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MEDICINALLY IMPORTANT ORCHIDS OF INDIAN HIMALAYAN REGION: PRESENT STATUS AND FUTURE PRIORITIES

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Abstract

Orchids, belonging to family Orchidaceae, hold highest position in the evolution of monocots and are well known for their beautiful long-lasting flowers and medicinal properties. The orchids exhibit tremendous medicinal properties due to the presence of a wide variety of chemical compounds; however, scientific advancement on most of the medicinal orchids remains largely unstated. The present paper provides an overview of some important medicinal orchids of Indian Himalayan region and suggests that extensive research is required for the characterization, commercial extraction, and purification of a wide range of biologically active compounds, present in orchids. More rigorous scientific validation of medicinal orchids is required, along with standardization of extract preparation method. This will stimulate herbal based novel drug discovery and will extend the scope of therapies using potential orchids of Himalayas. The present paper highlights various conservation issues/options along with the need for developing best package of practices for cultivation, mass multiplication, *in vitro* production of secondary metabolites, promotion of indigenous species for trade, and inventorization of orchid species both at the regional and national level. These efforts would be beneficial for the conservation of this unique group of plants for sustainable development of Himalayan communities.

Introduction

ORCHIDS BELONG to the family Orchidaceae and is represented by over 28,484 species in about 800 genera (Govaerts *et al.,* 2017). In India, around 1,256 species of orchids belonging to 155 genera are found, which are mainly distributed in Himalayas, North-East and Western Ghats, and a total of 388 orchid species are endemic to India (Singh *et al.,* 2019; Srivastava and Manjunath, 2020). However, numbers are expected to go up considerably once thorough explorations are carried out in remote regions. Orchids are well known for their floricultural and pharmaceutical values and also used in fragrance industries (De and Pathak, 2020; Devi *et al.,* 2018; Janakiram and Baskaran, 2018; Jhansi *et al.,* 2019; Pathak *et al.,* 2010; Prakash and Pathak, 2020). The entire orchid family is listed under Appendix I and II of CITES, and hence, there are some restrictions on international trade of orchid species (Hinsley *et al.,* 2018).

The Indian Himalayan Region, spreads over 11 states namely, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, Assam, West Bengal, and 2 union territories (Jammu and Kashmir and Ladakh), represents unique orchid biodiversity that attracts much attention since long. Several reports (Jalal and Jayanthi, 2015; Singh, 2015; Yonzone *et al.,* 2012) have enlisted different orchid species present in Himalayan states. A total of 960 orchid species are reported from the Indian Himalayan region (Samant and Pant, 2006) and the highest number of orchid species is recorded from Arunachal Pradesh (612 species), followed by Sikkim (560 species), Darjeeling-West Bengal (479), Meghalaya (446), Assam (293), Nagaland (376), Uttarakhand (238), Mizoram (287), Manipur (422), and Tripura (51) (Singh *et al.,* 2019). In the present paper, literature on some important medicinal orchids of Indian Himalayan region with immense therapeutic potential has been compiled, and bibliometric analysis was conducted to assess the recent research trends on medicinal orchids.

Material and Methods

The literature on important medicinal orchids of Indian Himalayan Region was searched on Google Scholar and Scopus databases. Various Ayurvedic products containing orchids were identified using different online Ayurvedic stores. For bibliometric analysis, literature published in English language was searched from the period of 1948 up to 2021. A standard database Scopus (www.scopus.com) was used to systematically identify peer-reviewed journal articles and books on medicinal orchids, using combination of keywords like medicinal, orchids, Himalaya, and Himalayan. For each publication, the information like journal name, authors names, title, year of publication, and publisher was retrieved. Based on the information available in the title, keywords, and abstracts, the articles were classified into the following broad research categories: biological activity, conservation, climate change, ecology, embryology, ethnobotany, genetics and molecular biology, habitat suitability, microbial studies, nutrient analysis, post-harvest, propagation/germination, quality

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inspection, primary metabolites, secondary metabolites, species discrimination, taxonomy, threats, uses, trade, and tourism.

Results and Discussion

Medicinal Importance of Himalayan Orchids

Based on the available literature, it was found that Himalayan orchids have been used since thousands of years for the treatment of different diseases like rheumatism, sciatica, neuralgia, insanity, heart problem, bone fractures, malaria, dysentery, tuberculosis, uterine diseases, hypertension, depression, epilepsy, obesity, asthma, inflammation, lung and liver diseases (Balkrishna *et al.,* 2020; Jalal *et al.,* 2008; Kumar *et al.,* 2018, 2019; Kumari and Pathak, 2020; Park *et al.,* 2020; Prakash and Pathak, 2019). They are also used in the preparation of *Chyavanprash*, a popular tonic with rejuvenating, aphrodisiac, and blood purifying properties. In Ayurveda, the ancient Indian system of health care, several orchid species are considered as medicinal. A rejuvenating herbal formulation called *Ashtavarga* which is derived from a group of eight vitality promoting and anti-ageing medicinal herbs, contains four orchid species of Himalaya namely *Crepidium acuminatum, Habenaria edgeworthii*, *H. intermedia,* and *Malaxis muscifera* (Handa, 1986; Hossain, 2011). Various other species mentioned in Ayurvedic system of medicine include *Acampe papillosa, Dendrobium monticola, Eulophia latifolia, Orchis latifolia*, *Vanda tessellata etc.* (Hossain, 2011).

Many recent reports have also highlighted the medicinal significance of orchids present in Himalayan region including Kashmir Himalayas (Shapoo *et al.,* 2013), Nagaland (Nongdam, 2014), Uttarakhand (Jalal *et al.,* 2008), and Arunachal Pradesh (Tsering *et al.,* 2017). Medicinal properties of these orchids are attributed to the presence of various secondary metabolites such as alkaloids, phenolics, and terpenoids which possess biological activities and are present in different plant parts (leaf, stem, seed, flower, and pseudobulb). Some of these compounds isolated from orchids include kinsenoside, moscatilin, bisbenzylgigantol, gastrodin, dihydrophenanthrene, ephemeranthoquionone, triterpenoids, bibenzyl derivatives, shihunidine, shihunine, dendrophenol, moscatin, denfigenin, defuscin, amoenumin, cypripedin, crepaditin, rotundatin, cumulatin, gigantol, orchinol, hircinol, jibantine, nidemin, loroglossin, dendrobine, nobiline, nobilonine, *etc.* (Joseph *et al.,* 2018; Khasim *et al.,* 2020). Some of the important medicinal orchids of Indian Himalayan region, their medicinal importance, phytochemical constituents, and biological activity are described in Table 1. Despite the rich diversity of medicinally important orchids in the Indian Himalaya, only a few species have been studied for their phytochemicals and biological activities, and very few are used commercially. Some commercially available ayurvedic preparations containing medicinally important orchids of Himalaya are given in Table 2. The photographs of some medicinally important orchids of Indian Himalayan region are shown in Fig. 1A-H.

Table 1. Medicinal uses, phytochemicals, and biological activities of Himalayan orchids.

Species	Traditional uses/ ailments cured	Phytochemicals	Biological activities
Acampe praemorsa (Roxb.) Blatt. & McCann	Stomachache, backache, earache, cough, wounds, neuralgia, rheumatism, eye diseases, sciatica, fracture (Vibha *et al*., 2019)	Saponin, terpenoid, tannin, glycoside, flavanoid, phenol, steroid (Suja and Williams, 2016)	Anticancer, antibacterial, antifungal, anti-inflammatory, antioxidant activities (Jhansi and Khasim, 2020; Vibha *et al.,* 2019)
Aerides odorata Lour.	Joint pain, swelling, wounds, tuberculosis, healing boils in nose and ear (Hossain, 2009)	Ascorbic acid, gallic acid, catechin, sinapic acid, methyl gallate, p-hydroxy benzoic acid, caffeic acid, syringic acid, ferulic acid, narigin, myrecetin, rutin, p-coumaric acid, quercetin, apigenin, and kaempferol (Prasad *et al.,* 2016)	Anticancer activity (Jhansi and Khasim, 2020; Katta *et al.,* 2019), antioxidant (Prasad *et al*., 2016), antimicrobial activity (Paul *et al.,* 2013)
Cymbidium aloifolium (L.) Sw.	Emetic, purgative (Hossain, 2009), tumors, nervous disorders, vomiting, diarrhea, vertigo, eyes weakness, paralysis (Ninawe and Swapna, 2017)	Simple sugars, alkaloids, tannins, flavonoids, anthraquinones, terpenoids, coumarins (Radhika *et al*., 2013), reducing sugar, saponin, steroid (Soumiya and Williams, 2018), leucoanthocyanins, anthocyanins, phlobatannins, glycosides (Bhowmik *et al.,* 2020) carbohydrates, alkaloids, coumarins (Shubha and Chowdappa, 2016), n-hexadecanoic acid, octadecanoic acid, 2-butyne (Rampilla and Khasim, 2020)	Antimicrobial, anticancer, anti-inflammatory, hypocholesteromic, nematicide, antiarthritic, anticoronary, anti-androgenic, diuretic, antitumour hypocholesteromic, nematicide, hemolytic, antipsychotic, antihistaminic, insectifuge, antieczemic, asphyxiant (Rampilla and Khasim, 2020),

Table 1. Medicinal uses, phytochemicals, and biological activities of Himalayan orchids (contd.).

Species	Traditional uses/ ailments cured	Phytochemicals	Biological activities
			antibacterial (Radhika *et al.,* 2013; Shubha and Chowdappa, 2016)
Dendrobium chrysanthum Wall. ex Lindl.	Antipyretic, eyes-benefiting, immuno-regulatory purposes, skin diseases (De *et al*., 2015a)	Flavonoids, alkaloids, phenolics, triterpenoids, glycosides, steroids and carbohydrates (Rao *et al*., 2020)	Anti-cancer, anti-tumor (De *et al.,* 2015b) antioxidant, hepatoprotective activity (Rao *et al*., 2020)
D. fimbriatum Hook.	Resetting of fractured bones (Shailajan *et al*., 2017)	Alkaloids, terpenoids, flavonoids, tannins, glycosides (Sinha and Biswas, 2020)	Antibacterial, antioxidant (Sinha and Biswas, 2020), hepatoprotective acticity (Shailajan *et al*., 2017)
D. nobile Lindl.	Pulmonary tuberculosis, general debility, flatulence, dyspepsia, reduced salivation, parched and thirsty mouth, night sweats, fever, anorexia (Singh and Duggal, 2009), eye infection, burnt, fever, stomachic, tongue dryness, nervous disorder, analgesic (Meitei *et al.,* 2019)	Mucilage, denbinobine, gigantol, dendroside A, dendronobilosides A and B, dendrobine, moscatilin, denbinobine, nobiline dendrophenol (Bhattacharyya *et al.,* 2014; Miyazawa *et al.,* 1997; Singh and Duggal, 2009; Suzuki *et al.,* 1973; Zhao *et al*., 2001)	Anti-mutagenic, antiphlogistic (Singh and Duggal, 2009) anti-ageing, antimicrobial, antioxidant (Meitei *et al*., 2019), antiviral (Li *et al*., 2017)
Flickingeria macraei (Lindl.) Seidenf.	Cooling, alterative, astringent to the bowels, stimulant, nervine tonic, aphrodisiac, expectorant, asthma, bronchitis, throat troubles, fever, burning sensations, biliousness, diseases of the eye and blood (Esha *et al*., 2016)	α and β jibantic acid, jebantine (Singh and Duggal, 2009) carbohydrates, coumarins, alkaloids, phytosterols, flavonoids, phenolics (Chimsook, 2016) denfigenin, defuscin (Esha *et al*., 2016)	
Habenaria edgeworthii Hook.f. ex Collett	Blood diseases, asthma, leprosy, skin diseases, general debility (Giri *et al.,* 2012a), cooling, spermopiotic (De *et al.,* 2015a)	Alkaloids, coumarin glycosides, phenolics (Sedai, 2015), sodium, riboflavin, thiamins, tannins (Rawat *et al*., 2014) habenariol (Giri *et al.,* 2012b)	Antioxidant, free radical scavenging activity (Rawat *et al.,* 2014)
H. intermedia D.Don.	Cooling, spermopiotic, blood purifier, skin diseases, cough, asthma, leprosy, gout, muscular pains, sprains, general debility (Khajuria *et al.,* 2017)	Alkaloids, phenols, thiamins, tannins, calcium, riboflavin cobalt (Rawat *et al.,* 2014) scopoletin, gallic acid (Habbu *et al*., 2012), alkaloids, carbohydrates, steroids, terpenoids, flavonoids, tannins, phenolics, sinapic acid (Virk *et al.,* 2020)	Antistress, antioxidant (Habbu *et al*., 2012)
H. plantaginea Lindl.	Chest pain, stomachache (Singh, 2018), snake bites, arthritis (De *et al*., 2015a) cough, asthma, helminthiasis, insanity (Keerthiga and Anand, 2015)	Alkaloids, flavanoids, tannins, phenolic compounds, phytosterols, saponins, glycosides (Keerthiga and Anand, 2015)	Antibacterial (Keerthiga and Anand, 2015)
Crepidium acuminatum (D.Don) Szlach.	Aphrodiasiac, styptic, antidysenteric, febrifuge, tonic, burning sensation, general debility, insect bites, tuberculosis, rheumatism (Sharma *et al*., 2011a)	â-sitosterol, pyromeconic acid, bibenzyls, 9,10-dihydrophenanthrenes (Kannan, 2008), alkaloids, glycosides, flavonoids, â-sitosterol, piperitone, citronellal, eugenol, limonene, 1,8-cineole, p-cymene, O-methylbatatasin, cetyl alcohol (Sharma *et al*., 2011a), fatty acids, tocopherol, terpenoids (Lohani *et al*., 2013), mucilage, starch, fats, calcium oxalate, lignins, protein (Arora *et al*., 2017), saponins, bitter principles, steroids, sterols, essential oils, anthraquinones, coumarin, flavonoids (Arora *et al*., 2018)	Antioxidant, analgesic, anti-inflammatory (Kannan, 2008), antimicrobial activities (Sharma *et al*., 2011b; Arora *et al*., 2017)

Table 1. Medicinal uses, phytochemicals, and biological activities of Himalayan orchids (contd.).

Species	Traditional uses/ ailments cured	Phytochemicals	Biological activities
Dactylorhiza hatageria (D.Don) Soo (*Orchis latifolia* auct. non L.)	Diabetes, diarrhea, dysentery, paralysis, convalescence, impotence, malnutrition (De *et al*., 2015a)	Dactylorhins A-E dactyloses A-B (Kizu *et al*., 1999; Wani *et al*., 2020), dactylorhin, ascorbic acid, butanedioic acid, dactyloses (Haruhisa *et al*., 1999; Thakur, 2019), butanedioic acid, hydroquinone, lesoglossin, militarrin, albumin, pyranoside, pyrocatechol, indole alkaloids, stilbene, resveratrol, saponins, ascorbic acid, phyllo- and naphthloquinones, glucomannan, carotenoids (Dhiman *et al*., 2019)	Antimicrobial (Avasthi *et al*., 2013), anti-inflammatory activity (Sharma *et al*., 2020)
Satyrium nepalense D.Don	Malaria, dysentery, Aphrodisiac (Jalal *et al.,* 2008)	Alkaloids, carbohydrates, Glycosides, flavonoids, unsaturated sterols, triterpenes (Mishra and Saklani, 2012), saponins, steroids (Kawra *et al*., 2020) reducing sugar, cardiac glycosides, anthraquinones, tannins, phlobatanins (Bhatnagar *et al*., 2017)	Antioxidant (Kawra and Saklani, 2020), antibacterial (Mishra and Saklani, 2012; Saklani *et al*., 2011), antimycobacterial and leishmanicidal activity (Bhatnagar *et al*., 2017)
Vanda roxburghii R.Br.	Hepatitis, dyspepsia, bronchitis, piles, rheumatism, diseases of nervous system, secondary syphilis, scorpion sting, boils, fever (Hossain, 2009)	Alkaloids, gigantol, flavonoids, tannins, ocimene, linalool, withanolides, glycosides, resin, saponin, fatty acids, alkyl perulate, sitosterols, heptacosane, octacosanol, acetyl tetracosylferulate, benzyl acetate, methylbenzoate, benzaldehyde, benzylalcohol, cinnamyl alcohol, methyl cinnamate, methyl salicylate (Mukhtar and Kalsi, 2017), anthocyanins, anthraquinones, coumarins, phalobatannin, (Biswas and Sinha, 2020)	Antimicrobial (Ahmed *et al*., 2000; Biswas and Sinha, 2020), analgesic, cholinesterase inhibitory activity (Uddin *et al*., 2015a, b)

Knowledge Gaps and Research Needs

A Scopus database was searched up to the year 2021 (limited by title-abstract-keyword), using keywords *medicinal and orchid* and *medicinal and orchid and Himalaya or Himalayan* which revealed a total of 373 hits and 47 hits, respectively. However, when a single keyword *orchid* was searched, a total of 9,814 hits were obtained. This indicated that although several studies have been done on orchids, medicinal orchids are very less investigated in spite of their enormous therapeutic importance. The results of the database search indicated that the total number of annual publications on medicinal orchids increased, especially after 2009

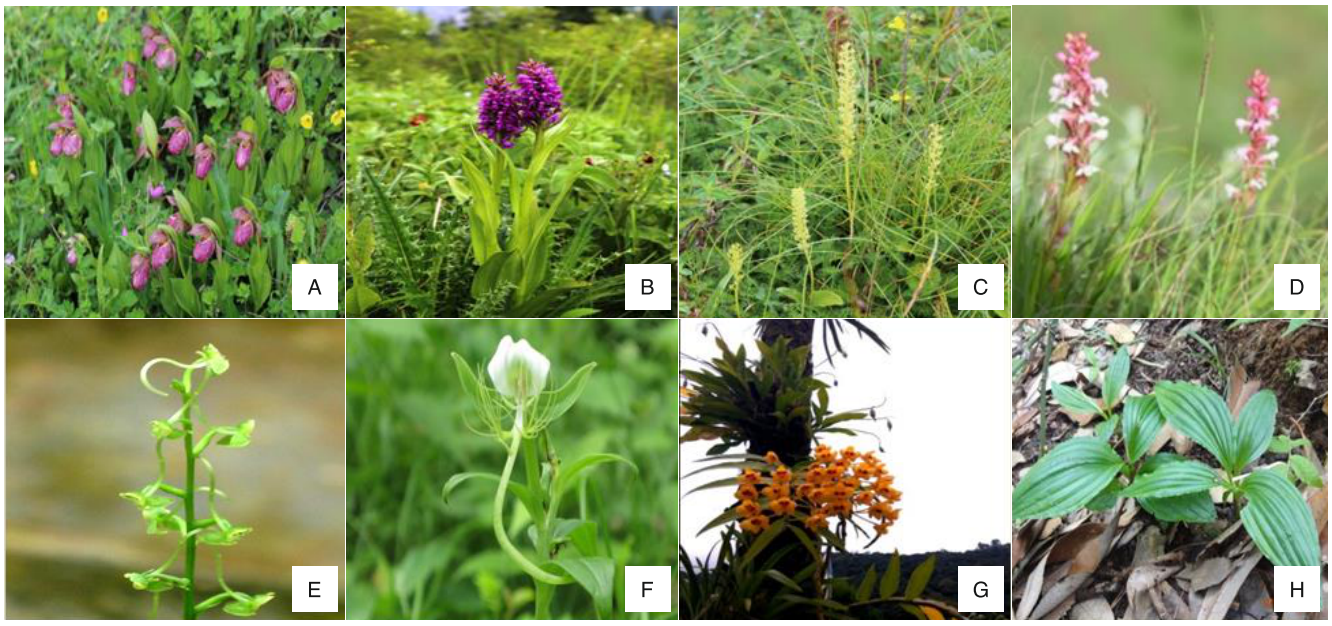

Fig. 1. A-H. Some medicinal orchids of India: A, *Cypripedium himalaicum*; B, *Dactylorhiza hatagirea*; C, *Malaxis muscifera*; D, *Satyrium nepalense*; E, *Habenaria edgeworthii*; F, *H. intermedia*; G, *Dendrobium* sp.; H, *Crepidium acuminatum*.

Table 2. Various ayurvedic preparations having medicinally important orchids of Himalaya.

Species	Ayurvedic Preparations	Ailments	Manufacturer
Flickingeria macraei (Lindl.) Seidenf.	*Anu Thailam*	Sinus congestion	Nagarjuna Ayurvedic Centre Ltd., Kerala
Habenaria edgeworthii Hook.f. ex Collett	*Chyavanprash*	Constipation, weakness, detoxification and boost immunity, heart health, improve digestion, and metabolism	Axiom Pharma Pvt. Ltd., Rajasthan
H. intermedia D.Don.	*Chyavanaprash*	Cough, dyspnoea, hoarseness, heart disease, brain tonic	Shree Baidyanath Ayurved Bhawan Pvt. Ltd., Dabur India Ltd.
	Mahanarayan oil	Relieves muscle pain, increases vitality, flexibility, circulation	Jaggi Pharmaceuticals, New Delhi
	Manasamitra Vataka	Psychiatric diseases, epilepsy, retarded intellect and improves memory	Nagarjuna Ayurvedic Centre Ltd., Kerala
Crepidium acuminatum (D.Don) Szlach.	*Chyavanprash*	Cough, dyspnoea, hoarseness, heart disease, brain tonic	Shree Baidyanath Ayurved Bhawan Pvt. Ltd., Delhi; Dabur India Ltd., Uttar Pradesh
	Manasamitra Vataka	Psychiatric diseases, epilepsy, retarded intellect, and improves memory	Nagarjuna Ayurvedic Centre Ltd., Kerala
	NG Herbal Face Pack	Prevents acne and pimples, exfoliates dead cells, tones skin, anti-ageing	Goodcare Pharma Pvt. Ltd., Uttarakhand
	Brhat Cagalyadi Ghrta	Epilepsy, burning sensation, bleeding diathesis, piles, dysuria	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Vidaryadi Kvatha	Cough, chronic obstructive jaundice/ chlorosis, astringent	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Brahma Rasayan	Nervous weakness, loss of memory, insomnia, mental exhaustion, high blood-pressure, headache, lung diseases, maintain heart efficiency	Dabur India Ltd., Uttar Pradesh
	Chyavanprash	Constipation, weakness, detoxification and boost immunity, heart health, improve digestion and metabolism	Axiom Pharma Pvt. Ltd., Rajasthan
Malaxis muscifera Lindl.	*Chyavanprash*	Cough, dyspnoea, hoarseness, heart disease, brain tonic	Shree Baidyanath Ayurved Bhawan Pvt. Ltd., Delhi; Dabur India Ltd., Uttar Pradesh
	Mahanarayan oil	Relieves muscle pain, increases vitality, flexibility, circulation	Jaggi Pharmaceuticals, New Delhi
	Manasamitra Vataka	Psychiatric diseases, epilepsy, retarded intellect and improves memory	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Brahma Rasayanam	Drowsiness, tiredness, weakness and maintain heart efficiency	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Brhat Cagalyadi Ghrta	Epilepsy, burning sensation, bleeding diathesis, piles, dysuria	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Vidaryadi Kvatha	Cough, chronic obstructive jaundice/ chlorosis, astringent	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Chyavanprash	Constipation, weakness, detoxification, boost immunity, heart health,improve digestion and metabolism	Axiom Pharma Pvt. Ltd., Rajasthan
Dactylorhiza hatageria (D.Don) Soo (*Orchis latifolia* auct. non L.)	*Aswagandhadi Leham*	Cough, asthma, tuberculosis	Vaidyaratnam Oushadhasala Pvt. Ltd., Kerala
	Rathina Pursh Capsules	Oligospermia, azospermia, and strengthens nervous system	SKM Siddha and Ayurvedha, Punjab

Table 2. Various Ayurvedic preparations having medicinally important orchids of Himalaya (contd.).

Species	Ayurvedic Preparations	Ailments	Manufacturer
Vanda tessellata (Roxb.) Hook. ex G.Don	*Manasamitra Vataka*	Psychiatric diseases, epilepsy, retarded intellect and improves memory	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Brhat Cagalyadi Ghrta	Epilepsy, burning sensation, bleeding diathesis, piles, dysuria	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Dasamula Rasayana	Cough, dyspnoea, rhinitis, impaired appetite, throat disease, chronic obstructive jaundice/chlorosis	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Kantakari Avaleha	Cough, dyspnoea, hiccough, colic	Dabur India Ltd., Uttar Pradesh
	Lasuairandadi Kasayam	Constipation, false tumor, hernia, abdominal disease	AVS Pharma, Haryana
	Nasta Puspantaka Rasa	Headache, irregular cycles, pain in the back and waist	Shree Baidyanath Ayurved Bhawan Pvt. Ltd., Delhi
	Rasnadi Churna	Sinusitis, disorder of head	Nagarjuna Ayurvedic Centre Ltd., Kerala
	Shadbindu Taila	Loose tooth, eye sight weakness, hair loss, disease of head	Shree Baidyanath Ayurved Bhawan Pvt. Ltd., Delhi
	Auromère Ayurveda Massage Oil	Effective for all types of massage and muscle treatment	Auromère Ayurvedic Imports, U.S.A.

(Fig. 2a). Similarly, the number of publications on Himalayan medicinal orchids was found to increase after 2013 (Fig. 2b).

Based on the information available in the title, keywords, and abstracts of 373 publications, the articles were classified into the following broad research categories: biological activity, conservation, climate change, ecology, embryology, ethnobotany, genetics and molecular biology, habitat suitability, microbial studies, nutrient analysis, post-harvest, propagation, quality inspection, primary metabolites, secondary metabolites, species discrimination, taxonomy, threats, uses, trade, and tourism. It was found that the major research areas of most of the publications on medicinal orchids were genetics and molecular biology (104) followed by propagation (64), biological activities (57), secondary metabolites (55), microbial studies (33), ethnobotany (30), conservation (26), ecology (11), and few articles on the remaining categories. Some newer disciplines like genetics and molecular biology have contributed greatly to the increasing number of papers appearing during the recent years (Fig. 2). Despite an encouraging increase in publications on medicinal orchids, more studies are required focusing on identification of various threats to orchids and different *ex situ* and *in situ* conservation approaches. Considering the research gaps, orchid research should be more focused on monitoring population trends and

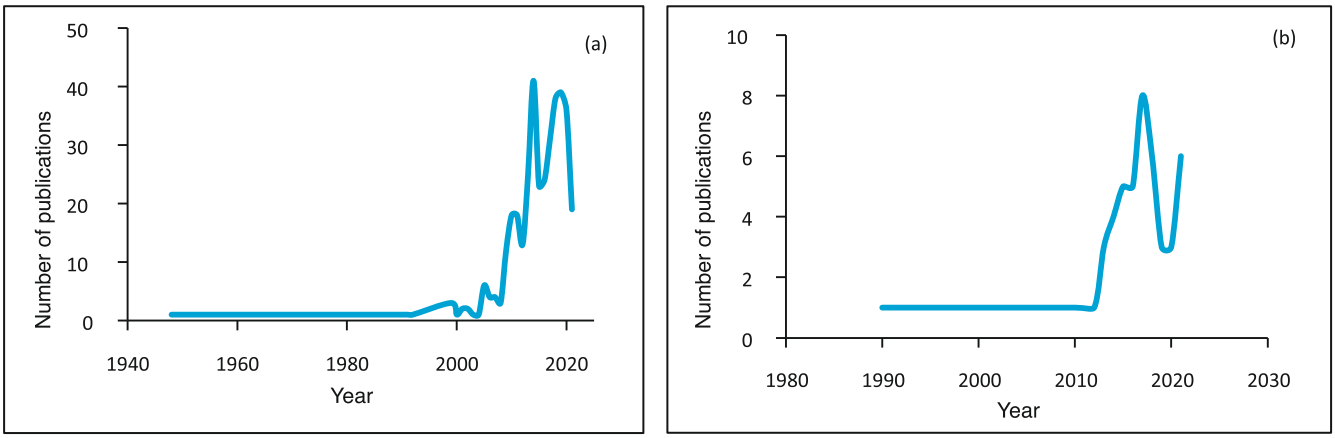

Fig. 2. a-b. Number of publications that integrate keywords: a, Medicinal and orchid; b, Medicinal and orchid and Himalaya or Himalayan.

distributions, management of species and their habitats, and increasing conservation education and awareness.

Strategies for Promoting Conservation and Sustainable Utilization of Orchids

Some of the strategies for promoting conservation and sustainable utilization of orchids are described below (Fig. 3).

Use of Biotechnological Tools for Mass Multiplication

Orchids are generally propagated by vegetative means as well as through seeds. Vegetative propagation of orchids is done by division and cutting, however, it is an extremely slow process. Propagation through seeds is also not suitable for orchids because of the minute and non-endospermic seeds, and the immature embryos at seed dispersal stage, which are responsible for reduced germination of orchids in nature (Bhowmik *et al.,* 2020; Gurudeva, 2019; Kaur *et al.,* 2017; Pathak *et al.,* 2017). Therefore, mass scale production of orchids could be effectively achieved through *in vitro* methods using plant tissue culture techniques (Lekshmi and Decruse, 2018; Madhavi and Shankar, 2019; Thakur and Pathak, 2020). Such methods help in sustainable production of quality planting material and also enable the conservation of valuable plant material for possible re-introduction and habitat restoration programs in future (Anuprabha and Pathak, 2019, 2020; Anuprabha *et al.,* 2017; Decruse and Gangaprasad, 2018; Vasundhra *et al.,* 2019). *In vitro* methods also allow the storage of propagules through two different methods: i) direct storage, where plant materials are transferred to growth chambers with various low temperature and light intensity; ii) development of synthetic seeds, where the plant materials are encapsulated by sodium alginate, using $Ca(NO_3)_2$ as gelling agent to develop synthetic seeds which are subsequently stored at various temperatures (Kaur and Pathak, 2014; Mondal and Banerjee, 2017; Pathak and Vij, 2005; Pehwal *et al.,* 2012; Verma and Pathak, 2021). Such *in vitro* methods are also used to increase the amount of high valued medicinally important secondary metabolites in orchids (Giri *et al.,* 2012a).

In Situ Conservation

The most ideal and economical way to conserve orchids is to conserve them in their original habitat (De and Pathak, 2018). Many protected areas have been established in the country, however only few protected areas are specifically created for orchids. Enhanced *in situ* orchid protection requires the creation of orchid reserves. Several Indian states have taken such initiatives for the protection of orchids in their natural habitats like Appangala in Karnataka and Loleyangaon in Darjeeling District of West Bengal have been declared as Orchid Reserves by their State Governments (Gurung and Gurung, 2016).

Ex Situ Conservation

In the current scenario of global climate change, *in situ* conservation techniques alone might not be sufficient to prevent the extinction of many orchid species (Barua *et al.,* 2019; Shapoo *et al.,* 2020). The goal of *ex situ* orchid conservation is to save the orchid

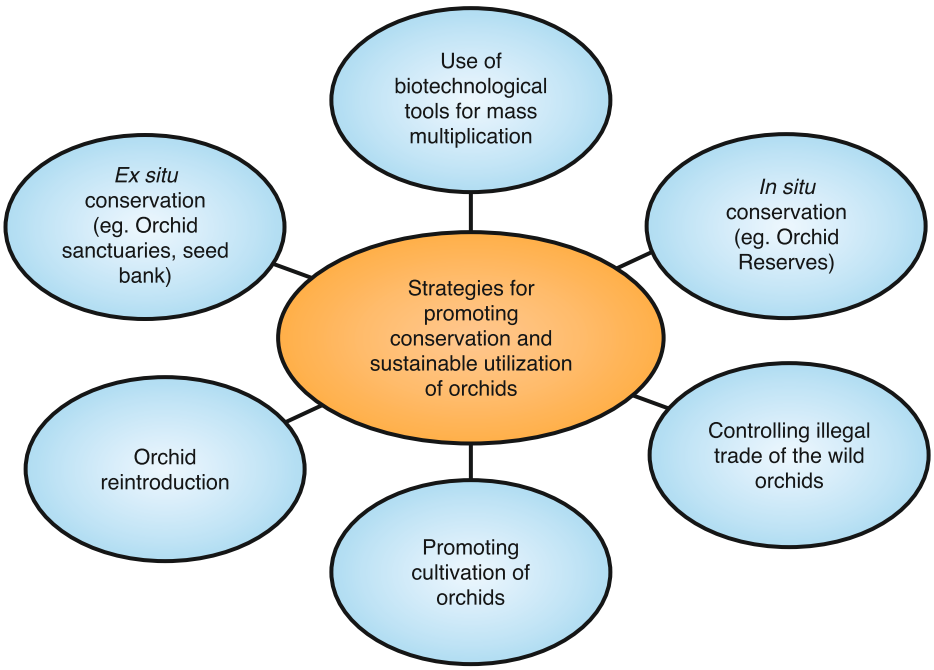

Fig. 3. Schematic representation of various strategies for promoting conservation and sustainable utilization of orchids.

species as they become extinct in their natural habitats. *Ex situ* method usually takes the form of a living collection in a collection garden such as in botanic gardens, as well as in universities and parks. Other *ex situ* strategies include orchid seed bank, germplasm banks, orchid repositories, *etc.* Orchid sanctuaries have been set up in Deorali and Singtam in Sikkim and Sessa in Arunachal Pradesh for *ex situ* conservation of orchids.

Reintroduction

Reintroduction is the release of individuals into a formerly occupied area after the native population has been lost (Reiter *et al.,* 2016). Reintroduction in conjunction with *in situ* habitat protection and *ex situ* conservation is recognised as a valuable tool for conservation. Orchid reintroduction using seedlings obtained from flasks or nurseries has been successfully done for some species like *Ipsea malabarica, Laelia cinnabarina, Paphiopedilum sanderianum etc*. (Irawati, 2013). Such type of orchid conservation strategies will also engage the community and raise public awareness for conservation.

Cultivation

Orchids occupy a significant position in floriculture which has emerged as a major international trade and thus immense scope exists for commercial cultivation of varieties of orchids for both domestic and international markets. However, there is a lack of proper information about their cultivation practices *i.e.* optimum congenial environment, soil preparation, planting and establishment, prevention of pests/diseases, harvest and post-harvest technologies *etc.* which must be worked out for promoting cultivation of orchids.

Controlling Illegal Trade

Orchids are amongst the plants most threatened by illegal trade (Ticktin *et al.,* 2020). Although, the majority of the global orchid trade consists of legal, greenhouse-grown flowers and plants, however, many orchid species are also harvested from the wild for local, regional and international trade, without the necessary harvest or trade permits. Thus, efforts should be made to reduce the illegal wildlife trade and to promote sustainable forms of trade.

Conclusion and Future Prospects

A large number of orchid species from the Indian Himalayan region possess strong medicinal properties and are being used traditionally to cure many ailments since time immemorial. A number of compounds have been isolated from these species which can be potential alternatives to conventional drugs that have many side effects. However, scientific validation of these medicinal orchids for the prevention and treatment of various health ailments and standardization of the method of preparation of herbal formulation along with evaluation of safety and efficacy is a fundamental requirement for promoting their use in health care system. Although the Himalayan orchids offer excellent medicinal properties, their natural populations are under high threat due to natural and anthropogenic pressures and the entire orchid family is listed under Appendix I and II of CITES. Thus, conservation of these plants through *in situ* and *ex situ* conservation approaches, reintroduction, and cultivation is required. Further, due to slow growing nature of these plants, poor propagation through seeds and poor availability of species in the wild for vegetative propagation, and multiplication, orchids should be promoted through non-conventional means like *in vitro* propagation or micropropagation techniques. These techniques should also be promoted to enhance production of pharmacologically important metabolites, present in orchids.

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