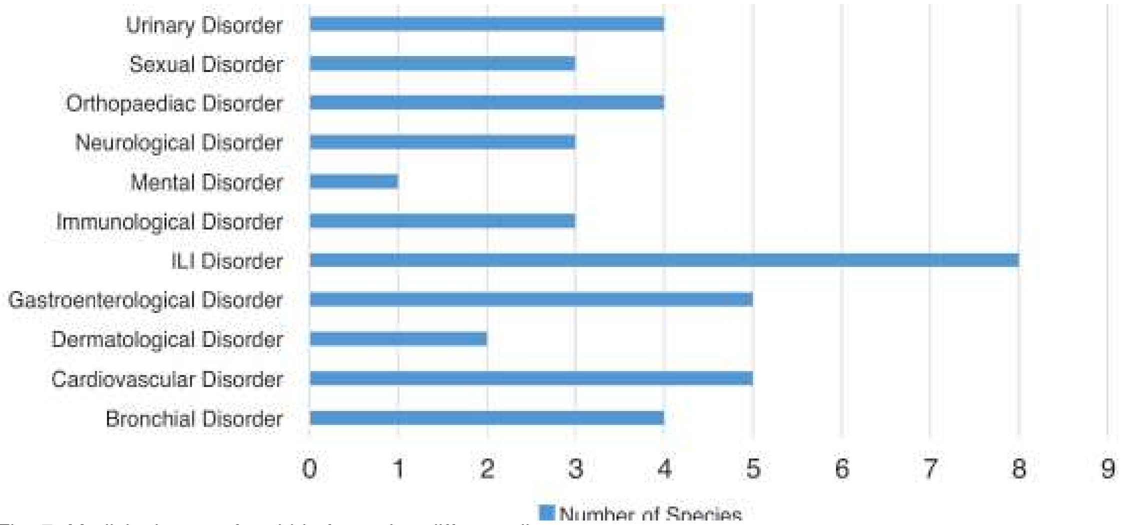


Fig. 7. Medicinal uses of orchids for curing different diseases.

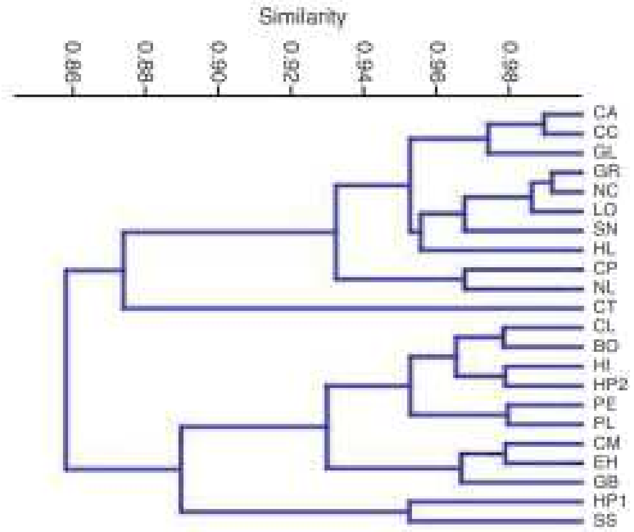


Fig. 8. Bray-Curtis similarity index of orchids with soil parameters.

CA, *Crepidium acuminatum*; CC, *Cypripedium cordigerum*; GL, *Galeola lindleyana*; GR, *Goodyera repens*; NC, *Nervilia concolor*; LO, *Liparis odorata*; SN, *Satyrium nepalense*; HL, *Herminium lanceum*; CP, *Calanthe plantaginea*; NL, *Neottia listeroides*; CT, *Calanthe tricarinata*; CL, *Cephalanthera longifolia*; BO, *Brachycorythis obcordata*; HI, *Habenaria intermedia*; HP1, *Habenaria plantaginea*; PE, *Platanthera edgeworthii*; PL, *Platanthera latilabris*; CM, *Cymbidium macrorhizon*; EH, *Epipactis helleborine*; GB, *Goodyera biflora*; HP2, *Habeneria pectinata*, and SS, *Spiranthes sinensis.*

Goodyera repens, Nervilia concolor, Liparis odorata, *Satyrium nepalense, Herminium lanceum, Calanthe plantaginea, Neottia listeroides,* and *Calanthe tricarinata* and cluster 2 had *Cephalanthera longifolia, Brachycorythis obcordata, Habenaria intermedia, H. plantaginea, Platanthera edgeworthii, P. latilabris, Cymbidium macrorhizon, Epipactis helleborine, Goodyera biflora, Habenaria pectinata,* and *Spiranthes sinensis* (Fig. 8).

Principal Component Analysis (PCA) was done to find out the key information from the multivariate data set by plotting all the data along with first two principal components (Fig. 9). The PCA revealed that most of the soil parameters were varied in similar ways except moisture content and Potassium which was found in opposite direction. The PCA plot summarizes the species by assessing the dominant patterns of variation in soil composition. The PCA diagram for orchid species has indicated that *Cephalanthera longifolia*, *Calanthe plantaginea,* and *Herminium lanceum* being at the right east corner of the ordination plot, has unique set of gradients for dominance and thus does not share its habitat with other orchid species. Similar characteristics were observed for *Calanthe plantaginea* and *Herminium lanceum*, which was positioned at the middle of south and eastern side of ordination plot. Three distinct clustering of orchid species indicated by A, B, and C could be clearly observed showing close association of species within the cluster and the sharing of same. A very close association of some orchids species (indicated in PCA; Fig. 9) suggests that these species

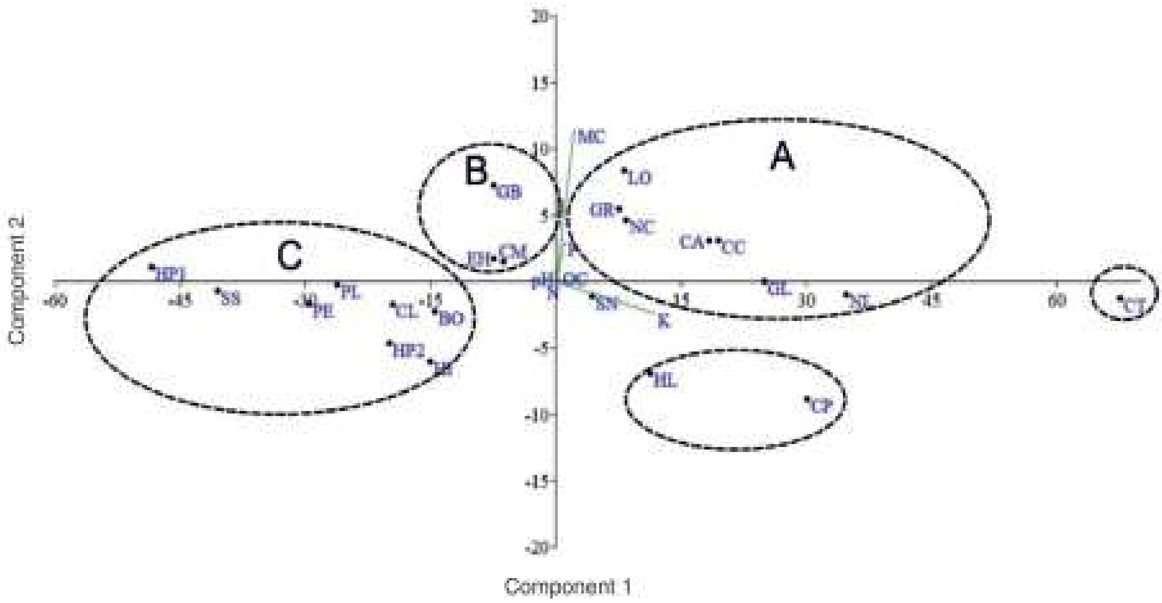


Fig. 9. Principal Component Analysis indicates distribution of the soil parameters with two principal components.

N, Nitrogen; P, Phosphorous; K, Potassium; MC, Moisture Content; OC, Organic Carbon; CA, *Crepidium acuminatum*; CC, *Cypripedium cordigerum;* GL, *Galeola lindleyana*; GR, *Goodyera repens*; NC, *Nervilia concolor,*; LO, *Liparis odorata*; SN, *Satyrium nepalense*; HL, *Herminium lanceum*; CP, *Calanthe plantaginea*; NL, *Neottia listeroides*; CT, *Calanthe tricarinata*; CL*, Cephalanthera longifolia*; BO, *Brachycorythis obcordata*; HI, *Habenaria intermedia*; HP1, *Habenaria plantaginea*; PE, *Platanthera edgeworthii*; PL, *Platanthera latilabris*; CM, *Cymbidium macrorhizon*; EH, *Epipactis helleborine*; GB, *Goodyera biflora*; HP2, *Habeneria pectinata,* and SS, *Spiranthes sinensis.*

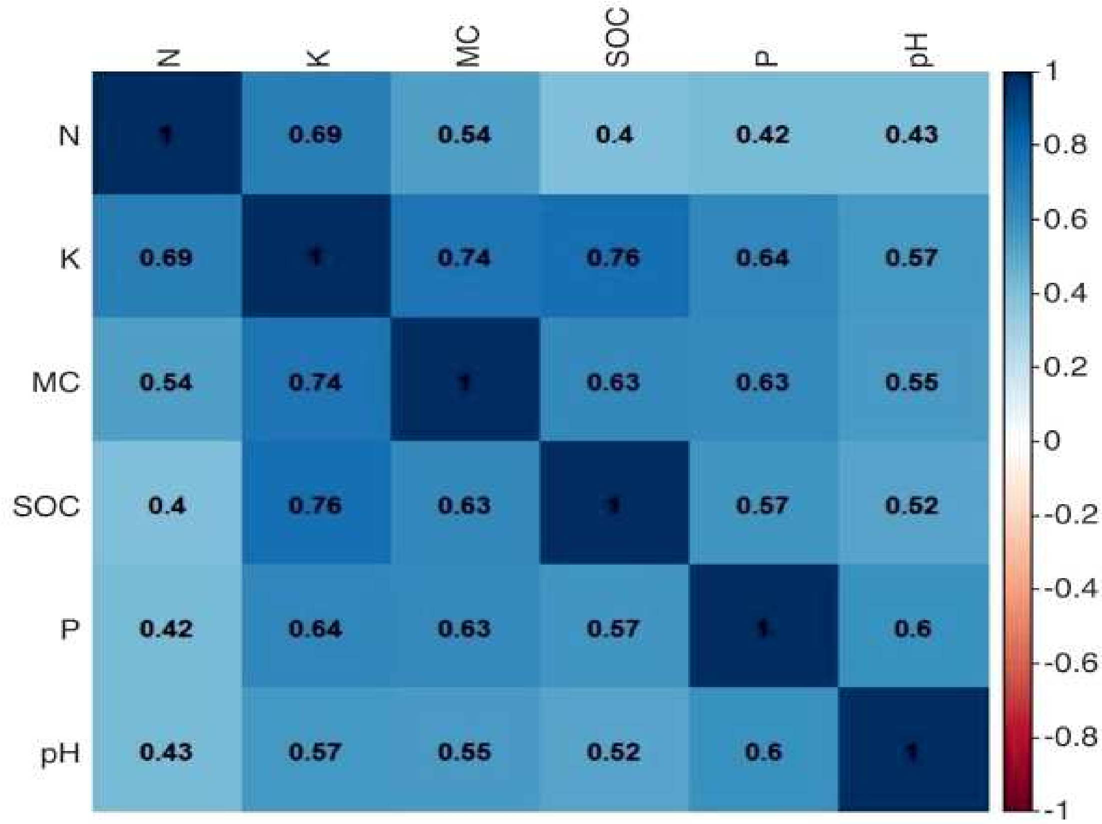


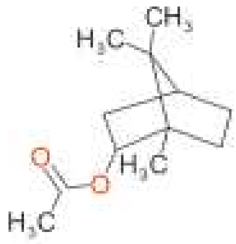
Fig. 10. Pearson pairwise correlation between soil parameters α = 0.05. Darker colour indicates positive correlation while light colour indicated negative correlation.

are affected simultaneously in nearly an equivalent manner and concentration by the available biotic and abiotic factors and therefore, showed almost similar importance values. Also, altitude played a significant role in the dispersion of these species in the study area. Species like *Cephalanthera longifolia, Calanthe plantaginea,* and *Herminium lanceum* did not share the relation/habitats/niches with any other orchid species and exhibited individually and uniqueness in the study area.

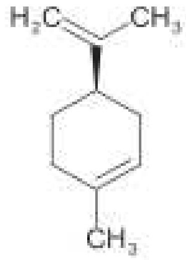
Correlation was calculated to understand the association between two or more soil parameters (Fig. 10). We found some soil parameters to be highly correlated with each other while others showed less correlation with each other. Significant correlation of Organic Carbon with available Potassium of soil (r^2 = 0.76, Fig. 10) indicates that both the important components increase simultaneously. Nitrogen and moisture content of the soil also showed significant correlation (r^2 = 0.54) indicating the increase might be driven by changing vegetation composition in these sites. Potassium showed significant relation with moisture content (r^2 = 0.74), Phosphorus (r^2 = 0.64) and pH (r^2 = 0.57), while pH showed less correlation with all the soil variables. High Nitrogen density and dense canopy of trees provided sufficient humus and soil moisture, which is required for the germination of a species.

Orchids as a Rich Source of Natural Compounds and their Pharmacological Uses

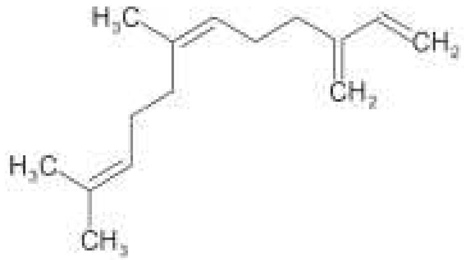
Orchids, like other plants, produce a large number of phytochemicals. Only a few of them have been investigated for their biological function, others are still unknown. Orchid phytochemicals are generally categorized as alkaloids, flavonoids, carotenoids, anthocyanins, and sterols. Amongst them alkaloids and flavonoids are the most important for their biological properties. Researchers have found the various activities of metabolites and extracts of different orchid species in the treatment of various diseases. They have been used variously in different diseases as anti-rheumatic, anti-inflammatory, antiviral, anti-carcinogenic, anticonvulsive, diuretic, neuro protective, relaxation, anti-aging, wound healing, hypoglycaemic, anti tumorous and anti cancerous, antimicrobial, antiviral, and many other activities (Ghanaksh and Kaushik, 1999; Kumari and Pathak, 2020; Pathak *et al.*, 2010). For drugs derived



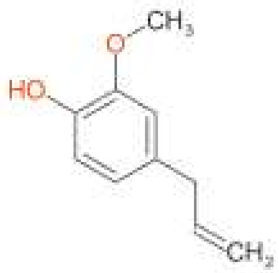
Isobornyl acetate



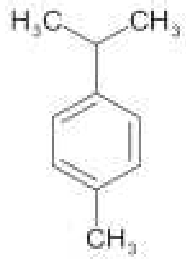
Limonene



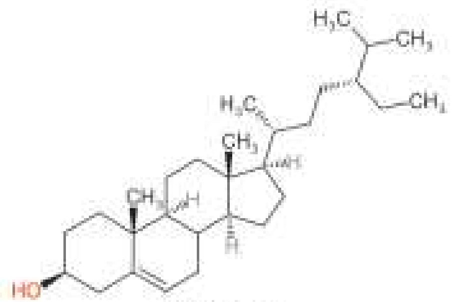
cis-β-farnesene



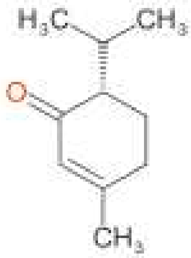
Eugenol



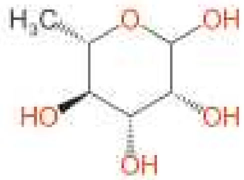
p-cymene



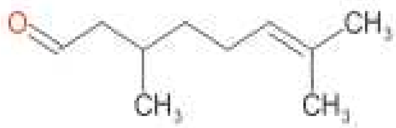
β-sitosterol



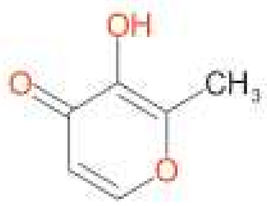
Piperitone



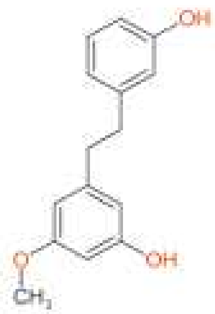
Rhamnose



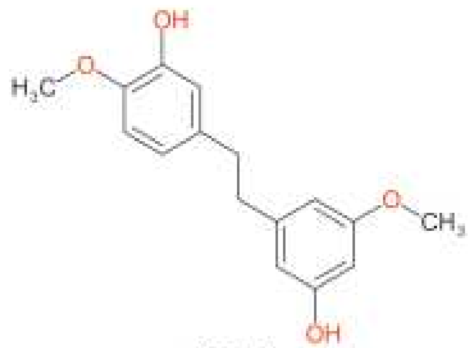
Citronellal



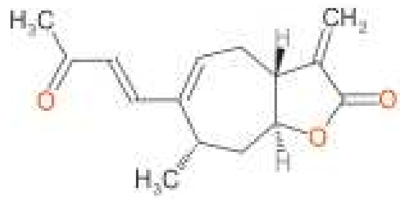
Pyromeconic acid



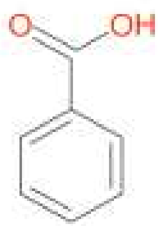
Batatasin III



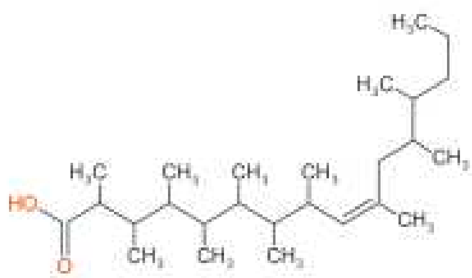
Gigantol



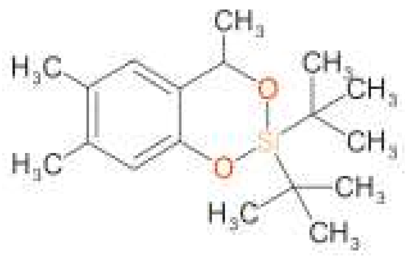
Xanthatin



Benzoic acid

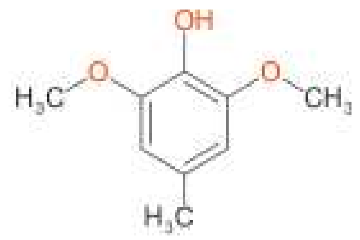


Oleic acid

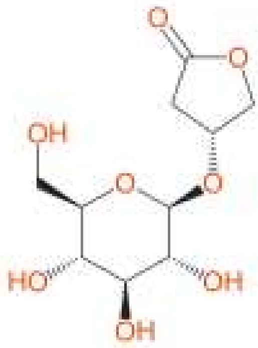


2-hydroxy-benzene-methanol

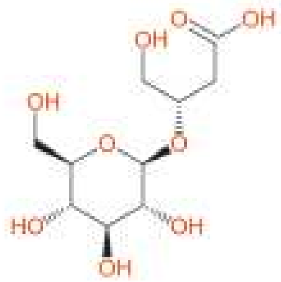
Vanillin



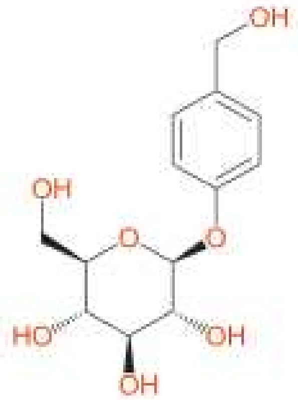
Syringol



Kinsenoside

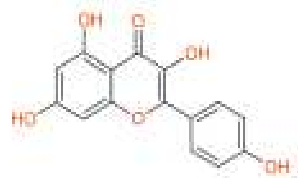


Goodyeroside

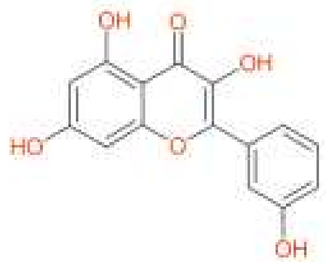


Gastrodin

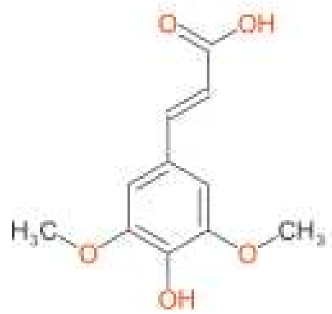
Narcissin



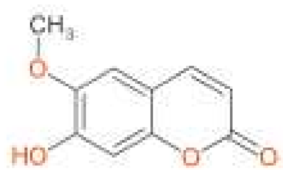
Kaempferol



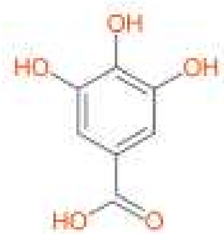
Quercetin



Sinapic acid



Scopoletin



Gallic acid

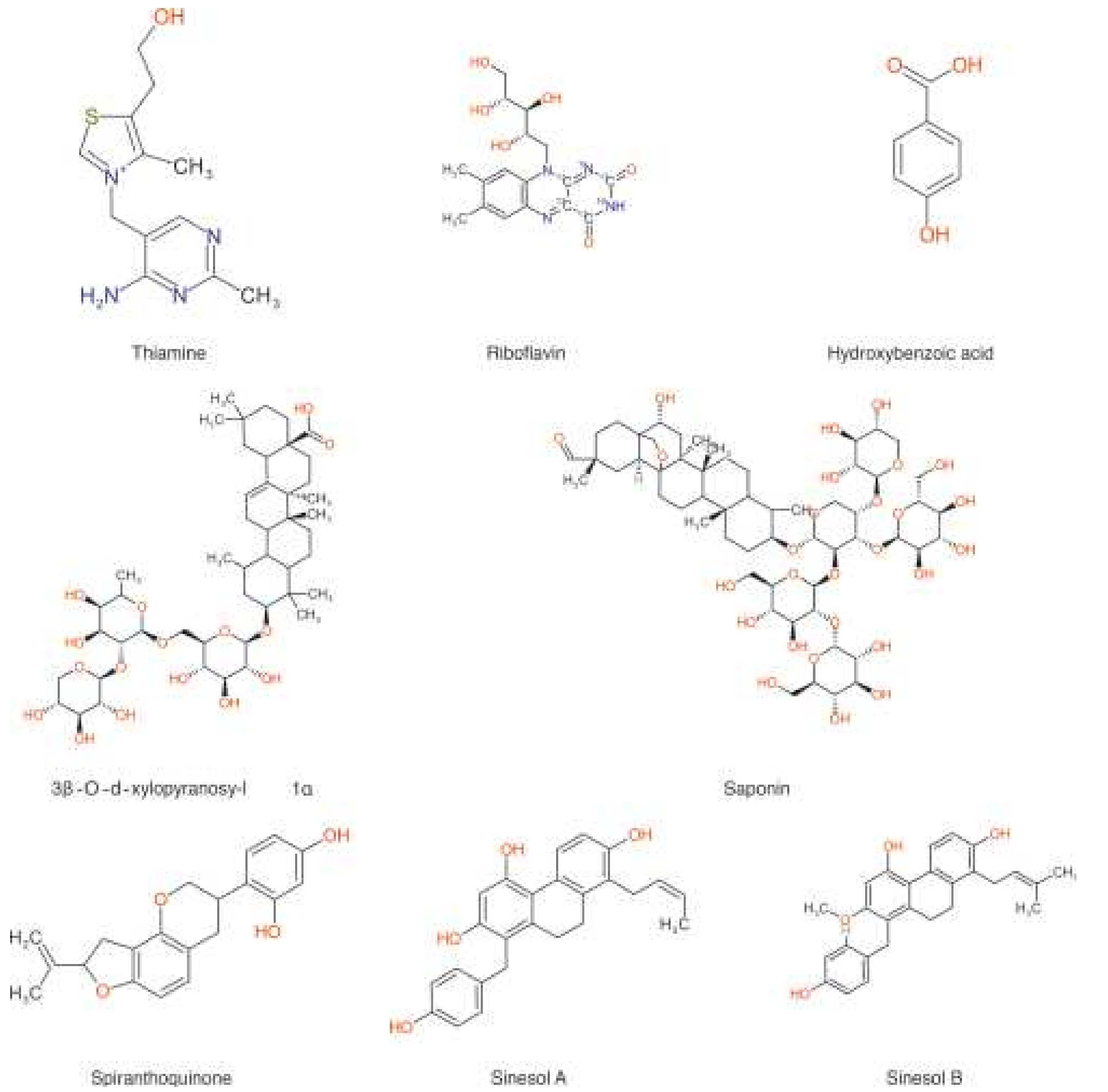


Fig. 11. Phytochemical compounds present in the orchids (Source: PubChem).

from orchids, some novel discoveries, both in phytochemical and pharmacological properties, were reported by some researchers. Studies have reported the isolation of wide range of important phytochemicals (from different genera of orchids) such as alkaloids, flavonoids, stilbenoids, anthocyanins, triterpenoids, orchinol, hircinol, cypripedin, bibenzyl derivatives, phenanthrenes, jibantine, nidemin, and loroglossin which are present in leaves, pseudobulb, roots, flowers or in the entire plant (Majumder *et al*., 1996). Thus, from various studies, it is well known that orchids have been used all over the world in traditional healing and treatment system of a number of diseases. Knowledge of different ethnopharmacological studies, linking of the indigenous knowledge of medicinal orchids to modern research activities provides a new reliable approach, which makes the chances of discovery of drugs much more effective than with random collection. Literature studies revealed the presence of following phytochemicals or active compounds in presently studied orchids (Table 3).

Table 1. Diversity, distribution, indigenous uses and status of orchids in Ban oak forests of Himachal Pradesh.

Species	Common name	Habitat(s)	Altitudunal range (m)	Flowering season	Plant part(s) Used	Medicinal uses	Nativity	Threat Status
Brachycorythis obcordata (Lindl.) Summerh.	Gamdol	Shady Moist	1500-2000	August-October	Root/Rhizome	Used in dysentery. Taken with milk as a tonic, nutritious Rhizome is used as expectorant, astringent, and as energy tonic	As Trop	LC
Calanthe plantaginea Lindl.*	Plantain	Shady Moist, Riverine	1700-2200	March-May	Rhizome	Dry powder with milk is taken as tonic and also as an aphrodisiac	Reg Himal	LC
C. tricarinata Lindl.	Monkey orchid	Shady Moist, Dry, Rocky, Riverine	1600-2200	June-September	Leaf, Bulb, Pseudo bulb	Leaf paste applied on sores and eczema. Leaves and pseudo bulbs are aphrodisiac	Reg Himal	LC
Cephalanthera longifolia (L.) Fritsch	Sword leaved helleborine, Hachchu fool	Shady Moist	1800-2300	May-August	Tuber, Leaf, Rhizome	Decoction of tubers is given for curing cough and paralysis, also decoction of the leaves and bulbs used in sores, eczema (especially helleborine eczema), and used as aphrodisiac and tonic	Europe Afr Bor As Temp	LC
Crepidium acuminatum (D.Don) Szlach.	Rishbhaka, Bandhura, Indraksa, Matrika	Shady Moist, Riverine	1600-2300	July-September	Rhizome, Pseudo bulb	Used as a nutritive tonic, to cure tuberculosis and enhance sperm production, in bleeding diathesis, burning sensation, fever and phthisis. It is also an ingredient Chayvanprash of Ashtavarga group of drug. Preparations from pseudo bulbs are useful in burning and fever. It is aphrodisiac, useful in thrust, emaciation and general body weakness, and increase body freshness and vitality	Reg Himal	CR
Cymbidium macrorhizon Lindl.	-	Shady Moist	1500-2200	June-October	Rhizome	Rhizome is used in boils and also used as diaphoretic and febrifuge	Reg Himal	LC
Cypripedium cordigerum D.Don*	Heart-shaped Slipper Orchid	Shady Moist	2000-2300	May-June	Root, Leaf, Rhizome	Used as Tonic and to cure mental disorder, edible as a vegetable	Reg Himal	NT
Epipactis helleborine (L.) Crantz	Broad leaved helliborine	Shady Moist, Riverine	1600-2400	July-September	Leaf, Rhizome, Tuber	Used to treat insanity, gouts, headache and stomach ache; used as an aphrodisiac and used to cure fever; as blood purifier	Reg Himal	NT
Galeola lindleyana (Hk.f. & Th.) Rchb.f.	-	Shady Moist	1500-2500	June-August	Root	Used to combat heat. It promotes diuresis, stops bleeding, reduces swelling and is used in the herbal treatment of nephritis, haematuria and uterine prolapse	Reg Himal	NT

Table 1. Diversity, distribution, indigenous uses and status of orchids in Ban oak forests of Himachal Pradesh (contd.).

Species	Common name	Habitat(s)	Altitudunal range (m)	Flowering season	Plant part(s) Used	Medicinal uses	Nativity	Threat Status
Goodyera biflora (Lindl.) Hk.f.*	-	Shady Moist, Rocky	1600-2500	June-August	Aerial part	Decoction is used as blood purifier. Also used to cure bronchial disorders	Reg Himal	VU
Goodyera repens (L.) R.Br.	Dwarf/Lesser rattlesnake plantain	Shady Moist	2000-2500	June-August	Tuber, Aerial part	Plant paste externally applied in syphilis, extract is taken as a blood purifier	Reg Himal, Bor Temp	NT
Habenaria intermedia D.Don**	Riddhi, Laksmi, Mangala, Siddhi, Rathanga	Shady Moist	1500-2400	July-September	Tuber, Leaf, Root	The tuberous roots are used in Chyavanprash-an important ingredient of Ashtavarga group of drugs. It is considered as general tonic, expectorant, rejuvenator, life span promontory, cooling and spermopiotic. Tender leaves as well as tubers are edible and cooked as vegetables	Reg Himal	EN
H. pectinata D.Don	Safed Musli	Shady Moist	1500-2200	July-September	Tuber, Leaf, Root	The leave are crushed and applied in snake bites. Tubers mixed with condiments are used in arthritis and also used to cure joint pains	Reg Himal	NT
H. plantaginea Lindl.	Kusuma Gadda	Shady Moist	1500-2200	September-November	Tuber	A tablet made from pasted tubers with black pepper and garlic, is prescribed for alleviate continual chest pain and stomachache	Reg Himal	NT
Herminium lanceum (Thunb. ex Sw.) Vuijk	Musk orchid, Jayla	Shady Moist, Dry, Riverine	1500-2300	July-September	Whole plant	The whole plant is medicinal and is used to treat cold and fever, rheumatism, typhoid fever, hernia, sores, eczema, snake bites, and for reducing swelling and pain. Extract of plant given in suppressed urination	Reg Himal	NT
Liparis odorata (Wild.) Lindl.*	-	Shady Moist	1600-2500	July-September	Pseudo bulb	The pseudobulbs of this plant are used to treat cancerous ulcers, gangrene, fever and dropsy	Reg Himal	LC
Neottia listeroides Lindl.	Broad-lipped twayblade	Shady Moist	1800-2300	July-September	-	-	Reg Himal	NT
Nervilia concolor (Bl.) Schltr.	-	Shady Moist	1500-2200	June-August	Whole plant	Used in uropathy, haemoptysis cough asthma, vomiting, diarrhoea and mental instability	Reg Himal	LC
Platanthera edgeworthii (Hk.f. ex Collett) R.K.Gupta*	Vriddhi, Mangala, Rathanga, Siddhi, Risisrista, Sukha	Shady Moist	1600-2500	July-September	Tuber	The tubers are used as an ingredient of Ashtavarga in Chyavanprash Avleha Regarded as tonic, blood purifier, and rejuvenator	Reg Himal	VU

Table 1. Diversity, distribution, indigenous uses and status of orchids in Ban oak forests of Himachal Pradesh (contd.).

Species	Common name	Habitat(s)	Altitudunal range (m)	Flowering season	Plant part(s) Used	Medicinal uses	Nativity	Threat Status
*P. latilabris** Lindl.	Bog orchid	Shady Moist	1600-2500	July-September	Whole Plant	Whole plant is used in herbal medicine	Reg Himal	LC
Satyrium nepalense D.Don*	Satyrion, Salam misri, Salang Misri, Ban-alu	Shady Moist, Dry	1600-2400	August-October	Tuber, Root	The sweet tubers are cooked and consumed. Dried ones sold as 'Salam misri' are considered as tonic. The roots are used to treat malaria and dysentery. In local folklore prevalent in upper Shimla region, the tubers are tied to the armpits in case of hydrocele. As the tubers start drying, it is claimed that the swelling in the testicle starts subsiding	Ind Or	NT
Spiranthes sinensis (Pers.) Ames	Lady's Tresses	Shady Moist	1500-2500	July-September	Tuber, Aerial part	Decoction of plant given in intermittent fever, tubers used as tonic. Paste of roots and stem is applied in sores. Extract of the leaves used to cure diarrhoea. Used for curing tuberculosis, debility, snake bite, cough, cold, leucorrhoea, and diabetes	China As Temp Aus Europe	NT

AR, Altitudinal Range; TS, Threat Status; **, Endemic; *, Near Endemic; Afr, Africa; As, Asia; Bor, Boreal; Ind, India; Or, Oriental; Temp, Temperate; Trop, Tropical; Aus, Australia; Reg Himal, Regional Himalaya; CR, Critically Endangered; En, Endangered; NT, Near Threatened; VU, Vulnerable, and LC, Least Concern.

Table 2. Physico-chemical properties of soil in different sites of Ban Oak forests.

Species	SR	pH	MC (%)	N (%)	P (kgha^{-1})	K (kgha^{-1})	OC (%)
Brachycorythis obcordata	09	5.5-6.5	20.32-38.23	0.21-0.54	03.01-15.26	088-180	0.75-5.51
Calanthe plantaginea	07	6.1-6.9	25.12-37.14	0.34-0.56	05.12-17.06	120-220	4.51-6.24
C. tricarinata	16	6.9-7.2	38.23-55.56	0.36-0.71	17.15-23.45	210-230	6.21-7.12
Cephalanthera longifolia	08	5.6-6.2	25.17-32.15	0.24-0.45	04.12-08.25	090-150	1.02-3.45
Crepidium acuminatum	12	6.2-7.3	31.98-43.12	0.32-0.54	07.15-22.26	145-234	4.95-6.85
Cymbidium macrorhizon	05	5.9-6.8	22.32-35.16	0.26-0.44	15.15-21.23	134-198	2.35-5.12
Cypripedium cordigerum	02	6.1-7.4	26.12-45.21	0.29-0.57	18.25-24.15	145-245	3.56-6.21
Epipactis helleborine	07	5.6-6.8	24.12-35.13	0.19-0.38	07.25-16.15	095-195	4.21-5.36
Galeola lindleyana	06	6.2-7.2	30.15-46.16	0.28-0.48	15.23-21.05	142-205	4.32-5.42
Goodyera biflora	03	5.8-6.5	34.26-48.26	0.22-0.31	07.15-13.65	135-178	3.32-5.02
G. repens	04	6.1-6.8	33.15-42.16	0.25-0.35	11.24-15.26	138-191	4.02-6.02
Habenaria intermedia	13	5.9-6.6	19.98-28.52	0.22-0.30	08.12-12.65	141-184	4.12-5.86
H. pectinata	10	5.4-6.2	15.56-27.21	0.19-0.27	04.05-09.15	085-140	3.89-4.86
H. plantaginea	05	5.3-6.5	15.12-29.12	0.17-0.28	05.15-12.65	081-165	3.21-5.02
Herminium lanceum	06	6.0-6.8	21.38-34.25	0.19-0.35	08.15-16.25	140-187	5.26-6.01
Liparis odorata	03	5.9-7.0	30.16-49.98	0.18-0.45	08.89-18.25	133-194	4.26-6.86
Neottia listeroides	14	6.2-7.3	32.39-51.21	0.25-0.51	09.56-20.15	145-237	5.46-6.32
Nervilia concolor	08	5.9-6.8	31.85-43.26	0.29-0.36	08.84-18.25	132-174	3.45-5.12
Platanthera edgeworthii	12	5.5-6.3	18.91-29.15	0.21-0.32	06.25-11.45	090-154	2.98-3.86
P. latilabris	09	5.8-6.4	21.85-34.15	0.25-0.35	07.25-11.89	125-147	3.14-4.85
Satyrium nepalense	10	6.1-6.8	29.71-38.18	0.29-0.41	08.15-17.25	130-178	4.57-6.21
Spiranthes sinensis	09	5.4-6.6	17.65-30.45	0.20-0.36	04.06-15.25	091-137	1.32-4.98

SR, Site Representation; MC, Moisture Content; N, Nitrogen, P, Phosphorus; Kg, Kilogram; ha, Hectare; K, Potassium, and OC, Organic Carbon

Discussion

As the presently studied orchid species inhabit the moist slopes and shady moist habitats, and less acidic content of study area, it may be concluded that the orchid species require sufficient amount of soil nutrients for the germination and development. Orchids are the most threatened species amongst the flowering plants in the world. Due to several natural and anthropogenic pressures, these species are being depleted rapidly. Medicinal orchids are under considerable threat due to habitat destruction and degradation. Over exploitation, over grazing, and illegal extraction of ecologically and economically important orchids have become major reason for their rampant depletion. Many orchid species has been categorized as critically endangered, vulnerable, and threatened regionally as well as globally. There is a major gap in conservation and management. Due to the recent trend of using orchids in the Himalayas, their demand is increasing. Hence urgent conservation measures need to be taken.

Conservation Measures

Rapid habitat degradation leads many orchid species at the verge of extinction, so it is high time to conduct effective strategies to conserve them. Conservation of orchids is an important issue that should be seriously considered by both government and private sector in participation with research institutions, non-government organization, and community growers as well as through international collaboration. Conservation of medicinal orchids can be addressed by both *in situ* and *ex situ* measures, in association with participation of local people.

In Situ Conservation

In situ conservation (the conservation of species in their natural habitats), is considered as the most appropriate way of conserving biodiversity. Habitat protection could be the most important *in situ* conservation strategy for orchids. Because of their small population size and restricted distribution, intensive care and habitat management is highly recommended for their *in situ* conservation. Thus, the Protected Areas (PAs) form a central element of any national strategy to conserve biodiversity. There is no substitution for conservation of threatened medicinal orchid species in their natural habitat as by natural propagation method as their vegetative propagation rate is very slow.

Ex Situ Conservation

Ex situ conservation (the preservation of components of biological diversity outside their natural habitats)

Table 3. Phytochemical and Active compounds present in orchids.

Species	Phytochemicals/Active compounds	References
Cephalanthera longifolia	Limonene; Tridecane; Isobornyl acetate; Tetradecane; Cis-â –farnesene; 2,6-Bis(1,1-dimethylethyl)-2, -cyclohexadiene-1,4-dione; Pentadecane; á-Farnesene; Methyl dodecanoate; Hexadecane; Ethyl dodecanoate; Pentadecanal; Heptadecane; Pristane; 3,5-Di-*t*-butyl-4-hydroxybenzal dehyde; Octadecane; Ethyl tetradecanoate; Phytane; Hexadecanal; Methyl hexadecanoate; Eicosane	D'Auria *et al.,* 2021
Crepidium acuminatum	â-sitosterol; p-cymene; Piperitone; Eugenol; Limonene; Liparacid C; Bulbophythrin A; Batatasin III; 2,3-dimethoxy-9,10-dihydro phenanthrene-4, 7- diol; 1,8-Cineole; Citronellal; Cetylalcohol; D-Glucose (Fischer); Rhamnose; Choline; Pyromeconic acid; O-Methylbatasin; Coelonin (4-methoxy- 9, 10- dihydrophenanthren- 2,7 –diol); Gigantol (3, 4'–Dihydroxy- 3',5- dimethoxy bibenzyl); Lusianthridin (7- methoxy-9, 10- dihydophenanthren-2, 5- diol)	Arora *et al.,* 2019; Singh *et al.,* 2017; Sharma *et al.*, 2011
Epipactis helleborine	3-{2-{3-{3-(benzyloxy)propyl}-3-indole; Xanthatin; 2-furan carboxyaldehyde (furfural); 2(5H)-furanone; 3-methyl-1,2-cyclo pentanedione; 2,6-dimethoxy-phenol (Syringol); 2-metoxy-4-(2-propenyl)-phenol (eugenol); 2,6-dimethoxy -4-(2-propenyl)-phenol (methoxyeugenol); Benzylalcohol; 4-hydroxy-3 -methoxy-benzaldehyde (vanillin); 2,2-diethoxyethanol; 2-hydroxy-benzene-methanol; 4-hydroxy-benzene-methanol; Pentadecanol; Heptadecanol; Eicosanol; Benzoic acid; Tetraeicosanoic acid; Octadecenoic acid; Pentadecenoic acid; Heptadecenoic acid; 9-hexadecenoic acid; Oleic acid; Eicosane; Heneicosane; Tricosane; Pentacosane; Hexacosane; Heptacosane; Octacosane; Eicosanoic acid; Tetracosanoic acid; Pentadecenoic acid; Methyl ester; Hexadecenoic acid; Heptanal; Hexadecanal; Octadecanal; Nonadecanal	Keng-Hong *et al.,* 2002
Goodyera biflora and *G. repens*	Kinsenoside; Goodyeroside; Gastrodin; Isorhamnetin-3-O-b-D-neohespeidoside; Rutin; Isoquercitrin; Kaempferol-7-O-b-D-glucoside; Kaempferol-3-O-b-D-glucoside; Isorhamnetin-3-O-b-D-glucoside; Narcissin; Quercetin; Kaempferol; Isorhamnetin.	Wu *et al.,* 2020
Habenaria intermedia	3,5-dimethoxy-4- hydroxycinnamic acid (Sinapic acid); Scopoletin (7-hydroxy -6-methoxy-2H-1-benzopyran-2-one); Gallic acid (3,4,5-trihydroxybenzoic acid); Thiamine; Riboflavin; Hydroxybenzoic acid	Virk *et al.,* 2020
H. plantaginea	Alkaloids, Terpenes, Flavones, Flavonoids, Steroids, Carbohydrates, Tannins, Anthraquinones, Glycosides, Cardiac glycosides	Keerthiga and Anand, 2015
Nervilia concolor	Nerviside I (3â-O-d-xylopyranosyl-1á, 24R, 31-trihydroxylcycloartan-28-oic acid); Nerviside J (3â-O-d-xylopyranosyl-31-O-acetyl-1á, 24R-dihydroxycycloartan-28-oic acid)	Tran *et al.,* 2019
Platanthera edgeworthii	Hydroxybenzoic acid; Alkaloids; Tannis; Phenols; Flavonoids; Riboflavin;	Sedai, 2015
Satyrium nepalense	Quercetin; Gallic acid (3,4,5-trihydroxybenzoic acid); Carbohydrates; Glycosides; Flavonoids; Phenols; Tannins; Resins; Saponin; Unsaturated sterols/triterpenes	Mishra and Saklani, 2012
Spiranthes sinensis	Sinensol A; Sinensol B; Sinensol C; Sinensol D; Sinensol E; Sinensol F; Spirasineol B; Spiranthol-C; Spiranthoquinone	Liu *et al.,* 2013; Hossain, 2011

measures can be complementary to *in situ* methods as they provide an "insurance policy" against extinction. These measures also have a valuable role to play in recovery programmes for endangered species. In this context, *ex situ* conservation is very important aspect of orchid conservation which can include both seed banks and *in vitro* cultured plant tissue collections. Hence, there is an urgent need to develop such conservatory for long term conservation and recovery programmes, specifically for medicinal orchids in the threatened area.

Conclusion

The Indian Himalayan Region (IHR) is known for its rich orchid diversity and the Central and Eastern Himalaya are known as the store house (as both the biogeographic provinces support >500 species). The present study provides first hand data on orchid diversity of the Ban Oak forests in Himachal Pradesh. Most of the species are representative, natural, unique, and socio-economically important ones, hence show high conservative value. The diversity of the orchid species decreases with the increasing altitude and similar trends have been recorded earlier by Samant (2009). Apart from the aesthetic values, the orchids are also used in the customary system of medicine, and as food (Samant and Dhar, 1997; Samant *et al*., 1998). These plants are rich source of alkaloids, flavonoids, glycosides, carbohydrates, and phytochemical contents and are used in indigenous systems of medicine to cure different types of human ailments. In fact, they have been used in the folk lore and other local medicines for past more than 3000 years. Interviewing the local inhabitants of the area revealed that almost all parts of orchids are of high commercial value. Different plant parts such as leaves, tubers, aerial parts, rhizomes, bulbs, roots and stems were used by the inhabitants for various therapeutic uses. Over-exploitation of these parts may lead to the extinction of species from the area. Unfortunately rapid decline of orchid populations was noticed due to massive anthropogenic pressures causing habitat degradation. Monitoring of habitats, mapping of populations of orchid species and awareness amongst the local inhabitants and officials of the Forest Department and conservation are suggested. Due to their small population size and restricted distribution, intensive care and habitat management is highly recommended. Very little effort has been made to cultivate the medicinal orchids on commercial scale. The species which has reached the threatened category because of the human activities can survive only with human support. Plant tissue culture method used in conservation of a few medicinally important orchids species of NorthWestern Himalayas (Bhatti *et al*., 2018; Thakur and Pathak, 2020; Vasundhra *et al*., 2019; Pathak *et al*., 2017) is one of the most suitable alternative tool to minimize the pressure on ever declining natural populations of medicinal orchids and their sustainable utilization and it may be applied for many other related orchid taxa.

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