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# *Dactylorhiza hatagirea* (D. Doon) Soo, an important medicinal herb of the Himalaya and urgent need for its conservation- A review

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*Dactylorhiza hatagirea* (D. Doon) Soo (Family Orchidaceae) is a terrestrial orchid, native to alpine and sub-alpine zones of Himalaya, well known for medicinal uses because of its immense pharmacological properties and therapeutic potential. Leaves and tubers of the herb finds enormous uses in traditional Indian medicinal system like Ayurveda, Siddha, Unani and Sowa-rigpa for treatment of different ailments like dysentery, diarrhoea, chronic fever, cough, wounds, burns, fractures, stomach-ache, etc. The present review analyses the distribution, medicinal uses, phytochemistry, pharmacology, and conservation status of *D. hatagirea*. The review is based on literature available on this orchid with an objective to compile and understand diverse medicinal uses among the indigenous Himalayan communities and phytochemical potential in pharmacology. This review also highlights the potential threats faced by this orchid and suggests future conservation prospects and strategies.

**Keywords**: *Dactylorhiza hatagirea*, Ethnomedicine, Himalaya, Orchid, Salampanja.

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## Introduction

*Dactylorhiza hatagirea* (D. Doon) Soo is a potential medicinal orchid belonging to the monocot family Orchidaceae which accounts for around 8% of flowering species[1,2]. The plant is facing great abiotic and biotic threats[3-5]. *D. hatagirea* is commonly known as Marsh Orchid or Himalayan Orchid in English nomenclature and Munjataka in Sanskrit[6] and is known by different vernacular in different languages and regions across the globe[7-20] (Table 1). The genus is represented by approximately 75 species, distributed in most parts of the Northern temperate zone[21]. It is a terrestrial, perennial herbaceous plant, 40-60 cm tall; stem erect, slender, roots tuberous, palmately divided into finger-like projections; leaves lanceolate or elliptic, appressed to stem; flowers purplish to spotted rose-purple in a dense cylindrical raceme (Fig. 1 and 2). The floral display is very attractive, which makes collection and overexploitation easy[22]. The plant is native to countries connected with Himalayan Mountains such as India, Pakistan, Afghanistan, Bhutan, Nepal, Tibet Autonomous Region (TAR), China, Iran, and Mongolia[23-25]. The species is facing great threat associated with habit and habitat and classified as one of the endangered orchid species[3-5,21,23].

As per APG IV classification, *D. hatagirea* is placed under basal angiosperms, clade monocot, order asparagales, family orchidaceae and genus *Dactylorhiza*. The plant grows preferably in temperate to alpine habitats (2500-5000 m) in the Himalayan region of Pakistan to Nepal[24]. Reported areas in Nepal and Bhutan are North-west Nepal, North-central Nepal, Hulma, Dolpa, Doti, Kaski, Rasuwa, Sindhupalchok, Dolakha[12,26,27], and Lingtshi, Phajodhng, Chele-la, Lingshi Dungkhang[20,28] respectively. It is endemic to the Hindu-Kush Himalayan region and distributed from Pakistan to China. In India, the plant is known to grow along with the Himalayan states Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh and union territories of Jammu and Kashmir and Ladakh[23,29-35]. The plant is extensively used in the traditional systems of medicine like Ayurveda, Siddha, and Unani medicine in India, Tibetan herbal system, and Sowa-Rigpa

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system in Trans-Himalayan Ladakh. The decline of the species is due to overexploitation for the preparation of *Salep*, which is made from its tuber[36]. *Salep* is extensively used for its aphrodisiac properties in traditional medicine in different parts of Himalaya[37]. Tibetan medicines use this wild plant *D. hatagirea* for the treatment of various ailments. Its overexploitation, improper excavation, and habitat deterioration are key causes of decline in Qinghai Province of the Tibetan region[38].

Table 1 — Local names of *Dactylorhiza hatagirea*

| Local Names | Languages/ region | References |
|---|---|---|
| Salab, Khusaa al-tha'lab, QaatilAkheehi | Arabic | 7, 8 |
| Salap | Urdu | 9 |
| Salam panja | Hindi | 10, 7 |
| Salam pamisri | Sanskrit | 7 |
| Salamisri | Tamil | 7 |
| Panchaungle | Bengali | 10, 11 |
| Panchaule, Pâncha | Nepali | 12 |
| Hathajari, Hathajadi | Hindi, Garhwali | 13, 14 |
| Salmpanja | Pahari, Hindi | 15 |
| Ambolakpa, Wanglak | Spiti Bhoti, Tibetan | 16, 17, 18 |
| Salampanja, Parja | Hindi, Lahauli or Lahul Bhoti | 17 |
| Narmad | Shina, Kashmiri | 19 |
| Wangla, Ja-ola-Omla | Dzongkha, Bhutan | 20 |

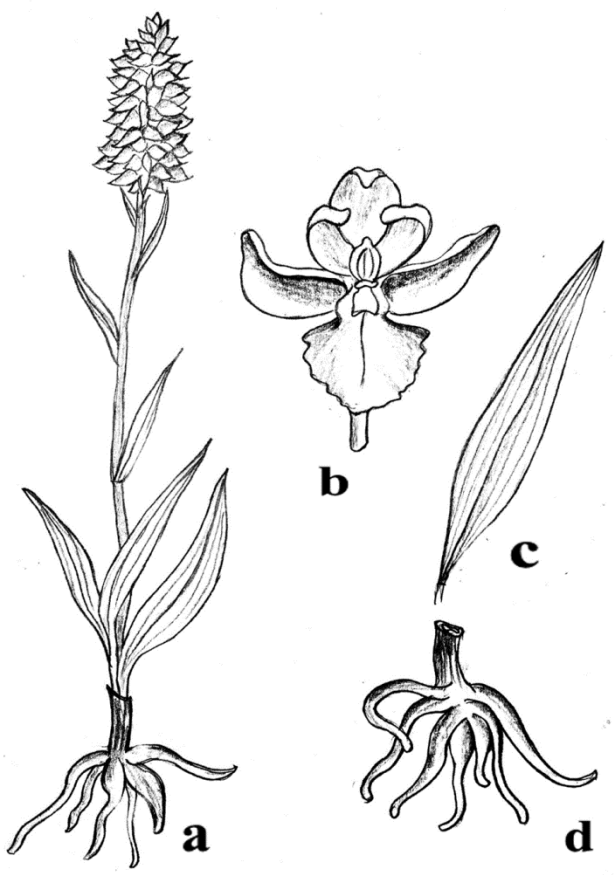


Fig. 1 — *Dactylorhiza hatagirea*: Hand drawings, a) Habit; b) Flower; c) Leaf; and d) Tuber.

## Methodology

For the present review, literature resources available and accessible on *D. hatagirea* were consulted. Information was gathered from primary and secondary sources including scientific journals, books, thesis and online search engines like JSTR, PubMed, Science Direct, Springer, Academia, ResearchGate, Google Scholar etc. The information extracted from these literary sources were analysed and reviewed. Simultaneously, information was also gathered from the local indigenous populace and traditional healers through direct communication and semi-structure interviews, particularly Amchis of Ladakh. Photographs of plant habit and habitat were also captured in wild mountains of Ladakh. Illustrations of different plant parts were hand drawn.

## Medicinal uses

The orchids have been used historically as medicine for a long time and Chinese were the first to apply them as herbal medicine because of their

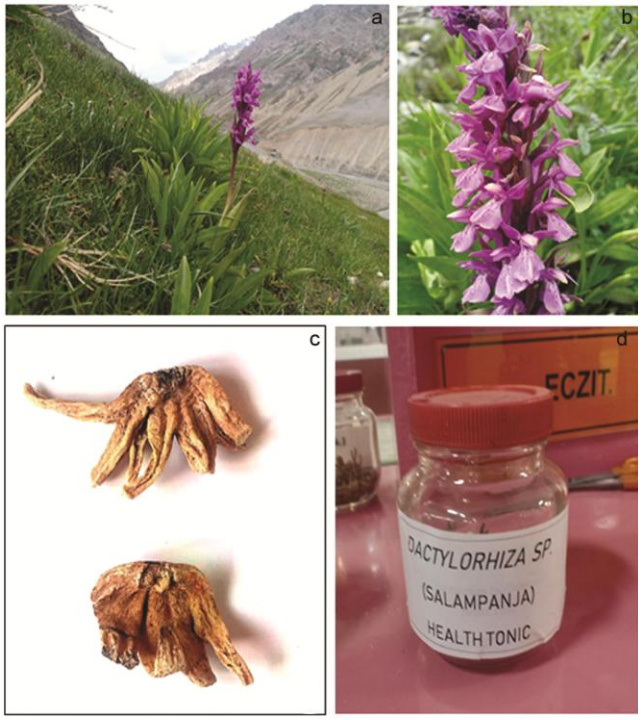


Fig. 2 — *Dactylorhiza hatagirea*, a) Habit in natural habitat; b) Magnified inflorescence; c) Dried tubers; and d) Tuber used as health tonic by Amchis.

valuable phytochemicals[39]. *D. hatagirea* has immense medicinal properties and has been extensively used for hundreds of years by natives of high altitudes of Himalaya. The tubers of this species yield high-quality "*Salep*" which is extensively used for its astringent and aphrodisiac properties, and as a sexual stimulant in traditional medicines in different parts of Himalaya[27,40]. The underground tubers are used by the indigenous people of Garhwal Himalaya for treatment of general debility, stomachache, bone fracture, cold, wound healing, and general weakness in women and children[27]. The indigenous people of Himachal Pradesh use the tubers of Salam-panja for treating different ailments[41]. In Himachal Pradesh, tubers are also used as an antibiotic, blood purifier, tonic, expectorant, and for curing wounds, bone fracture, cough, cold, cuts, sexual disabilities, and rheumatism[28].

In Nepal, the root powder is applied on cuts and wounds to stop bleeding[42,43]. Besides, the roots are also eaten as farinaceous food and nerve tonic in different communities of Nepal[44,45]. In the Ladakh region of Trans-Himalaya, the tubers are used by indigenous people and local healers in making aphrodisiac tonic by mixing a spoonful of dried, powdered tubers in a glass of milk (Fig. 2c-d). The Ayurvedic system of medicine considers this species as one of the highly valued medicinal orchid[40]. In the Amchi and Tibetan system of medicine, the plant is known as *Wanglak*, and tuberous roots are used as a health tonic and also against urine and kidney-related problems[23].

## Phytochemistry and molecular information

As orchids are the largest group of plants in angiosperms but data on molecular variation is less available to decipher its secret of diversity[2]. Biochemical parameters showed great variability among studied populations in parameters such as soluble sugar, starch, and soluble proteins. These variations could be due to edaphic, microclimate, environmental factors[32]. Several studies have been undertaken to ascertain the chemical compounds present in *D. hatagirea*. The roots contain glycosides identified as dactylorhin A, dactylorhin B, dactylorhin C, dactylorhin D, and dactylorhin E. In addition to it, two more glycosidic compounds namely dactylose A and dactylose B are also present[46]. The extracts of tuber contain albumin, butanedioic acid, hydroquinone, lesoglossin, militarrin, pyranoside, pyrocatechol, and volatile oil[47]. Transcriptomic studies also indicate the presence of biosynthetic pathways related to resveratrol, phenylpropanoid, and trans stilbenes[48]. Roots of the species also contain flavonoids, tannins, and saponins[49] (Table 2 & Fig. 3).

## Pharmacology

Pharmacology is concerned with the research, discovery and characterization of drug composition, properties, synthesis, drug design, and cellular & molecular mechanism. With the advancement in medical sciences and simultaneous emergence of new chronic diseases, pharmacological studies of medicinal plants have gained much more attention in

Table 2 — Chemical constituents of *Dactylorhiza hatagirea*

| Plant part | Chemical compound | IUPAC name | References |
|---|---|---|---|
| Root | Dactylose A | (2R,3S,4R,5S)-2-[(4-hydroxyphenyl)methyl]oxane-2,3,4,5-tetrol | 50 |
| | Dactylose B | 2-[(4-hydroxyphenyl)methyl]oxane-2,3,4,5-tetrol | 50 |
| Root | Dactylorhin A | bis[[4-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]methyl] (2R)-2-(2-methylpropyl)-2-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxybutanedioate | 46 |
| | Dactylorhin B | bis[[4-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]methyl] (2R,3S)-3-hydroxy-2-(2-methylpropyl)-2-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxybutanedioate | 46 |
| | Dactylorhin C | Butanedioic acid, 2-(beta-D-glucopyranosyloxy)-2-(2-methylpropyl)-, (2R)- | 46 |
| | Dactylorhin D | (2R, 3S)-2-β-D-glucopyranosyloxy-3-hydroxy-2-(2-methylpropyl) butanedioic acid 1-(4-β-D-glucopyranosyloxybenzyl) ester. | 46 |
| | Dactylorhin E | (3R)-5-methyl-3-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl) oxan-2-yl]oxy-3-[[4-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2yl]oxyphenyl]methoxycarbonyl]hexanoic acid | 46 |
| | Resveratrol | 5-[€-2-(4-hydroxyphenyl)ethenyl]benzene-1,3-diol | 48 |
| | Indole Alkaloids | | 48 |
| | Napthoquinone | naphthalene-1,4-dione | 48 |
| | Ascorbic Acid | (2R)-2-[(1S)-1,2-dihydroxyethyl]-3,4-dihydroxy-2H-furan-5-one | 48 |

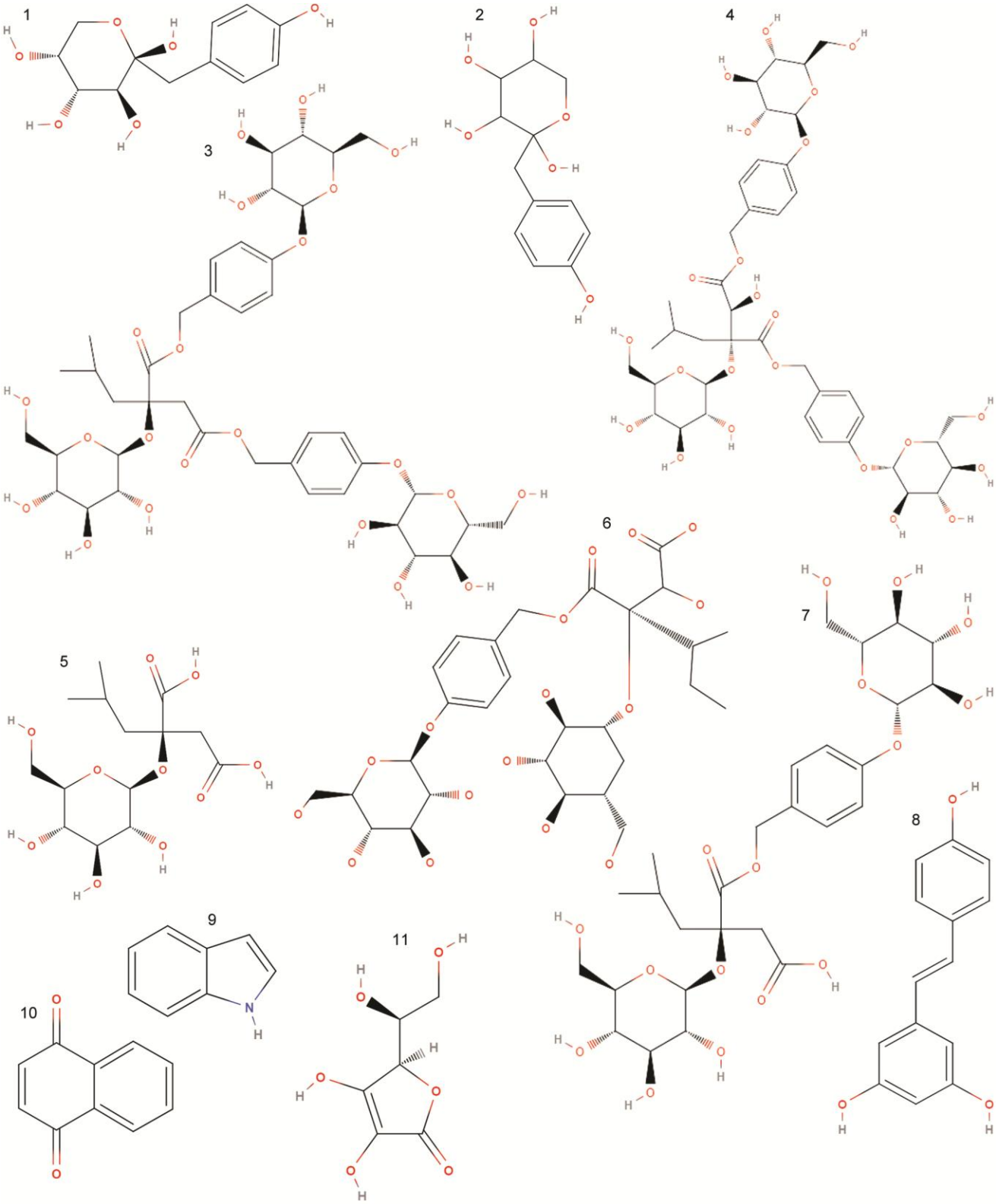


Fig. 3 — Chemical compounds of *Dactylorhiza hatagirea*. 1) Dactylose A; 2) Dactylose B; 3) Dactylorhin A; 4) Dactylorhin B; 5) Dactylorhin C; 6) Dactylorhin D; 7) Dactylorhin E; 8) Resveratrol; 9) Indole Alkaloids; 10) Napthoquinone; 11) Ascorbic Acid.

recent times. *D. hatagirea* is a high-value medicinal orchid with diverse ethnomedicinal usage and a broad range of phytochemicals with immense biological efficacy. Pharmacological activities of some selected phytochemicals with pharmacological studies of this plant are elaborated in this review.

***Anti-inflammatory properties***

Roots and rhizomatous parts of *D. hatagirea* have been proved to be effective against several ailments and diseases. Recent studies have revealed that hydroalcoholic extracts of roots were found to exhibit anti-inflammatory properties in rats, which justifies the use of this plant in the treatment of inflammatory diseases in the traditional system of medicine[51]. Similar studies[52,53] on tubers of this plant showed immense anti-inflammatory responses which was assessed in a rat paw oedema model induced by carrageenan and a cotton pellet granuloma model for acute and chronic inflammation. It was observed that hydroethanolic extract of *D. hatagirea* tubers showed better anti-inflammatory responses in Wistar rats as compared to standard (aspirin 100 mg/kg and Indomethacin 10 mg/kg).

***Antibacterial properties***

Studies have shown that rhizomatous part of *D. hatagirea* is more effective and possess antibiotic properties providing resistance against broad range of bacteria including both gram-positive (*Bacillus subtilis, Staphylococcus aureus*) and gram-negative (*Escherichia coli, Shigella flexneri, Pseudomonas aeruginosa*) bacteria, in contrast to the aerial part which has shown limited resistance against some of the bacteria[54]. Further, it is interesting to note that aerial part plant extract for *E. coli* and rhizome part extract for *S. flexneri* was very effective[55]. This finding suggests that the plant can be a possible source for sprouting newer antimicrobial compounds for treating dysentery and other stomach problems caused by *E. coli* bacteria. The antibacterial activity of root and shoot ethanol and methanolic extracts of *D. hatagirea* against *B. subtilis*, *S. aureus*, *E. coli*, and *P. aeruginosa* showed MIC at lower values[55]. Therefore, *D. hatagirea* antibiotic properties available in aerial and/or rhizome part exerting an antibiotic effect that is comparable to the available regimes of synthetic antibiotic medicines reflects its potential for use as effective antibacterial agent.

***Aphrodisiac properties***

Another significant study suggests that lyophilized aqueous extract of roots of *D. hatagirea* causes a significant anabolic effect in male albino rats which is comparable to testosterone treatment[40]. An increase in testosterone level has been associated with a moderate but significant increase in sexual desire as well. This study validates the effectiveness of this herb in improving as well as preventing the functionality of sexual organs and substantiates the belief of the traditional herbal system that this plant has aphrodisiac activity and may help improve sexual behaviour and performance.

## Propagation and multiplication

*D. hatagirea* has minute non-endospermic seeds, low viability, poor regeneration, pollinator specificity, and unique requirement of mycorrhizal association. These reasons make them difficult in cultivation through seed. Multiplication of *D. hatagirea* species has been done through splits and divisions of the tuber having stem portions with bud and the germplasm is very well maintained in Sikkim state forest nursery located at Kyongnosla in East Sikkim[56]. The *D. hatagirea* resorts to mycotrophy at maturity as it forms numerous pelotons in the roots, which harbour diverse fungal strains. It was found that peloton-forming fungi belong to the anamorphic genus *Ceratorhiza*. Its symbiotic association helps in seed germination and could be used potentially for the reintroduction and conservation of the orchid species[11]. Combination of 2-iP (0.5 mg/L) and BA (1.0 mg/L) showed better performance in terms of per cent survival, multiplication, and growth of proto-corms. Formation of protocorm and initiation of shoot meristem was observed in 70±5 days. Light and scanning electron microscopic studies were also performed to describe the stages of germination, development of shoot apex, and leaf primordia in a 225±3 days old protocorm[57]. However, the details of polyploidy evolution in *D. hatagirea* has been revealed by amplified fragment length polymorphisms (AFLP)[58].

## Conservation status

In India, the annual consumption of '*salep*' obtained from this species is about 7.38 tonnes, most of which is imported from other countries[59]. High market demand for this medicinal orchid has created a wide gap between the supply and demands of raw plant material of this species in West Himalaya where

the supply and demand are about 100 and 500 tonnes respectively[60]. The estimated annual trade of *D. hatagirea* is approximately 10 to 50 metric tons[61] with an economic value of US$ 68.88-89.54 $kg^{-1}$ of the dried tuber[62]. The Owing to high-value medicinal properties of *D. hatagirea*, the species has great demand in the national and international market[32] and each mg of dactylorhin E extracted from dried rhizome is priced at about US$ 311.49 (Sigma-aldrich, Merck KGaA, Darmstadt, Germany)[48]. Such a huge demand has led to continuous exploitation by indigenous healers from its natural habitat making substantial loss of the species. Therefore, the plant has been categorized as near endemic, critically endangered[63], rare[64] and listed as critically endangered species by the Conservation Assessment and Management Plan under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)[65] and threatened by International Union for Conservation of Nature (IUCN)[3]. The Government of Nepal has strictly protected and listed it as endangered species[66]. Recognition under these categories call for an urgent action plan for the conservation of this species.

A study revealed that the species shows high density in the open slope of the alpine region and low density in the open slope of the sub-alpine region of the Nepal Himalayan region due to significant anthropogenic impact on its habitat[67]. It has been found that the key cause of decline in plant species population is its narrow requirement of habitat[68]. The plant prefers to grow in shady moist habitat[69] suggesting its *in-situ* promotion for conservation. As the species prefer to grow in alpine and sub-alpine region, the tribals and nomads carry their livestock in high pasture lands during summer. Such temporal movement of livestock's puts huge pressure on the natural population of this orchid because of habitat destruction and overgrazing. Apart from that, unawareness about proper collection and propagation procedure[25], small population size[67,70], strong geographical isolation, harsh environmental conditions[71], high habitat specificity[72], exhibiting pollinator specificity and requirement for a mycorrhizal association, resulting in inherently slow growth and poor regeneration capacity[24] are also major factors for the decline of this species from its natural habitats[73] (Fig 4).

Since the plant is critically endangered, there is an urgent need for awareness among the local community to address the declining rate and conservation measures. In order to get a promising result of conservation and protection of this medicinal species, there is a need for collaboration and study of various dimensions of study including ecology, biology, social, cultural, and economics of the plant species[27]. For conservation and propagation, different methods including biotechnological, conventional, and plant tissue culture techniques could be used[11]. The plant can also be promoted for conservation by providing plantlets to local people and need to encourage plantations in their land as herb of immense medicinal importance.

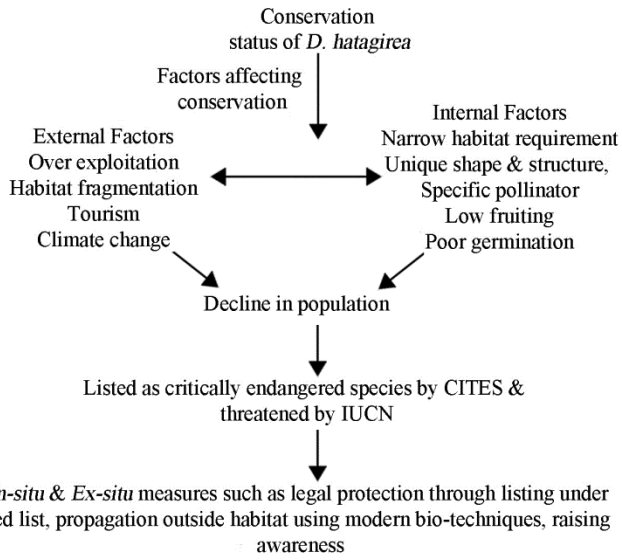


Fig. 4 — Schematic representation of the various factors affecting the conservation status of *D. hatagiera.*

## Conclusion and future prospects

D. *hatagirea* (D. Doon) Soo, is an important medicinal orchid having potential uses in traditional as well as modern medicinal systems. The plant is used by the indigenous people of Himalaya communities for the treatment of different ailments. The plant is rich in bioactive compounds whose pharmacological activities have been established. Owing to excessive use and exploitation, the population is on a decline. Therefore, there is an urgent need for awareness among the local community to address the declining population and adopt conservation measures through collaborative study of ecologists, scientists, and conservationists is required for better conservation of the plant species. This will in turn boost the pharmaceutical industries for the extraction of more active principles. However,

for this, there should be a systematic and scientific approach to grow *ex-situ* for extraction of compounds. The non-invasive methods of utilization of plants should also be formulated to minimize the damage of the plant. Biotechnological approaches including tissue culture techniques may also prove handy for rapid regeneration of plantlets for mass propagation and plantation. Cell and protoplast cultures may also be employed for the extraction of phytochemicals of the plant. The plant also requires a thorough investigation at the molecular level to study the change in genetic makeup leading to rapid decline in population. This will enable to devise of suitable strategies to protect the population from extinction. Government policies related to sustainable management of the plant species must be implemented taking into account the needs of the communities. The plant is of immense importance and requires attention from the scientific communities for conservation purposes and also possible approaches for future bioprospection to pool medicinal principles for the benefit of mankind.

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**Conflict of interest**

The authors have no conflict of interest to disclose.

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