Biotechnological Interventions and Societal Impacts of Some Medicinal Orchids

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1 Introduction

Orchids are extremely fascinating plants that surpass all the plant groups in the "Plant kingdom." It belongs to the Orchidaceae family, which is the second largest as well as the highly advanced family among flowering plants. It encompasses approximately 850 genera and 35 thousand species (Stewart and Griffith 1995; Gutierrez 2010). Orchids are better known for their alluring, enchanting attractive floweret, which are extremely precious globally in floricultural trades. Orchids became the second most top-selling cut flowers as well as potted floricultural products due to their increasing demand in the globe for trading. Their aristocratic, adorable, and wonderful colors, sometimes-intricate forms, have enchanted men and women through the ages. Orchids lend a charming beauty with their extraordinary flower heterogeneity, in terms of size, shape, structure, number, density, color, and fragrance. Besides their adorning values, the orchids are also mentioned specially for their therapeutic medicinal properties as well as economic importance especially in the traditional pharmacopeias extensively since time immemorial (Withner 1959; Kaushik 1983). Earlier in China and Japan orchids were used as herbal medicine for different illnesses nearly 3000–4000 years ago, respectively (Reinikka 1995; Bulpitt 2005; Jalal et al. 2008).

Many species of *Vanda, Dendrobium, Habenaria, Malaxis, Cymbidium, Coelogyne, Cypripedium, Anoctochilus*, *Bletilla, Calanthe,* and *Cymbidium,* etc. are significantly important for having medicinal importance. Medicinal orchid

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plays an outstanding part in therapeutics with the presence of important phytochemicals such as alkaloids, flavonoids, carotenoids, sterols, saponins, anthocyanins, and polyphenols either in their pseudo bulb, tubers, leaves, stems, flowers, roots, or in the complete plant (Okamoto et al. 1966; Williams 1979; Majumder and Sen 1991; Majumder et al. 1996; Zhao et al. 2003; Yang et al. 2006; Singh and Duggal 2009). Several ailments like arthritis, tumors, fever, malaria, snakebite, scorpion bite, depression, tuberculosis, cervical carcinoma, diabetes, and biliousness, etc. are cured by medicinal orchids (Szlachetko 2001). These orchids were also employed as food and fodder, and local medicine by rural communities for their livelihoods and revenue generation. Moreover, uprooting the whole plant from its habitat for sale to the traders as well as over-exploitation by rural communities causes the extinction of many important orchid species (Kala 2004). Other than that native environment of many orchids is rapidly declining due to hefty desertification, habitat loss, urban sprawl, and usage of land for farming and cultivation. Therefore in medicinal orchids, it leads to a wide gap between booms and busts.

In recent years, in Western countries, the growing use of herbal medicine and its demand is increasing. Ultimately, this type of over-exploitation requisites an intense protection measure. But in situ or ex situ of medicinal orchids conservation in their natural habitat is not sufficient for propagation as their rate is low. Orchid seeds are small, have no endosperm, and require fungal pathogens to germinate; therefore, germination rates in nature are very low (Arditti 1992). It takes a long time to obtain the desired number of orchids through asexual reproduction by rhizomes, bulbs, or rooting branches. Hence, it needs proactive mass distribution and re-establishing them in nature. To meet their growing pressure and to reduce collection pressure on wild species, biotechnological approaches such as the plant tissue culture technique has contributed immensely to plantlets production on large scale and developed different protocols for rapid cloning of desired genotypes using various types of explants. This technique has come up as a key drive in the production of planting quality material for commercially and medicinally important orchids to fulfill the increasing demand and to reduce the collection pressure on wild orchids.

Under the above circumstances, biotechnological approaches enhance the in vitro propagation as well as conservation and mass multiplication of important medicinal orchids has raised high hopes by adopting asymbiotic seed germination, vegetative explants materials, artificial seed technology and secondary metabolites production, in vitro acclimatization of raised plantlets and their establishment in nature, etc. This chapter briefly endows the state-of-the-art information mediated on tissue culture with biotechnological interventions in some medicinal orchids through micropropagation, along with its societal impacts such as ethnomedicinal properties, phytochemistry, biological activities, and economics that being the need of the hour.

2 In Vitro Propagation

To establish a successful propagation of orchids explants type selection is the most crucial factor. Among the various vegetative explants materials, the leaf has been utilized as a potent and potential source of explants for the mass multiplication of orchids. Leaf has the viability for producing a large number of uniform plantlets from a single leaf or leaf segment through direct embryogenesis or organogenesis. Knudson (1922) explored the asymbiotic seed germination in orchids under the aseptic condition, which was the first feasible technique of in vitro propagation that formed the base of modern biotechnology (Knudson 1922). Later on, Rotor (1949) developed a method to culture *Phalaenopsis* using uni-nodal flower stalk cuttings but all credit goes to George Morel for developing a micropropagation technique for orchids at a large scale (Rotor 1949). Virus-free *Cymbidium* clones were obtained from in vitro shoot meristem culture (Morel 1960). Later on, Morel (1964) reported that it was possible to produce million of plantlets within a year using a single bud by frequent sub-culturing of protocorm-like bodies (PLBs) that motivated the orchid growers (Morel 1964). The present-day micropropagation in both basic and practical aspects is much more organized than it was in the beginning. Though shoot-tips have remained the most commonly used explants for propagating orchids, the regeneration potential of other explants like axillary buds, stem discs, inflorescence segments, floral stalks, leaves, leaf peels, perennating organs (pseudobulbs, rhizomes, tubers), and roots has also been utilized successfully (Vij et al. 2004; Arditti 2008).

2.1 Seed Germination

To produce firm seeds and flowers, it takes 5–10 years for an orchid plant. Orchid seeds are one of the most distinctive features of the Orchidaceae family. They are tiny, very small, and powdered, and are produced in large quantities, with 1300–4000,000 seeds per capsule (Harley 1951; Arditti 1961). Very fragile, relatively undifferentiated, and without endosperms or cotyledons, seeds are produced from the majority of orchid species (Mitra 1971).

Due to a lack of metabolic machinery and functional endosperm, the natural germination rate of orchid seeds is very poor. Only 0.2–0.3% germinates in natural conditions (Prasad and Mitra 1975). It is well known that the seeds of almost all orchids are entrusted to mycorrhizal fungi for germination in natural conditions. Symbiotic fungi have been extensively exhibited to induce seed germination in both terrestrial and epiphytic orchids for seedling development. But, asymbiotic seed germination has imparted a systematic way for the mass multiplication of orchids (Chen et al. 2022).

2.1.1 Asymbiotic Seed Germination

The ability of orchid seeds to germinate asymbiotically by in vitro means was demonstrated for the first time by Knudson in *Cattleya* species (Knudson 1922). Asymbiotic in vitro seed germination of orchids occurred by culturing immature ovules often known as either embryo, fruit, or pod (Fig. 1a–d). The germination potential of immature embryos was much better than that of mature ones and varied with their developmental stages. Due to pH, dormancy, and other metabolic factors, very young orchid oocytes cannot germinate and thus cannot form suitable explants (Withner 1953). During in vitro seed germination of orchids, the intermediate protocorm stage is followed by subsequent seedling development (Fig. 1e–f). A protocorm is a chlorophyll-like, hairy, and pear-like bulbous or oblong structure that originates from the apical or lateral suture of the seed coat and provides nutrients like cotyledons during embryonic development and subsequent seedling growth (Lee 1987). Protocorms have been inconsistently assessed as uniform callus structures or distinct shoots (Kanase et al. 1993). The protocorm-like body specified the orchids for the regeneration of multiple plantlets which is a blessing to the world floricultural market (Fig. 1g–j).

Asymbiotic seed germination of orchids was exploited for in vitro mass production of orchids with commercial and medicinal importance for conservation and ecorestoration. It was reported by several investigators from time to time.

Half strength of Murashige and Skoog (MS) medium (Murashige and Skoog 1962) were used for seed germination of *Bletia purpurea* (Dutra et al. 2008), *Coelogyne stricta* (Parmar and Pant 2016), *Cymbidium giganteum* (Hossain et al. 2010), *Cymbidium goeringii* (Gong et al. 2018*)*, and *Spathoglottis plicata* (Aswathi et al. 2017; Hossain and Dey 2013). Accordingly, *Cymbidium aloifolium* was germinated in 1.0 mg/L 6-benzylaminopurine (BAP) and 0.5 mg/L α-naphthaleneacetic acid (NAA) supplemented (Paul et al. 2019). However, a modified half-strength MS medium was tested for in vitro germination of *Dendrobium ovatum* (Shetty et al. 2015).

Six different media compositions for testing were examined for their effectiveness towards the growth of *Dactylorhiza hatagirea* (Warghat et al. 2014) and *Bletia purpurea* seeds in BM-1 (Van Waes and Debergh 1986); 1/2 MS, Vacin and Went modified (VW) medium (Vacin and Went 1949); Malmgren modified terrestrial orchid medium (MM) (Malmgren 1996) and Knudson C (KC) medium (Knudson 1946). *Dendrobium macrostachyum* seeds were accomplished on MS, VW, and KC medium having different accumulation, amalgamation of growth hormones, and other additives. Among them, VW basal medium tested with 0.5 mg/L BAP and 5 mg/L NAA was more acceptable for plantlet formation (Li et al. 2018). *Dactylorhiza hatagirea* was cultured on Heller and Lindemann (LD) medium (Warghat et al. 2014), MM, VW, MS, and KC media. Both MS and KC medium were examined for asymbiotic seed germination of *Eria bambusifolia (*Basker and Bai 2010*)*. MS, KC, and KC-modified Morel medium were used for *Satyrium nepalense* (Mahendran and Bai 2009) seed germination. Seeds from mature capsules

Fig. 1 In vitro micropropagation of *Cymbidium aloifolium*, (**a**) Mother plant, (**b**) Seed capsule, (**c**) In vitro seed germination, (**d**) Swelling of seeds, (**e**) PLBs formation, (**f**) Enlargement of PLBs, (**g**) Shoot formation, (**h**) Formation of shoot and root, (**i**) Shoot elongation, (**j**) Shoot multiplication, (**k**) Hardening and acclimatization, (**l**, **m**) Acclimatized plantlets ready for ecorestoration

of *Dendrobium trigonopus* were augmented in B_5, MS, and 1/2 MS with NAA, BAP, and bark powder for in vitro germination (Pan and Ao 2014). MS + 1.0 mg/L BAP + Phytamax™ were provided for seed germination of *Dendrobium aphyllum* (Hossain et al. 2013).

Vacin and Went (1949) medium was alone tested for seed germination of *Dendrobium parishii* (Vacin and Went 1949; Kaewduangta and Reamkatog 2011). Likely, on VW medium mature seeds of *Dendrobium lasianthera* were enhanced with the incorporation of different concentrations of peptone of 1, 2, and 3 gm/L (Utami et al. 2017). Mature seeds of *Cypripedium macranthos* were sown on hyponex-peptone (HP) medium that contained 1 μM NAA and BAP after sterilization (Shimura and Koda 2004). Mature capsules of *Ansellia africana* were tested on Vasudevan and Van Staden (2010) medium for seed germination in vitro (Vasudevan and Van Staden 2010; Bhattacharyya et al. 2017a). However, in vitro germination of *Dendrobium nobile* Lindl. (Bhattacharyya et al. 2014), *D. thyrsiflorum* (Bhattacharyya et al. 2015), *D. heterocarpum* (Longchar and Deb 2022), *Cymbidium iridioides* (Pant and Swar 2011), *C. kanran* (Shimasaki and Uemoto 1990), *Cypripedium debile* (Hsu and Lee 2021), and *C. macranthos* (Shimura and Koda 2004) was reported in MS medium of full strength. *Cymbidium iridioides* young pods were cultured on MS medium containing 1 mg/L of NAA and BAP (Longchar and Deb 2022). Immature seeds of *Cymbidium kanran* were inoculated on MS medium for shoot multiplication (Shimasaki and Uemoto 1990). Young pods of *Cymbidium iridioides* were cultured on MS medium having NAA (1 mg/L) + BAP (1 mg/L) for micropropagation (Pant and Swar 2011).

2.2 Micropropagation of Orchids Via Vegetative Explants Materials

In orchids, as a result of out crossing, heterozygous offspring were produced from seeds. Therefore, it is necessary to augment various vegetative parts of mature plants to validate micropropagation protocols in orchids. Georges Morel was the pioneer for culturing *Cymbidium* shoot tips and attained protocorm-like bodies (PLBs) from contaminated plants to regenerate mosaic virus-free plants (Morel 1960). He introduced the term "protobulb (PLB)" in his work published in the Bulletin of the American Orchid Society (Arditti 2010). At the same time, a number of orchid species have yielded fruitful results, including *Lycaste, Cattleya, Ondontoglossum, Dendrobium, Phaius, Miltonia*, and *Vanda* (Arditti and Ernst 1993).

Large-scale propagation of medicinal orchids through in vitro method, different vegetative explants sources such as shoot tip, axillary bud, leaves, nodal segments, and inflorescence were augmented through callus formation or PLB mediation or direct shoot bud formation as described below:

2.2.1 Shoot Tip Culture

To induce efficient clonal propagation of medicinal orchids, shoot tips have been efficiently cultured. It was first implemented in *Cymbidium* by Morel (Morel 1960). This technique enables the rapid propagation of *Vanda coerulea (*Seeni and Latha 2000*)*. Response of bud formation is obtained from the shoot tips in vitro and mature plants in a medium having 8.8 μM BAP and 4.1 μM NAA. For forming multiple shoots in *Vanda tessellate* BAP and NAA combination was found to be more effectual as compared to indole-3-acetic acid (IAA), NAA, and kinetin at single action (Rahman et al. 2009). Shoot primordium of *Doritis pulcherrima* was cultured for rapid propagation and regeneration of plantlets (Mondal et al. 2013). In VW medium, *Dendrobium* shoot tip was cultured containing 15% coconut water plus 10 ppm NAA for a rapid proliferation of PLB and plantlet formation as well as the growth of seedlings (Soediono 1983). Sixty days old *Dendrobium chrysotoxum* shoot tips was inoculated on MS + 0.1 mg/L NAA + 3% sucrose + 0.5 mg/L BAP for proliferation, shoot induction (Gantait et al. 2009).

2.2.2 Nodal/Internodal Culture

Dendrobium fimbriatum segments were conferred for shoot induction, and proliferation in MS + 0.2–0.5 mg/L NAA + 1.0–4.0 mg/L BAP (Huang et al. 2008). But MS medium with NAA and BAP at 17.76 μM recorded maximal regeneration (14.0 ± 0.47) of shoots (Paul et al. 2017). Stem nodes of *Dendrobium devonianum* cultured at MS + 0.01–0.5 mg/L NAA + 1.0–4.0 mg/L BAP for PLB and shoot induction and proliferation in vitro (Li et al. 2011, 2013a). 0.5–1.0 cm nodal segments excised with axillary buds from 4–5-month-old *Dendrobium chrysanthum* seedlings grown in vitro, half strength MS + 0.1 mg/L NAA + 6 mg/L BAP + 3% sucrose + 0.65% agar (Mohanty et al. 2013a).

Nodal explants of *Malaxis acuminata* were cultured on MS + sucrose (3% w/v) + 3 μM NAA + 3 μM BAP and resulted in well-developed plantlets with shoots and root growth (Arenmongla and Deb 2012). Young healthy nodal shoot segments from the newly grown branches of wild *Bulbophyllum odoratissimum* were taken and cultured on BAP (4.0 mg/L) and IBA (0.5 mg/L) fortified MS medium for producing maximum shoot proliferation (Prasad et al. 2021). Nodal cultures of *Ansellia africana* were tested in an MS medium supplemented with 5 μM NAA and 10 μM of meta-topolin (mT) for multiple shoot induction (Bhattacharyya et al. 2017a). Pseudo-stem segments of *Dendrobium nobile* with nodes (0.5–1 cm) was used as explants for induction of PLBs with varied concentration of thidiazuron (TDZ) for culture (Bhattacharyya et al. 2014). *Malaxis acuminata* internode cultures responded to MS + 0.5 mg/L NAA + 3 mg/L TDZ; MS + 0.5 mg/L NAA + 3 mg/L TDZ + 0.4 mM spermidine (spd); MS + 1.5 mg/L activated carbon (AC) + 4 mg/L IBA was used for shoot induction (Cheruvathur et al. 2010).

2.2.3 Leaf Culture

Leaves and leaf tips of young orchids were cultured in vitro for PLB initiation and shoot proliferation. Wimber (1965) showed the potential of *Cymbidium* leaves (Wimber 1965). Growth stimulation in the nutrient pool, donor axis location, and physiological age of the mother plant strongly determine the regeneration potential (Trunjaruen and Taratima 2018). Therefore, factors like growth hormones, medium nutrients composition, leaf part, leaf source (in vivo/in vitro), explants preparation, leaf maturity, etc. determine the efficiency of a leaf explants micropropagation protocol (Chugh et al. 2009).

The leaf base of Vandaceous orchids evinced greater proliferative potential than leaf tips (Na and Knodo 1995; Jena et al. 2013; Seeni and Latha 1992; Nayak et al. 1997). Younger leaves perform better than older leaves. Leaves of mature *Vanda coerulea* did not respond to bud formation or PLB in vitro (Seeni and Latha 2000). Whereas, mature plants of *V. spathulata* (L.) Spreng the regeneration potential of leaf explants was noticed with 28.5 μM IAA + 66.6 μM BAP medium (Mitra et al. 1976).

2.2.4 Axillary Bud Culture

Axillary bud culture also played a very important role in medicinal orchid micropropagation. *Cymbidium elegans*'s axillary buds were responsive to PLBs formation (Pant and Pradhan 2010). Axillary bud culture of *Dendrobium longicornu* was tested in MS medium with 0.8% agar + 3% sucrose + 5 μM NAA and 15 μM BAP (Dohling et al. 2012). In *Cypripedium formosanum* a quarter concentration of MS medium containing 22.2 or 44.4 mM BAP was sufficient to propagate 6.3 and 7.1 shoots per explant with an average length of 10.6–11.7 mm to produce cultures after 90 days (Lee 2010). Five species of *Dendrobium* (*D. crumenatum*, *D. fimbriatum, D. moschatum, D. nobile,* and *D. parishii*) induced multiple shoots when axillary buds were cultured in vitro (Sobhana and Rajeevan 1993). Field-grown axillary buds of *Lycaste* hybrids were grown in half-strength MS basal medium supplemented with 0.5 mg/L BAP and 1.0 mg/L TDZ and 2% (w/v) sucrose (Huang and Chung 2011). Six to seven millimeter long shoot tips of *Aranda* Deborah hybrids grown in VW medium supplemented with coconut water (20% v/v) produced an average of 2.7 PLB after 45 days (Lakshmanan et al. 1995).

2.2.5 Pseudobulb Culture

The pseudobulb of *Coelogyne cristata* was cultured with basal medium + BAP (1–10 mg/L) + kinetin (1–10 mg/L) alone and in combination with NAA (1–10 mg/L). In parallel sets of experiments, 0.2% AC was used in the medium for shoot multiplication (Sharma 2021); 6-BAP (2.0 mg/L) + NAA (0.5 mg/L) induced shoot proliferation in *C. flaccid* (Parmar and Pant 2016). The pseudobulb of *Malaxis acuminata* was cultured on MS + 1.0 mg/L BAP + 1.0 mg/L NAA + 2.0 g/L AC for PLB formation (Suyal et al. 2020).

2.2.6 Flower Bud Culture

Ascofinetia, Neostylis, and Vascostylis were the first species to culture the young flower buds or inflorescence for medicinal orchid micropropagation (Intuwong and Sagawa 1973). Similarly, *Phalaenopsis*, *Phragmipedium,* and *Cymbidium* were also cultured equivalently (Kim and Kako 1984). The floral buds were exposed to either higher auxin levels or higher cytokinin levels and anti-auxin levels (Zimmer and Pieper 1977; Tanaka and Sakanishi 1978; Reisinger et al. 1976). Younger floral buds or inflorescence were more responsible than the matured ones in terms of shoot or PLB proliferation in *Oncidium Gower Ramsey*, *Phalaenopsis capitola*, *Dendrobium Miss Hawaii*, *Ascofinetia (*Intuwong and Sagawa 1973*;* Mitsukuri et al. 2009*;* Nuraini and Shaib 1992*).*

2.2.7 Root and Rhizome Segment Culture

The in vitro root culture was so far attempted with success in a few species of medicinal orchids. The capacity of orchid root to induce shoot regeneration was very low as reported earlier (Kerbauy 1984). Thereafter roots of *Catasetum*, *Cyrtopodium*, and *Rhyncostylis* were utilized to regenerate plantlets a very high proliferation rates (Kerbauy 1984; Sanchez 1988; Sood and Vij 1986). Root tips excised from *Vanda* hybrids and *Rhyncostylis* were cultured in 1.0 mg/L IAA, 1.0 mg/L BAP and 200 mg/L of casein hydrolysate for a speedy shoot proliferation rate (Chaturvedi and Sharma 1986). Rhizome of *Cymbidium goeringii* responded to MS + 0.2% (w/v) AC, 3% (w/v) sucrose, 0.2% (v/v) coconut water, and 0.8% (w/v) agar powder (Park et al. 2018). Moreover, auxin, particularly NAA was responsible for stimulating rhizome formation of some medicinal orchids and ultimately new shoots were developed from a rhizome in a cytokinin-enriched medium of *C. kanran* Makino (Shimasaki and Uemoto 1990), *C. forrestii* (Paek and Yeung 1991), and *Geodorum densiflorum* (Roy and Banerjee 2002).

Rhizome tips were also tested for PLB formation and shoot development (Udea and Torikata 1972). In a few cases, cytokinins were inductive for stimulation of shoots from rhizome segments of medicinal orchids such as *Cymbidium forrestii (*Paek and Yeung 1991*)* and *Geodorum densiflorum* (Lam.) Schltr. (Roy and Banerjee 2002; Sheelavantmath et al. 2000). Sometimes BAP was responsible for the reduction of rhizome growth and branching but induced certain rhizome tips gradually into shoots (Paek and Yeung 1991).

2.2.8 Thin Cell Layer Culture

Longitudinal or transverse sections of the thin cell layers are isolated from different plant parts such as leaves, floral primordia, stems, or PLBs. The efficiency of normal plant tissue culture and thin cell layer culture techniques is compared very methodically (Rout et al. 2006). In vitro raised seedlings of *Dendrobium chrysotoxum,* cross-section (2 mm thickness) of stem-nodes is grown in MS medium (semi-solid and liquid) supplemented with BAP 4.44 μM and Kinetin 4.65 μM induced shoot buds (Kaur 2017).

2.2.9 Protoplasts Culture

Different explants of orchids like stem, root, leaf disc, petal, and protocorm were used for the isolation of protoplasts. Chris K. H. Teo (Malaysian scientist) and K. Neumann (German botanist) first introduced the induction and synthesis of orchid protoplasts (Teo and Neumann 1978a, b). Since then studies were carried out in this field for the isolation of orchid protoplasts. However, during the screening of more than 24 orchid species, from bases of juvenile leaves of medicinal orchid *Cymbidium aloifolium* protoplast culture was achieved (Seeni and Abraham 1986).

2.3 Root Induction

Concentrations of different auxins were incorporated into basal media either singularly or in combination for testing their root-promoting efficiency in medicinal orchids. For root induction of *Dendrobium fimbriatum* with 100% rooting frequency, MS + 0.5 mg/L NAA or 0.3–1.0 mg/L IBA and a combination of 0.5 mg/L IBA and NAA were used (Huang et al. 2008). IBA, IAA, and phenolic elicitor PG containing MS medium were responsible for root induction of *Ansellia africana* within 6 weeks interval (Bhattacharyya et al. 2017a). IBA was responsible for root promotion of medicinal orchids viz., 1.0 mg L/1 IBA in *Acampe praemorsa* (Nayak et al. 1997) and *Cymbidium iridioides* (Pant and Swar 2011), and 1.5 mg L/1 IBA in *Dendrobium densiflorum* (Pradhan et al. 2013).

A decline in root number and length was reported with increased concentration of IBA. In *Dendrobium nobile*, IBA was better than NAA in maximizing root numbers (Asghar et al. 2011). MS + 3% sucrose + 2 g/L AC + 0.2 mg/L IBA was used in *Dendrobium chrysotoxum* (Gantait et al. 2009). Whereas, in the root formation of *Vanilla planifolia* and *Geodorum densiflorum*, NAA exhibited a conducive effect (Sheelavantmath et al. 2000; Tan et al. 2011).

In *Dendrobium transparens* (Sunitibala and Kishor 2009) and *Dendrobium primulinum* (Pant and Thapa 2012) supplementation of IAA increased the rate of root proliferation whereas its affectivity was poor during root formation. However, rooting of *Vanda spathulata* shoots was observed within 3–9 weeks in a medium containing 75 g/L banana pulp and 5.7 μm IAA. In vitro shoots of 2–5 cm in length developed two to five roots easily in pots at 80–90% survival rates instead of hardening (Decruse et al. 2003).

2.4 Photoperiodic Condition

In vitro seed culture and micropropagation of medicinal orchids were influenced by ambiance conditions, like photoperiod (PP) for efficient early culture development.

Cool white light, 16/8-h PP, 1000 lux light intensity, 25 ± 2 ° C, and pH 5.2 have been reported for *Dendrobium moschatum* (Kanjilal et al. 1999). Fluorescent light, 12/12-h PP, 60 μL mol m^{-2} s^{-1}, 25 ± 2 °C was provided in *D. parishii* (Kaewduangta and Reamkatog 2011). *D. trigonopus* was probably supplemented with 14/12-h PP, 25 ± 2 °C, 50 μL mol m^{-2} s^{-1} (Pan and Ao 2014). In *D. aphyllum* provide 14/12-h PP, 60 μL mol m^{-2} s^{-1}, cool white fluorescent, 25 ± 2 °C (Hossain et al. 2013). 1000–1500 lux, 12/12-h PP, white fluorescent tube, 25 ± 1 °C extended to *D. candidum* (Zhao et al. 2008). 50 μL mol m^{-2} s^{-1}, 12/12-h PP, 25 ± 2 °C was furnished in *D. chrysanthum* (Mohanty et al. 2013a). In *D. chrysotoxum* 16/8-h PP, 30 μL mol $m^{-2}s^{-1}$, white fluorescent tube, 60% RH, 25 ± 2 °C was supplied (Gantait et al. 2009). Originally, 25 ± 2 °C in the dark for 2 weeks, 23 μL mol $m^{-2}s^{-1}$ 25 ± 2 ° C, 16/8-h PP, (callus + PLB) was described in *D. crumenatum* (Kaewubon et al. 2015). 350–500 lux 16/8-h PP, 25 ± 2 °C was supplied in *D. densiflorum* (Pradhan et al. 2013). 1500–2000 lux, 12/12-h PP, 25 ± 2 °C and pH 6.0 was suitable for *D. devonianum* (Li et al. 2011, 2013a). Cool white fluorescent tubes, 12/12-h PP, 40 μL mol m^{-2} s^{-1}, 25 ± 2 °C were used in *D. draconis* (Rangsayatorn 2009). 2000 lux, 12/12-h PP, 25 °C and pH 5.4–5.6 was reported in *D. fimbriatum* (Huang et al. 2008). Cultures of *Ansellia africana* were maintained in cool white fluorescent tubes in a culture room with a light intensity of 40 μ mol m^{-2} s^{-1} at 25 ± 2 °C under a dark and light cycle of 12 h (Bhattacharyya et al. 2017a). *D. fimbriatum* was cultured under a photoperiod of 14 h with a light intensity of 50 μ mol m^{-2} s^{-1} using cool-fluorescent tube lights, at 25 ± 2 °C (Paul et al. 2017).

2.5 Hardening and Acclimatization

Hardening and acclimation of in vitro cultured plantlets are important steps of micropropagation for better survival and successful plant establishment under ex vitro conditions. The percentage of plant loss or damage is higher during the transfer of in vitro growing plants to ex vitro conditions. Regenerates have to adapt to many abnormal conditions such as high irradiance, low humidity, and water hydraulic conductivity of the root and root-stem connections in an ex vitro environment (Fila et al. 1998). Acclimatization of regenerates with gradually reducing humidity will overcome this threat (Bolar et al. 1998).

Well-rooted micropropagated orchid plantlets were ready for acclimatization after attaining sufficient growth in terms of root or shoot length. After removal from flasks, the well-rooted plants were cleaned thoroughly to remove the remnant of artificial media such as sucrose and nutrient agar. Thereafter, clean plantlets were soaked in an effective fungicide solution before shifting them into pots or poly sleeves having a potting mixture. The blending of various potting mixtures plays an important part in the survivability of orchid plantlets raised in vitro. A combination of the potting mixture was pounded of dried coconut husk or coco peat, tiny pieces of tree cortex, peat moss or sphagnum moss, and pieces of broken bricks or charcoals in various ratios. The ideal potting mixture should have water retaining capacity along with draining out of extra water and aeration for proper hardening and acclimatization of plants (Diaz et al. 2010; Kang et al. 2020) (Fig. 1k–m).

Brick pieces and charcoal chunks (1:1) mixture were fruitful for acclimatization of *Dendrobium chrysanthum* with a topmost cover of moss (Mohanty et al. 2013a). Plantlets of *Dendrobium moschatum* were shifted for hardening to a blending of charcoal, brick, coal, sand, and soil (1:1:1:1:1) with 48% survivability (Kanjilal et al. 1999). Rooted shoots of *Dendrobium macrostachyum* were provided with a perlite and peat moss mixture and kept in the green house for acclimatization (Li et al. 2018). In the mixture of coco peat, litter, and clay in the ratio of 2:1:1 with a covering of sphagnum moss *Cymbidium aloifolium* plantlets were acclimatized with an 85% survival rate (Pradhan et al. 2013). Acclimatization was carried out for hardening plantlets of *Dendrobium draconis* and shifted to cocopeat and perlite (1:1) composition with 92% achievement (Rangsayatorn 2009). In *Coelogyne cristata, the* composition of pine bark, brick, moss, and charcoal pieces (1:1:1:1) was used for transplanting (Sharma 2021). In *Coelogyne finlaysonianum*, brick, charcoal, coco peat and litter (1:1:1:1); brick, charcoal, litter, and saw dust (1:1:1:1); brick, charcoal, and litter (1:1:1); and brick and charcoal (1:1) were utilized for survival (Islam et al. 2015). A mixture of humus and sand (1:1) was tested in *Changnienia amoena* (Jiang et al. 2011). A composition of brick, charcoal, coconut husk, and sand (1:1:1:1) was provided for acclimatization of *Spathoglottis plicata (*Grell et al. 1988*)*. In *Cymbidium iridioides*, plantlets were acclimatized by using cocopeat, peat moss, and brick (Pant and Swar 2011). In the ratio of 1:1:1 substrate of brick, charcoal, shredded bark, and a moss cover were imparted for the survivability of *Dendrobium longicornu* in a greenhouse (Jaime et al. 2015). *Eria bambusifolia* was tested on coconut husk, charcoal, brick pieces, broken tiles, and perlite (Basker and Bai 2010). Hardening plantlets of *Satyrium nepalense* were transferred to a 1:1:1 ratio of a mixture containing vermicompost, sand, and coconut husk in plastic pots (Mahendran and Bai 2009). *Rhynchostylis retusa* was adapted in small plastic pots containing (2:1) moss and bark (Naing et al. 2010). *Cypripedium macranthos* was hardened in a plastic bag that contain wet vermiculite and acclimatized in a soil mixture of coarse volcano ash and clay granules (Shimura and Koda 2004). *Dactylorhiza hatagirea* was survived in a potting mixture consisting of (1:1:1) cocopeat, vermiculite, and perlite (Warghat et al. 2014). Rooted plantlets of

Dendrobium lasianthera were planted in a composition of coconut husk and sphagnum moss (3:1) and achieved a 90% survivability rate (Utami et al. 2017). In vitro rooted *Ansellia africana* plantlets were tested with a mixture of vermiculite, sand, and decaying litter (1:1:1) and found 87% survivability after 60 days (Bhattacharyya et al. 2017a). *Dendrobium nobile* plantlets were acclimatized with various compositions of mixture viz., (1) charcoal and bricks in the ratio 1:1; (2) in the ratio 1:1 of decaying litter and brick; (3) in the ratio 1:1:1 of brick chips, leaf litter, and charcoal; and (4) brick chips, leaf litter, and charcoal in the ratio 1:1:1 in addition to the topmost coating of moss. Among various compositions brick, charcoal, and decaying litter treatment as well as moss covering received the highest 84.3% survivability (Bhattacharyya et al. 2014). Composition of (a) brick and charcoal (1:1) (b) brick and coco peat in the ratio 1:1 (c) coco peat, brick, charcoal pieces in the ratio 1:1:1; and (d) leaf mold, brick chips, and cocopeat in the ratio 1:1:1 were supplied for transplantation of *Bulbophyllum odoratissimum* in Green house condition with 90% relative humidity (RH) and 91.66% survival rate. Among the different treatments, brick chips, charcoal, and coco peat (1:1:1) containing the mixture was best for high water retention as well as good aeration capacity (Prasad et al. 2021).

3 Ecorestoration

Ecosphere restoration is the "task reconstructing of an ecosystem that has been damaged due to manmade catastrophe" (Libini et al. 2008). The main objective of restoration is to re-establish the environmental system that is disturbed by various factors with respect to its structure and functional properties.

After successful acclimatization, in vitro-raised *Vanda coerulea* plantlets were transferred to tree trunks of forest segments, for successful ex situ harbor by using the binding medium like moss and coconut husk with 70–80% survivability rate for ecorestoration. Such a study commencing in India for restoring the natural habitat is of great interest from a horticultural and conservation point of view (Seeni and Latha 2000). Similarly, *Epidendrum ilense* and *Bletia urbana* were also shifted to the forest ecosystem or typical natural habitat for ecorestoration (Christenson 1989; Rublo et al. 1989). During the lab to land transfer strategy, it was observed that host trees with rough bark were selected and the in vitro-raised orchids were fixed either to the tree trunks with the roots or tree bark for ecorestoration efforts (Decruse et al. 2003; Aggarwal and Zettler 2010; Aggarwal et al. 2012; Gangaprasad et al. 1999; Grell et al. 1988; Kaur et al. 2017). Micropropagated plantlets of *Smithsonia maculate* showed 48% survival after one year reinforced at Karamana river of Peppara Wildlife Sanctuary, Kerala, India. The pilot trial on restoration through micropropagation was useful for further reintroduction and population enhancement for the practical conservation of this orchid (Decruse and Gangaprasad 2018). In vitro rooted plantlets of *Vanda spathulata* were observed with a 50–70% survival rate, which were introduced into forest segments at Ponmudi and Palo de in the Southern Western Ghats of India (Decruse et al. 2003).

The reintroduction trials of orchid plantlets should be conducted with well-established in vitro-rooted plantlets during the monsoon period to corroborate the maximum survival rate of the plantlets for ecorestoration or eco-rehabilitation study.

4 Artificial Seed Technology

The concept of artificial or synthetic seed was first coined by Murashige and at present it is well known by some different names such as manufactured seed, synthetic seed, or synseed (Murashige 1977). Artificial seeds were originally defined as "encapsulated single somatic embryos" by Murashige (1978), i.e., a clonal product that can grow into plantlets at in vitro or ex vivo conditions if used as real seeds for sowing, storage, and transport (Murashige 1978). Gray and Purohit (1991) also define somatic embryos with practical usage in commercial plant production (Gray et al. 1991). Therefore, the production of synthetic seeds has previously been restricted to those plants where somatic embryogenesis has been reported. Although somatic embryogenesis is restricted to selective plant species, to overcome this limitation, exploration of a suitable alternative to somatic embryos, i.e., non-embryogenic vegetative propagules like shoot tips, segmental/axillary buds, protocorm-like bodies (PLBs), organs or embryogenic callus is practiced (Ahmad and Anis 2010; Ara et al. 2000; Danso and Ford-Llyod 2003).

However, artificial/synthetic seeds or beads production was reported first time by Kitto and Janick (Kitto and Janick 1985). Since then, several flowering plant species have extensively utilized this technique including orchids. Production of synthetic seeds opens a new vista in plant tissue culture technology by adding many fruitful improvements on a commercial scale. Artificial seeds were utilized for transformation into plantlets under in vitro and in vivo circumstances. It was applied for the multiplication of rare, threatened, and endangered plant species which are hard to propagate by normal propagation process and by natural seeds.

Synthetic seed production in orchids is especially important as they produce minute non-endosperm seeds. Corrie and Tandon (1993) have used protocorms to produce synthetic seeds of *Cymbidium giganteum* which are transferred to a nutrient medium or sterile sand and soil medium developed healthy seedlings (Corrie and Tandon 1993). Comparable conversion frequencies of 100%, 88%, and 64% were obtained on in vitro, sand, and sand-soil mixture condition, respectively. These observations enable the direct transplantation of aseptically grown protocorms into the soil as well as reduce the cost of growing plantlets in vitro and subsequent acclimatization. As orchids produce tiny and non-endospermic seeds, the production of artificial seeds was beneficial.

Several reports on encapsulation using somatic embryos have been carried out (Ara et al. 2000; Danso and Ford-Llyod 2003; Castillo et al. 1998; Ganapati et al. 1992). For synthetic seed production, meristematic shoot tips or axillary buds were also utilized in orchids along with somatic embryos or PLBs (Ganapati et al. 1992; Bapat et al. 1987; Piccioni and Standardi 1995). Encapsulation of PLBs is well reported in many orchids such as *Cymbidium giganteum*, *Dendrobium wardianum*, *Dendrobium densiflorum*, *Phaius tonkervillae*, and *Spathoglottis plicata* (Danso and Ford-Llyod 2003; Saiprasad and Polisetty 2003; Vij et al. 2001).

In *Dendrobium* orchid, Saiprasad and Polisetty found that fractionated PLB was best suited for encapsulation at leaf primordia stage 13–15 days after culture (Saiprasad and Polisetty 2003). Encapsulation matrices prepared with MS medium (3/4 strength) + 0.44 μMB BAP + 0.54 μM NAA result in 100% conversion of encapsulated PLBs when cultured on MS medium + 0.44 μMB BAP + 0.54 μM NAA (*Dendrobium*). Sarmah et al. (Sarmah et al. 2010) production of synthetic seeds in an endangered monopod orchid, i.e., *Vanda coerulea* by leaf-based encapsulating PLBs with 94.9% conversion frequency on immediate inoculation in Ichihashi and Yamashita (IY) medium (Ichihashi and Yamashita 1977). 95% conversion was achieved on encapsulating PLB of *Flickingeria nodosa* in Burgeff medium (Withner 1955) + 2% sucrose + 2 mg/L Adenine sulfate + 1 mg/L IAA at 4 °C for 3 months (Nagananda et al. 2011). Alginate encapsulation of *Aranda* × *Vanda* PLB was also reported (Gantait et al. 2012). Three percent sodium alginate and 75 mM calcium chloride support better encapsulation of individual PLBs (4 mm long). Plant growth regulator (PGR)-free MS medium (1/2 strength) reported 96.4% of conversion. Likely, short-term storage of PLBs of *Dendrobium shavin* (Bustam et al. 2012); 60-day-old PLBs in *Dendrobium nobile* (Mohanty et al. 2013b) and *Coelogyne breviscapa* (Mohanraj et al. 2009); 30-day-old PLBs in *Geodorum densiflorum* (Datta et al. 1999); PLB of *Spathoglottis plicata* Blume (Haque and Ghosh 2017); somatic embryos in *Dendrobium candidum* (Guo et al. 1994) were used for encapsulation with varied binding solution, polymerization time, and conversion percentage. During the sowing of artificial seeds contamination is one of the main barriers to the commercialization of encapsulation technology. However, Chitosan was used as a fungal growth retardant.

5 Genetic Stability

The somaclonal variations are a phenomenon of plant tissue culture that is dependent on medium composition, multiplication, explants type, adventitious shoots formation, culture period, and plant genotype (Côte et al. 2001). Despite several experiences of in vitro regeneration, either genetic uniformity or variability was observed in micropropagated plantlets (Larkin and Scowcroft 1981). Micropropagation provides a feasible substitute to seed propagation as it entitles rapid propagation of elite stock cultivars in a fairly short duration of time. For the raising of quality plant material, the genetic consistency of micropropagated plants is a prerequisite factor. In contrast, genetic instability occurs in the in vitro-regenerated plants (somaclonal variation) due to the use of hyper-optimum potency of growth regulators and continuous sub-culturing. Orchid micropropagation was interrupted with an intervening callus phase, which interfered with the integrity of the regenerated clonal plantlets (Nookaraju and Agrawal 2012); on the other hand, micropropagation via meristem culture was considered as uniform culture (Rani and Raina 2000).

To examine the in vitro protocols, whether propagation was either true-to-type or not clonal fidelity was tested with various Single Primer Amplification Reaction (SPAR)-based methods such as Inter Simple Sequence Repeats (ISSR), Random Amplified Polymorphic DNA (RAPD), and Direct Amplification of Minisatellite DNA (DAMD) markers (Zietkiewicz et al. 1994; Williams et al. 1990; Heath et al. 1993). In addition, a recently invented molecular marker, the Start Codon-Targeted (SCoT) polymorphism (Collard and Mackill 2009) has gained popularity as a powerful tool for the evaluation of clonal fidelity or genetic diversity in regenerated orchid plants (Bhattacharya et al. 2005; Ranade et al. 2009) (Table 1).

Very few studies were endured for testing of clonal fidelity of micropropagated orchids. Among them, the genetic stability of micropropagated *Dendrobium* plantlets was screened by Random Amplified Polymorphic DNA (RAPD) marker (Ferreira et al. 2006). Likely, in *Habenaria edgeworthii* (Giri et al. 2012a); *Aerides crispa* (Srivastava et al. 2018); *Anoectochilus elatus* (Sherif et al. 2017); *Changnienia amoena* (Li and Ge 2006); *Cymbedium finlaysonianum* (Worrachottiyanon and Bunnag 2018); *Cymbidium giganteum* (Roy 2012); *Cymbidium aloifolium* (Sharma et al. 2011; Choi et al. 2006); *Dendrobium densiflorum* (Mohanty and Das 2013); *Dendrobium chrysotoxum* (Tikendra et al. 2019a); *Dendrobium fimbriatum* (Tikendra et al. 2021); *Dendrobium heterocarpum* (Longchar and Deb 2022); *Dendrobium moschatum* (Tikendra et al. 2019b); *Dendrobium nobile* (Bhattacharyya et al. 2014); *Eulophia dabia* (Panwar et al. 2022); *Rhynchostylis retusa* (Oliya et al. 2021); *Spathoglottis plicata* (Auvira et al. 2021); *Vanda coerulea* (Manners et al. 2013) and in *Vanilla planifolia* (Sreedhar et al. 2007) genetic uniformity was tested by RAPD marker.

Moreover, Inter Simple Sequence Repeats (ISSR) marker was tested in *Anoectochilus elatus* (Sherif et al. 2017, 2018); *Anoectochilus formosanus* (Lin et al. 2007; Zhang et al. 2010); *Bletilla striata* (Wang and Tian 2014); *Bulbophyllum odoratissimum* (Prasad et al. 2021); *Cymbidium aloifolium* (Sharma et al. 2011, 2013; Choi et al. 2006); *Dendrobium aphyllum* (Bhattacharyya et al. 2018); *Dendrobium chrysotoxum* (Tikendra et al. 2019a); *Dendrobium crepidatum* (Bhattacharyya et al. 2016a); *Dendrobium fimbriatum* (Tikendra et al. 2021); and in *Dendrobium nobile* (Bhattacharyya et al. 2014); *Dendrobium thyrsiflorum* (Bhattacharyya et al. 2015); *Habenaria edgeworthii* (Giri et al. 2012a); *Platanus acerifolia* (Huang et al. 2009); *Vanda coerulea* (Manners et al. 2013; Gantait and Sinniah 2013); and *Vanilla planifolia* (Gantait et al. 2009; Sreedhar et al. 2007; Bautista-Aguilar et al. 2021) for studying the effectiveness of in vitro protocol. Simple Sequence Repeats (SSR) marker was tested in *Vanilla planifolia* (Bautista-Aguilar et al. 2021). Amplified Fragment Length Polymorphism (AFLP) marker was tested in *Anoectochilus formosanus* (Zhang et al. 2010) and *Dendrobium thyrsiflorum* (Bhattacharyya et al. 2017b). Inter-Retrotransposon Amplified Polymorphism (IRAP) marker was tested in *Bletilla striata* (Guo et al. 2018) and *Dendrobium aphyllum* (Huang et al. 2009). Directed Amplification of Minisatellite-region DNA (DAMD) marker was tested on *Cymbidium aloifolium*

Table 1 Genetic stability analysis of some medicinal orchids with various markers

Sl no	Plant species	Markers	Findings	References
1	*Aerides crispa*	RAPD	RAPD was used to confirm the genetic variations among 52 in vitro morphological variants. Among these, only 15 mutant lines were established based on genetic diversity	Srivastava et al. (2018)
2	*Anoectochilus elatus*	ISSR	2.38% polymorphism and 97.61% monomorphism with genomic uniformity that of the mother plant was revealed with band patterns using ISSR	Sherif et al. (2017)
		ISSR	Using ISSR, homogeneity in direct somatic embryo regenerated plants was found to be 94.22% whereas 93.05% from plants elevated from an indirect somatic embryo	Sherif et al. (2018)
3	*Anoectochilus formosanus*	ISSR and AFLP	Among the regenerated shoots, the range of genetic variation was from 0.00% to 5.43%	Lin et al. (2007)
		ISSR	Among the total 1810 scorable bands, 94% were genetically similar whereas only 2.76% polymorphism was observed	Zhang et al. (2010)
4	*Ansellia africana*	SCoT	Using SCoT in micropropagated plants, an increment in clonal variability with a higher gene flow value (Nm = 1.596) was recorded	Bhattacharyya et al. (2017a)
5	*Bletilla striata*	SCoT and IRAP	96.17% polymorphic bands were recorded using the SCoT marker and 94% polymorphic bands were recorded using the IRAP marker	Guo et al. (2018)
		ISSR	Clonal fidelity assessment by ISSR markers revealed 99.8–100.0 % similarity between the regenerants and their mother plants and 99.5–100.0 % similarity among the regenerants	Wang and Tian (2014)
6	*Bulbophyllum odoratissimum*	ISSR	The genetic homogeneity degree using ISSR markers was high among the clones	Prasad et al. (2021)
7	*Changnienia amoena*	RAPD	Percentage of polymorphic bands at the species level was 76.5% and at the population level it was 37.2%	Li and Ge (2006)
8	*Cymbidium aloifolium*	ISSR	At the inter-specific level, 90% of polymorphism was observed. Among the species, the average cumulative genetic similarity was 66%. The	Sharma et al. (2013)

(continued)

Table 1 (continued)

Sl no	Plant species	Markers	Findings	References
			range of average polymorphism at the intra-specific level was 29.8–69.9 % within five Cymbidium species	
		RAPD, ISSR, and DAMD	Polymorphism in five species of *Cymbidium* viz., *C. aloifolium*, *C. mastersii*, *C. elegans*, *C. eburneum*, and *C. tigrinum* was found to be 96.6% at an inter-specific level and 51.2–77.1% at an intra-specific level	Sharma et al. (2011)
		RAPD	Similarity values for total bands score analysis ranged from 0.501 for *Cymbidium aloifoilum* and *C. kanran* to 0.935 for *Cymbidium ensifolium* and *Cymbidium marginatum*	Choi et al. (2006)
9	*Cymbedium finlaysonianum*	RAPD	The genetic stability of the cryopreserved synthetic seeds was confirmed with a similar index value of 0.998	Worrachottiyanon and Bunnag (2018)
10	*Cymbidium giganteum*	RAPD	5.81% molecular variation was detected in the regenerants	Roy (2012)
11	*Dendrobium aphyllum*	IRAP and ISSR	Among the regenerants, the pooled data revealed 5.26% clonal variability whereas individually 7.69% (IRAP) and 4% (ISSR) variability was detected	Bhattacharyya et al. (2018)
12	*Dendrobium chrysotoxum*	RAPD and ISSR	Among the *in vitro* clones and mother plants, 96.30% of monomorphism, and 3.6% of polymorphism was detected	Tikendra et al. (2019a)
13	*Dendrobium crepidatum*	SCoT and ISSR	Cumulative ISSR and SCoT data revealed high genetic fidelity among the regenerates with 6.25% clonal variability. Whereas within the micropropagated plants SCoT data revealed a 10% total variability	Bhattacharyya et al. (2016a)
14	*Dendrobium densiflorum*	RAPD	No genetic variation was observed	Mohanty and Das (2013)
15	*Dendrobium fimbriatum*	RAPD, ISSR & SCoT	Among the regenerants, 100% monomorphism was observed, while low genetic polymorphism of 1.52%, 1.19%, and 3.97% with RAPD, ISSR, and SCoT markers, respectively, was exhibited	Tikendra et al. (2021)
16	*Dendrobium heterocarpum*	RAPD, DAMD, and SCoT	Genetic homogeneity of the regenerates was confirmed with 96.89% monomorphism and 3.11% polymorphism	Longchar and Deb (2022)

17	*Dendrobium nobile*	RAPD and SCoT	94.04% monomorphism and 5.95% polymorphism confirmed the high degree of genetic stability within the *in vitro* propagated plants	Bhattacharyya et al. (2014)
		SCoT	The very high degree of clonal fidelity within the propagated plantlets was confirmed	Bhattacharyya et al. (2016b)
18	*Dendrobium thyrsiflorum*	ISSR and SCoT	In detecting clonal variability, SCoT is more efficient compared to ISSR	Bhattacharyya et al. (2015)
		AFLP	High genetic diversity with 98.50% polymorphism was observed	Bhattacharyya et al. (2017b)
19	*Eulophia dabia*	RAPD	Genetic stability was evaluated which proved true to typesets of the in vitro-raised plants	Panwar et al. (2022)
20	*Habenaria edgeworthii*	RAPD	Genetic stability was confirmed among regenerates	Giri et al. (2012a)
21	*Platanus acerifolia*	ISSR	A genetically stable micropropagated line of *P. acerifolia* was confirmed with 2.88% polymorphism	Huang et al. (2009)
22	*Rhynchostylis retusa*	RAPD	Genetic uniformity among all the analyzed in vitro samples and with the mother plant was confirmed	Oliya et al. (2021)
23	*Spathoglottis plicata*	RAPD	53.28% polymorphism was reported in the orchid variants	Auvira et al. (2021)
		SCoT	Genetic uniformity of the regenerates with the mother plant was confirmed	Manokari et al. (2022)
24	*Vanda coerulea*	ISSR	Genetic stability was confirmed in plantlets from converted capsules stored in 4 and 25 °C	Gantait and Sinniah (2013)
		RAPD and ISSR	Natural genetic diversity with 58.88% polymorphism was shown at the intra-specific level	Manners et al. (2013)
25	*Vanilla plantifolia*	RAPD & ISSR	No genetic diversity was recorded among the micropropagated plants	Sreedhar et al. (2007)
		SSR & ISSR	High genetic stability with low polymorphism percentages was detected	Bautista-Aguilar et al. (2021)

(Sharma et al. 2011) and *Dendrobium heterocarpum* (Longchar and Deb 2022). Start Codon-Targeted Polymorphism (SCoT) was performed in micropropagated plantlets of *Anseilla africana* (Vasudevan and Van Staden 2010); *Bletilla striata* (Guo et al. 2018); *Dendrobium crepidatum* (Bhattacharyya et al. 2016a); *Dendrobium fimbriatum* (Tikendra et al. 2021); *Dendrobium heterocarpum* (Longchar and Deb 2022); *Dendrobium nobile* (Bhattacharyya et al. 2014, 2016b); *Dendrobium thyrsiflorum* (Bhattacharyya et al. 2015), and *Spathoglottis plicata* (Manokari et al. 2022) for homogeneity demonstration.

Genetic variation or polymorphism was analyzed in *Bulbophyllum odoratissimum* as 3.94% (Prasad et al. 2021); 2.76% in *Anoectochilus formosanus* (Zhang et al. 2010); 2.53% in *Dendrobium chrysotoxum*; 2% in *Dendrobium moschatum* (Tikendra et al. 2019a, b); 2.38% in *Anoectochilus elatus* (Sherif et al. 2018); and 2.88% in *Platanus acerifolia* (Huang et al. 2009). The results of the ISSR analysis confirmed the feasibility of the micropropagation protocol of orchids although tiny dissimilarity in genomic constituents was noticed. Such negligible variation may be due to the maintenance of in vitro culture for a longer duration, concentration of growth regulators, and in vitro stress conditions that lead to clonal variations (Tikendra et al. 2019a; Razaq et al. 2013; Devarumath et al. 2002).

6 Ethno-Medicinal Properties

Orchids are the backbone of traditional herbal medicines and have been extensively studied because of their pharmacological importance. From ancient times orchids are being used in traditional systems of medicine like Ayurveda, Siddha, Yunani, Homeopathy, Traditional Chinese Medicine (TCM), etc. Chinese described a *Dendrobium* species and *Bletilla striata* in *Materia Medica* of Shen-Nung (twenty-eighth century B.C.) and in many other Chinese writings orchids symbolize friendship, perfection, numerous progeny, noble, and elegant (Reinikka 1995). In India, there are nearly 1600 species that constitute about 9% of the total flora (Medhi and Chakrabarti 2009). The therapeutic importance of Indian orchids in treating ailments is well documented in the literature (Lawler 1984; Handa 1986) (Table 2).

Several orchid species have important ingredients in various traditional medicinal formulations. Whole plants or their parts are used as a paste or in boiled form, single or mixed with other food stuffs as therapeutics in several ailments (Pant 2013; Gopalakrishnan and Seeni 1987).

The roots of *Acampe papillosa* are used in rheumatism, burning, boils, expectorant, biliousness, asthma, bronchitis, eyes, and blood, and help in curing infections, curing secondary syphilis, uterine diseases, tuberculosis, fever, and throat troubles (Hossain 2009; Zhan et al. 2016; Chopra et al. 1969). The root of *Acampe praemorsa* is used as a tonic for rheumatism and treats neuralgia, sciatica, syphilis, and uterine disorders. Various parts of this orchid are used for the treatment of cough, stomachache, ear-ache, and eyes diseases, reduce body temperature, antibiotic for wounds, traumatic pain, backache, menstruation pain, burning sensation, asthma, bronchitis,

Table 2 Distribution and therapeutic importance of some medicinal orchids

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
1	*Acampe papillosa*	Small Warty Acampe	Epiphytic Bangladesh, Bhutan, India (North West Himalaya, Sikkim, West Bengal); Laos, Myanmar, Nepal, Thailand, and Vietnam	Root	Asthma, bronchitis, eyes, and blood Helps to cure syphilis and uterine diseases, tuberculosis, poisonous infections, throat troubles, and fever. Also used as a cooling agent, astringent, and expectorant Crusted roots are used as a tonic; pasted roots are used for rheumatic pains, sciatica, and neuralgia	Piri et al. (2013), Hossain (2009), Chopra et al. (1969)
2	*Acampe praemorsa*	Wight's Acampe, Brittle Orchid Kannada: Seete hoo, Seete dande; Konkani: Kanphoden	Epiphytic Tropical Africa, India, eastwards to China and southwards to Malaya, Indonesia, The Philippines, and New Guinea	Root	Used as a tonic for arthritis, rheumatism, sciatica, neuralgia, syphilis, and uterine disorders. Pulverized plant mixed with egg white and calcium heal fractured limbs. Freshly prepared paste of its roots along with *Asparagus recemosus* root paste cures arthritis	Suja and Williams (2016), Perfume workshop (n.d.-a), Hossain (2009), Leander and Lüning (1967), Shanavaskhan et al. (2012), Devi et al. (2015), Panda and Mandal (2013), Nongdam (2014), Mishra et al. (2008)
3	*Aerides crispa*	Curled aerides Marathi: Pan Shing	*Epiphytic* Karnataka: Districts of Hassan, Mysuru, Ballari, Chikkamagaluru, Chitradurga, Kodagu (Coorg), Shivamogga,	-	2–3 drops of boiled pulverized plant with neem is used to treat earache	Jayashankar and Darsha (2021), Perfume workshop (n.d.-a)

(continued)

Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
			Uttara Kannada, Dakshina Kannada			
4	*Aerides multiflorum*	The Multi-Flowered Aerides—In Thailand—Aiyaret—Phuang Malai, Fox brush orchid, Maana	Terrestrial, epiphytic, saprophytic Found in Bangladesh, eastern Himalayas, India, Nepal, western Himalayas, Andaman Islands, Myanmar, Thailand, Laos, Cambodia, and Vietnam Elevation: 1100 m	Whole plant	Leaf paste is applied on wounds and earaches. The powdered leaf is used as a tonic. In vitro tubers and leaves have an antibacterial effect and antimicrobial effects, respectively	Lal et al. (2020), Perfume workshop (n.d.-a), Baral and Kurmi (2006), Basu et al. (1971), Behera et al. (2013), Bhattacharjee (1998)
5	*Aerides odorata*	Fragrant Fox Brush Orchid, Fragrant Aerides, Fragrant Cat's-tail Orchid Mizo: Nau-ban	Epiphyte Native to South-Central and South-East China, Bangladesh, East Himalaya, West Himalaya, Nepal, India, Cambodia, Laos, Myanmar, Thailand, Vietnam, Borneo, Jawa, Lesser Sunda Islands, Malaya, Philippines, Sulawesi, and Sumatera	Roots, leaves, fruits	Leaf paste and Fruits are used to heal wounds and cure tuberculosis. Leave juice and seeds are used for treating boils in the ear, nose and other skin disorders. Combination of the fresh root of *A. odorata*, root powder from *Saraca asoca*, bark from *Azadirachta indica* and common salt used as an oral medicine for painful swollen joints	Hongthongkham and Bunnag (2014), Devi et al. (2013), Perfume workshop (n.d.-a), Leander and Lüning (1967), Hossain (2009), Baral and Kurmi (2006), Behera et al. (2013)
6	*Anacamptis pyramidalis*	Pyramidal Orchid	Terrestrial Throughout the UK, many European countries	-	For skin whitening; exhibits antioxidant and scavenging capacities	Parker (2016), Perfume workshop (n.d.-a)

			including Slovenia, in North Africa and the Near East Elevation: 0–1600 m			
7	*Anocetochilus elatus*	South Indian Jewel Orchid Malayalam: Nagathali Assamese: Boga-kopou-phul	Terrestrial Distributed along Southern Western Ghats of India	Whole Plant	Used in the chest and abdominal pain and to treat snake bites	Sherif et al. (2012, 2018)
8	*Anocetochilus formosanus*	Jewel orchid	Terrestrial Widely distributed in Taiwan and Fujian Province of China, and Japan	Whole plant	The whole plant is used as a cooling agent, an antipyretic, for relieving pain in the waist and knee, and for treating tuberculosis, diabetes, bronchitis, renal infections, snake bites, and stomach aches. The plant also possesses anti-cancerous properties	Jiang et al. (2015), Perfume workshop (n.d.-a), Aswandi and Kholibrina (2021), Nandkarni (1976)
9	*Ansellia africana*	Leopard orchid	Perennial, and epiphyte, or sometimes terrestrial Tropical and subtropical areas of southern Africa	Whole plant	Stem infusion is used as an antidote to bad dreams. Leaves and stems are used for treating madness	Bhattacharyya and Staden (2016), Saleh-E-In et al. (2021)
10	*Arundina graminifolia*	Bamboo orchid, Bird Orchid, Kinta Weed Manipuri: Kongyamba lei; Mizo: Le-len	Terrestrial Myanmar, India, Sri Lanka, Nepal, Thailand, Vietnam, the Ryukyu Islands, Malaysia, Singa pore, China to Indonesia, the Philippines and New Guinea	Whole plant	It possesses anti-bacterial activity. The root is used as a pain reliever. The scrapped bulbous stem is applied on the foot heels to treat the cracks	Hu et al. (2013), Aswandi and Kholibrina (2021), Hossain (2009), Kumar (2002), Dakpa (2007)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
11	*Bletilla striata*	*Hyacinth orchid or Chinese ground orchid*	Terrestrial Japan, Korea, Myanmar (Burma), and China (Anhui, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hubei, Hunan, Jiangsu, Jiangxi, Shaanxi, Sichuan, Zhejiang)	Tuber, Root	Tubers are used in treating hemorrhage, tuberculosis, and bleeding. It promotes the regeneration of muscle and other tissues. They are used to treat sores, chapped skin, dysentery, fever, malignant ulcers, gastrointestinal disorders, hemorrhoids, anthrax, malaria, eye diseases, etc. The powdered roots mixed with oil are applied to burns and skin diseases. Effective against leucorrhea. Leaves are used to cure lung disease	He et al. (2017), Perfume workshop (n.d.-a), Kong et al. (2003), Bulpitt et al. (2007)
12	*Bulbophyllum odoratissimum*		Lithophytic *China, India* *Native to:* Andaman Is., Assam, Cambodia, China South-Central, China Southeast, East Himalaya, India, Laos, Myanmar, Nepal, Thailand, Tibet, Vietnam	Whole plant	Fractures, pulmonary tuberculosis, hernia pain	Perfume workshop (n.d.-a), Bhattacharjee (1998)
13	*Calanthe discolor*	*Japanese Hardy Orchid*	Terrestrial Korea, Japan, and China	Whole plant	The entire plant is used to improve blood circulation, heal abscesses,	Suetsugu and Fukushima (2014), Perfume

					rheumatism, bone pain, and traumatic injuries as well as treat skin ulcers and hemorrhoids	workshop (n.d.-a), Yoshikawa et al. (1998)
14	*Changnienia amoena*			Whole plant, roots		Teoh (2019)
15	*Coelogyne cristata*	*Swarna Jibanti;* Jibanti India: *Hadjojen* (bone joiner) Nepal: *ban maiser, jhyanpate*	Found in moss forests associated with tree bark and rocks, often exposed to sun India, Bhutan, Nepal, Tibet and mountainous regions of Northern Thailand Elevation: 1500–2600 m	Pseudobulbs	Pseudo bulbs are used for constipation and aphrodisiac. The juice is used for healing wounds, boils, and sores	Sharmaa et al. (2014), Mitra et al. (2018), Perfume workshop (n.d.-a), Pant and Raskoti (2013), Subedi et al. (2011), Pamarthi et al. (2019)
16	*Coelogyne flaccida*	Bearded Coelogyne, loose Coelogyne China: *Lilinbeimu Lan*, *Guishangye*	Epiphyte or lithophyte Himalayas, Nepal, North India, Bhutan, China, and Myanmar Elevations: 900–1400 m	Pseudo bulb	Used to treat headache, fever, and indigestion	Kaur and Bhutani (2013), Pant and Raskoti (2013), Teoh (2016), Pamarthi et al. (2019), Perfume workshop (n.d.-a)
17	*Coelogyne nervosa*	Veined coelogyne	Epiphytic Southern Western Ghats of Kerala and Tamil Nadu	Whole plant	Has potential antimicrobial, antioxidant, and anticancer properties	Sathiyadash et al. (2014), Ranjitha et al. (2016)
18	*Coelogyne stricta*	The Rigid Coelogyne Pseudobulb India: Harjojan	Found on tree trunks or lithophytes on mossy rocks Elevations: 1400–2000 m North-East India, Sikkim, Bhutan, Myanmar, and Nepal	Pseudobulbs	The paste is used to cure headaches and fever	Perfume workshop (n.d.-a), Basker and Bai (2006), Yonzone et al. (2012), Pamarthi et al. (2019)
19	*Cymbidium aloifolium*	Malanga, aloe-leafed cymbidium Boat Orchid	Epiphytic herb Global Distribution India, Sri Lanka, Thailand,	Rhizome, root, pseudo bulbs	The paste is used to treat fractured and dislocated bones	Behera et al. (2013), Perfume workshop (n.d.-a), Pamarthi et al. (2019)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
		Tamil Nadu: *panaipulluruvi* Assam: Kopou-Phul	Indonesia, Java, Indo-Malaysia			
20	*Cymbidium ensifolium*	Golden-thread orchid, burned-apex orchid, spring orchid, and rock orchid	Epiphytic *Global Distribution: India and Sri Lanka* *Native to:* Assam, Cambodia, China South-Central, China Southeast, Hainan, Japan, Korea, Laos, Myanmar, Philippines, Taiwan, Thailand, Tibet, Vietnam	Root, flower	Root decoction is used to treat gonorrhea. Flower decoction used in eye sore disorders	Chang and Chang (1998), Tsering et al. (2017)
21	*Cymbidium finlaysonianum*	Finlayson's Cymbidium Malay: *Sepuleh* Thai: *Ka Re ka Ron Pak Pet*	Terrestrial (Primary Rainforest, Secondary Rainforest, Coastal Forest) Thailand, Vietnam, Cambodia, Peninsular Malaysia, Java, Borneo and the Philippines Elevation: 0–1200 m	-	Restore health	Islam et al. (2015), Perfume workshop (n.d.-a)
22	*Cymbidium giganteum*	Iris-like Cymbidium	Epiphytic Chinese Himalayas, India, eastern Himalayas, Nepal, western Himalayas, Myanmar, and Vietnam Elevation: 0–1200 m	Leaves	Wounds	Hossain et al. (2010), Bulpitt (2005), Fonge et al. (2019), Linthoingambi et al. (2013)

23	*Cymbidium goeringii*	Noble orchid *Japan: Chun Lan (spring orchid)*	Terrestrial East Asia including Japan, China, Taiwan, and South Korea Elevation: 300–3000 m	Seed, whole plant	Seeds are used to cure wounds and injuries and also in curing fractures, and traumatic soft tissue injuries	Perfume workshop (n.d.-a), Teoh (2016)
24	*Cymbidium iridioides*	Iris Cymbidium Chinese: *Huang chan Lan*	Epiphytic China, India, Bhutan, Nepal, Myanmar; and Vietnam Elevation: 900–2,800 m	Leaves, pseudo bulbs, roots	Fresh juice of this plant is used to stop bleeding. The powder is used as a tonic. During diarrhea, pseudo bulbs and roots are consumed	Perfume workshop (n.d.-a), Aggarwal and Zettler (2010), Arditti et al. (1982), Arditti and Ernst (1984), Medhi and Chakrabarti (2009)
25	*Cymbidium kanran*	The Cold Growing Cymbidium	Terrestrial Exclusively distributed in Northeast Asia including China, Japan, and Korea	Whole plant	Cures coughs and asthma. Roots are used to cure ascariasis and gastroenteritis	Perfume workshop (n.d.-a), Jeong et al. (2017)
26	*Cymbidium lancifolium*	Lance leafed Cymbidium	Grows in broad-leaved forests where the soil is rich in humus and also plenty of leaf litter In the Himalayas, India, Nepal, Bhutan, China, Taiwan, Japan Elevation: 300–2300 m	Whole plant	Used to cure rheumatism, improve blood circulation and treat traumatic injuries	Perfume workshop (n.d.-a)
27	*Cymbidium longifolium*	Red-Spotted Lip Cymbidium; In China Chang Ye Lan	Epiphytic, lithophytic, or terrestrial Found in China, Eastern Himalayas, Nepal, Bhutan, Burma, and India Elevation: 1000–2500 m	Pseudo bulb	The fresh shoot is used for nervous disorders, madness, epilepsy, hysteria, rheumatism, and spasms. Salep used as demulcent. An aqueous solution of powdered pseudo bulbs is taken orally on an empty stomach	Nongdam (2014), Sood et al. (2006), Yonzone et al. (2013), Zhan et al. (2016)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
28	*Cymbidium sinense*	Japan—Hosai-Ran—Taiwan-Ran—In China Mo Lan	Terrestrial Found in India, Myanmar, northern Thailand, Vietnam and east China, Japan	Whole plant	Used in purifying heart, lungs, treating cough and asthma	Perfume workshop (n.d.-a)
29	*Cypripedium calceolus*	Lady's-slipper orchid Japanese: Ko-atsumori-sou	Shady, deciduous and mixed woodland, predominantly on calcareous soils Spain, Europe, China, Siberia, Sakhalin Island, and Japan Elevation: 2000 m	Root, rhizome	It acts as a sedative, promotes sleep, and reduces pain when powdered roots are mixed with sugar water. A tea prepared from roots is used to treat jangling nerves and headaches	Kull (1999), Kolanowska and Busse (2020), Singh and Dey (2005)
30	*Cypripedium debile*	Frail lady's slipper ***Lan*** (two leaf spoon orchid)	Japan, Korea, Taiwan, and China	Whole plant	Used to improve blood circulation, reduce swelling, relieves pain, and act as a diuretic	Perfume workshop (n.d.-a)
31	*Cypripedium formosanum*	Formosa lady's slipper	Terrestrial Found on sandy floor of the forest and in open areas in Taiwan Elevation: 2000–3000 m	Whole plant	Improves blood circulation, regulates menses, and relieves pain and itching. Roots and stems are used to treat malaria, snake bites, traumatic injury, and rheumatism	Perfume workshop (n.d.-a)
32	*Cypripedium guttatum*	Spotted lady's slipper	Hardy terrestrial European Russia to Korea, Alaska to Yukon Elevation: 1000–4100 m	Roots and leaves	Used to treat epilepsy	Zhang et al. (2007), Perfume workshop (n.d.-a)
33	*Cypripedium macranthos*	Large flowered lady's slipper		Rhizome, flower,	Used to treat skin disease, roots and stem promote	Shimura and Koda (2004), Shimura et al. (2007),

			Terrestrial East Belarus to temperate East Asia	stem, and root	dieresis, reduce swelling, expel gas, relieve pain and improve blood flow. Dried flowers are used to stop in wound bleeding	Perfume workshop (n.d.-a)
34	*Cypripedium parviflora*	Yellow lady's slipper or moccasin flower	Terrestrial *Native to:* Delaware, Nebraska, North Dakota, Québec, Rhode I., Elevation: 1400 m	Rhizome	Cures insomnia, anxiety, headache, emotional tension, fever, palpitations, tumors, irritable bowel syndrome, neuralgia, and reduces menstrual and labor pain	Meier et al. (2018), Moerman (1986), Grieve (1998), Kumar et al. (2005)
35	*Cypripedium pubescens*	Yellow lady's slipper	Deciduous and coniferous forest, meadows, fens Newfoundland to British-Columbia, south to Georgia, Arizona, Washington, and Europe Elevation: 5750–11,000 ft.	Root	The plant is diaphoretic, hypnotic, nervine, antispasmodic, sedative, and tonic. Used in diabetes, diarrhea, dysentery, paralysis, joint pain, convalescence, impotence, and malnutrition	Pant and Rinchen (2012), Wani et al. (2020), Shrestha et al. (2021), Perfume workshop (n.d.-a), Singh and Duggal (2009), Khory (1982)
36	*Dactylorhiza hatagirea*	Himalayan Marsh Orchid India: Munjataka in Ayurveda	Terrestrial India, Pakistan, Afghanistan, Nepal, Tibet, and Bhutan. Elevation: 2500–5000 ft.	Tubers	Used as a tonic, heals wound, fever, and control burns and bleeding. Also used as food due to the presence of starch	Pant and Rinchen (2012), Wani et al. (2020), Shrestha et al. (2021), Perfume workshop (n.d.-a), Aggarwal and Zettler (2010), Arditti (1967, 1968, 1992), Arditti et al. (1982), Arditti and Ernst (1984)
37	*Dendrobium amoeneum*	The Lovely Dendrobium	Epiphytic Western Himalayas, India,			Venkateswarlu et al. (2002)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
			eastern Himalayas, Nepal, Bhutan, Sikkim, Bangladesh, Myanmar Elevation: 600–2000 m	Pseudo bulbs, leaves	The freshly prepared paste is used to cure skin diseases and dislocated bones	
38	*Dendrobium aphyllum*	Thai names: Uean sai, Ueang sai long laeng, etc. Assamese: Haliki-thutia-phul	Epiphytic Continental Southeast Asia, Southwest China, Sikkim, and Nepal	Pseudo bulbs	Leaf paste is applied on the abnormal and deformed head parts of the newly born baby to get a normal shape	Liu et al. (2018), Perfume workshop (n.d.-b), Pant (2013)
39	*Dendrobium candidum*	Shihu in Chinese and Sekkoku in Japanese	Epiphytic Southern China, Taiwan, Nepal, Thailand, Vietnam, India, Myanmar Elevation: 2000–3000 m	Leaves	Used to treat diabetes	Nongdam (2014), Wu et al. (2004)
40	*Dendrobium chrysanthum*	Golden yellow-flowered dendrobium	Epiphytic and Lithophytic India, Nepal, Bhutan, Burma, China, Thailand, Laos, and Vietnam Elevation of 450–2000 m	Stem, leaf	The stem is used as a tonic to enhance the immune system, promote body fluid production, and reduce fever. The leaf is used as an antipyretic and mild skin disease as well as benefits the eyes	Nongdam (2014), Bulpitt (2005), Jalal et al. (2008, 2010), Li et al. (2016)
41	*Dendrobium chrysotoxum*	Golden Orchid Thai: Uang Khan Vietnam: Kim diep	Epiphytic North-East India, Nepal, Bhutan, Burma, China, Thailand, Laos, and Vietnam	Whole plant	The whole plant possesses antitumoral and anticancerous properties. Stem and flower extract is used as tonic and leaf extract as antipyretic	Nongdam (2014), Perfume workshop (n.d.-b), Sood et al. (2006), Bulpitt et al. (2007), Joshi et al. (2009)

42	*Dendrobium crepidatum*	Shoe-Lip Dendrobium China: Meigui Shihu (rose Dendrobium)	Epiphytic	Pseudo bulbs, stem	Pseudo bulb paste is used to treat the fracture and dislocated bones. Stems are used as a tonic for treating arthritis and rheumatism	Perfume workshop (n.d.-b), Joshi et al. (2009), Joshi and Joshi (2001), Hu et al. (2016)
43	*Dendrobium crumenatum*	Pigeon orchid, Dove orchid India: Jivanti Malay: bunga angin (wind orchid)	Malaysia, Singapore	Leaf	Leaves are used to treat boils and pimples	Perfume workshop (n.d.-b), Joshi and Joshi (2001), Topriyani (2013)
44	*Dendrobium densiflorum*	Pineapple Orchid Thai: Ueang Mon Kai Liam Vietnam: Thy-tien	Epiphytic China, Bhutan, NE India, Myanmar, Nepal, Thailand Elevation: 400–1000 m	Pseudo bulbs, leaf	Pulps of the pseudo bulbs are used to treat boils, pimples, and other skin eruptions. Leaf paste is used on fractured bones, to relieve sprains and inflammations	Perfume workshop (n.d.-b), Arditti (1992), Arditti et al. (1982), Arditti and Ernst (1984), Keerthiga and Anand (2014), Pant et al. (2022)
45	*Dendrobium devonianum*	Devon's Dendrobium China: Chiban Shihu (teeth pedal Dendrobium)	Epiphytic Native to south China, the eastern Himalayas (Bhutan, Assam), Myanmar, Thailand, Laos, Vietnam	Stem	Dried stems are used as an immune system enhancer	Li et al. (2011, 2013a), Perfume workshop (n.d.-b), Cakova et al. (2017)
46	*Dendrobium draconis*	Thai names: Ueang ngoen, ueang ngum Myanmar Name: Kein na ri	Terrestrial India, Cambodia, Laos, Myanmar, Thailand, and Vietnam	Stem	Used in antipyretic and hematinic	Rangsayatorn (2009), Perfume workshop (n.d.-b)
47	*Dendrobium fimbriatum*	Fringe Lipped Dendrobium China: Liusushihu (tasseled stone orchid)	Epiphytic, lithophytic and terrestrial China, Western Himalayas, Bangladesh, Eastern Himalayas, India, Nepal,	Whole plant	Used in upset of liver and severe anxiety. Leaves are used for treating fractured bone, the pseudo bulbs are used in fever	Huang et al. (2008), Nongdam (2014), Perfume workshop (n.d.-b), Arditti et al. (1982)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
		India: Fringed lip Dendrobium	Bhutan, Laos, and Vietnam Elevation: 800–2400 m			
48	*Dendrobium heterocarpum*	*Golden-Lip Dendrobium* Thailand: Ueang Si Tan in	Epiphyte Native to: China, Nepal, Bhutan, the Indian subcontinent and Southeast Asia	Pseudo bulb	The paste is used to treat fractured and dislocated bones	Arditti and Ernst (1984), Warinhomhoun et al. (2022)
49	*Dendrobium lasianthera*	Sepik Blue Orchid	Epiphyte New Guinea, Papuasia, Asia Tropical	Roots, stem, leaves	Anticancer	Utami et al. (2017)
50	*Dendrobium longicornu*	Long-horned dendrobium	Epiphyte or terrestro-lithophyte Native to southern China, the Himalayas (Nepal, northeastern India, Bhutan, Bangladesh) and northern Indo-China region Elevation : 1200–3000 m	Whole plant	The plant juice mixed with lukewarm water is used for treating children with fever. The boiled root is used to feed the livestock to remove cough	Dohling et al. (2012), Perfume workshop (n.d.-b)
51	*Dendrobium macrostachyum*	Fringed Tree Dendrobium	Epiphytic India, Myanmar, Sri Lanka and on the Cape York Peninsula Native to Australia, tropical Asia, and eastern Malaysia	Tender shoot tip	Tender shoot tip juice is used for earaches	Pyati et al. (2002), Perfume workshop (n.d.-b), Reddy et al. (2001)
52	*Dendrobium moschatum*	Musk Dendrobium Thai: Ueang Champa	Epiphytic Northeast India, Bhutan and Nepal across Myanmar	Pseudo bulb	Pseudo bulb paste is used to treat dislocated and fractured bones	Kanjilal et al. (1999), Perfume workshop (n.d.-b)

			and Thailand to Laos, Vietnam, and China			
53	*Dendrobium nobile*	Noble Dendrobium China: Jinchashihu (gold hairpin Dendrobium) Japanese name: Koki	Epiphytes or lithophytes Himalayas and China	Pseudo bulb, seed, Stem	The pseudo bulb extracts cure eye infections and burns; the plant is used to treat pulmonary tuberculosis, flatulence, and dyspepsia, and reduce salivation, night sweats, fever, and anorexia. Also used as an antiphlogistic, tonic. Seeds are used to heal wounds; stems to cure fever and tongue dryness; stems are used for longevity	Bhattacharyya et al. (2014), Asghar et al. (2011), Luo et al. (2010), Singh and Duggal (2009), Perfume workshop (n.d.-b), Arditti (1967), Arditti et al. (1982)
54	*Dendrobium ovatum*	Green Lipped Dendrobium India: Anantali Maravara	Epiphytic Global Distribution: Western Ghats of India	Whole plant	Fresh plant juice cures stomach ache, excites bile, also acts as a laxative to the intestines, and cures constipation	Pujari et al. (2021), Shetty et al. (2015), Perfume workshop (n.d.-b), Kirtikar and Basu (1981), Caius (1986)
55	*Dendrobium parishii*	Parish's Dendrobium Thai: Ueang Khrang Sai San	Epiphyte. Native to the Eastern Himalayas, China, Thailand, Myanmar, Laos, Cambodia, and Vietnam	Pseudo bulbs	Antipyretic encourages the secretion of body fluids	Kongkatitham et al. (2018), Perfume workshop (n.d.-b)
56	*Dendrobium primulinum*	Primrose Yellow Dendrobium	Epiphyte Assam, Himalayas, Nepal, Andaman Islands, Myanmar, Thailand, China, and Vietnam	Dried stems	Immune system enhancer	Pant and Thapa (2012)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
57	*Dendrobium thyrsiflorum*	Pinecone-like raceme dendrobium	Epiphytic, lithophytic, or terrestrial Native to the Eastern Himalayas, China, Thailand, Myanmar, Laos, Cambodia, and Vietnam Elevation: 1200–2000 m	Stem	Used to resist heat, benefits the stomach, and promotes the production of body fluid	Wrigley (1960), Ruixuan et al. (2015), Perfume workshop (n.d.-b)
58	*Dendrobium transparens*	Translucent Dendrobium	Epiphytic Western Himalayas, Bangladesh, eastern Himalayas, India, Nepal, Bhutan, Sikkim, Myanmar, China, and Vietnam Elevation: 500–2100 m	Pseudo bulb	The paste is used to treat fractures and dislocated bones	Sunitibala and Kishor (2009), Arditti and Ernst (1984)
59	*Dendrobium trigonopus*	Thailand: Triangular Column Foot Dendrobium	Epiphyte The plant grows in the forest of Burma, Thailand, SW China, Laos and Vietnam Elevations: 300–1500 m	Stem	Used to cure fever and anemia	Hu et al. (2008a), Perfume workshop (n.d.-b)
60	*Doritis pulcherrima*	Beautiful Moth Orchid	Terrestrial, epiphytic Myanmar, Thailand, China, Laos, and Vietnam Elevation: 1000–4900 ft.	Leaves	Used to treat ear infections	Perfume workshop (n.d.-c)
61	*Eria bambusifolia*	Bamboo-Leaf Eria	Epiphytic World distribution: India, Thailand Elevation: 1000–1300 m	Whole plant parts	Treating hyperacidity and stomach disorders	Basker and Bai (2010), Zhan et al. (2016)

62	*Eulophia dabia*	Dubious Eulophia Salibmisri, Sung Misrie	Terrestrial Afghanistan, Baluchistan, Uzbekistan, Southern Himalayas, South China	Tubers	Stimulate appetite, cures stomach ache, and stimulates blood flow	Pant (2013), Perfume workshop (n.d.-b), Panwar et al. (2022)
63	*Eulophia epidendraea*	Epidendrum Eulophia Katou kaida maravara	Terrestrial South India, Sri Lanka, Bangladesh	Tubers	Cure tumor, and diarrhea; acts as an appetizer, anthelmintic, aphrodisiac, stomachic, and worm infestation, stimulate appetite, and purifies blood during heart troubles	Perfume workshop (n.d.-d), Narkhede et al. (2016)
64	*Eulophia graminea*	Grass Eulophia Kattuvegaya	Terrestrial India, Sri Lanka, Southeast Asia, China, and Japan	Whole plant	Juice to treat earache	Perfume workshop (n.d.-d)
65	*Eulophia nuda*		Terrestrial Found in the Western Ghats of India, tropical Himalayas, Myanmar and South China, Indochina, Malaysia, Indonesia, Philippines and the Pacific Islands	Whole plant	A thick paste of tubers is applied on the stomach to kill intestinal worms, cure rheumatoid arthritis, bronchitis, scrofulous glands, and tumors, purify the blood, and used as a tonic, acts as an anti-aphrodisiac, demulcent and anthelmintic. The leaf is used as a vermifuge, the whole plant is used in stomachache and snake bites, and the stem is used to stop bleeding and pain from trauma	Hada et al. (2020)
66	*Gastrodia elata*	Tianma China: Ming Tianma, Japan: Tenma, Korean name: Cheon ma	Saprophytic Nepal, Bhutan, India, Japan, North Korea,	Tuber	Used in stroke, tetanus, migraine, malaise, generalized dermatitis dizziness,	Perfume workshop (n.d.-d), Chen et al. (2014)

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Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
			Siberia, Taiwan, and China Elevations: 400–3200 m		sleepiness, insomnia, high blood pressure, blood circulation, rheumatism, numbness, paralysis, backache, skin boils, ulcers, and body pain	
67	*Geodorum densiflorum*	Nodding Swamp Orchid Bangladesh: Kukurmuria China: Dibao Lan India: Kukurmuria	Terrestrial Japan, China, Taiwan, Sri Lanka, Myanmar, Philippines, Indochina, Thailand, Malaysia, Ryukyu Islands, Indonesia, Nepal, India	Pseudo bulbs, roots	Used as a disinfectant. Root paste mix with ghee and honey in menstrual disorders and root paste is applied on insect bites and wounds	Nongdam (2014), Perfume workshop (n.d.-d), Sheelavantmath et al. (2000)
68	*Gymnadenia conopsea*	China: shou shen, Shouzhangshen Japan: Tegata-chidori	Lithophytes Russia, Europe, Japan, Korea	Stem	Treat kidney disorders, cough, dysfunction, discharge, traumatic injuries, thrombosis, chronic hepatitis, lactation failure stops bleeding, and fever	Perfume workshop (n.d.-d), Gustafsson (2000)
69	*Habenaria edgeworthii*		Terrestrial	Leaves and roots	Cooling and spermophytic	Singh and Duggal (2009)
70	*Habenaria pectinata*	Comb Habenaria	Terrestrial Assam, China South Central, East Himalaya, Myanmar, Nepal, Pakistan, West Himalaya	Bulb	Bleeding diathesis, burning sensation, fever, and phthisis	Singh and Duggal (2009)
71	*Herminium lanceum*	Lanceleaf Herminum China: Shuangchunjiaopan Lan	Terrestrial Shandong, Tibet, Dongbei,	Roots	The root is beneficial for the lungs and kidney, strengthen muscles and	Perfume workshop (n.d.-d)

			Guangxi, Taiwan Elevation: 1100–3500 m		bones, stops bleeding, and treats tuberculosis	
72	*Liparis odorata*	Fragrant Liparis	Terrestrial *Global distribution: Wide-spread* *Native to: Japan, Bangladesh, Cambodia, China South-Central, China Southeast, East Himalaya, India, Laos, Myanmar, Nansei-shoto, Nepal, Sri Lanka, Thailand, Tibet, West Himalaya*	Whole part	The whole plant is used for external use, tubers are used to treat stomach dis-orders and its paste is for chronic ulcers	Perfume workshop (n.d.-e)
73	*Malaxis acuminata*	Jeevak	Terrestrial Bangladesh, India, Nepal, Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia, and Philippines Elevation: 1500–2100 m	Pseudo bulb	Used as tonic, Aphrodisiac, styptic, antidysentery and febrifuge. The paste is applied on insect bites, and treats rheumatism, bleed-ing, burning sensation, and lungs disease	Pushpa et al. (2011)
74	*Oberonia ensiformis*	Word-Leaf Oberonia China: Jian Ye Yuan Wei Lan	Lithophytic, epiphytic Nepal, India, China, Myanmar, Thailand, Laos, and Vietnam Elevation: 600–1000 m		Used to encourage diuresis, treat cystitis, urethritis, injuries, and fractures and improve blood circulation	Perfume workshop (n.d.-c)
75	*Papilionanthe teres*	Cylindrical Vanda, Parrot Flower China: Banghua Lan, India: Chaitek Lei in	Epiphytic India, Andaman Island., Bangladesh, China South-Central, East Himalaya, India, Laos, Myanmar,	Stem and leaves	Stem and leaves are used to improve blood flow and reduce swelling. The paste is used to treat dislocated bone. Leaf paste is applied	Perfume workshop (n.d.-c)

(continued)

Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
		Manipuri, cylindrical Vanda	Nepal, Thailand, Vietnam Elevation: 600 m		to reduce fever. Stem juice protects from coughs and colds	
76	*Pholidota articulata*	Rattlesnake orchids India: Harjojan; Jivanti Myanmar: Kwyet mee pan myo kywe Nepal: Thurjo, Pathakera	Epiphytic Montane to submontane zones, Uttarakhand Himalayas, Arunachal Pradesh, and Indo-China to Malaysia India, Nepal, Bhutan Myanmar, Thailand, Cambodia, Vietnam, Malaysia, and Indonesia	Whole plant	Enriched in remove gas and reduce swelling, treat coughs, headache, dizziness, traumatic injuries, sores and ulcers, irregular menses and uterine problems, and fractures, used as a stimulant, demulcent, and tonic. Pseudo bulbs paste is applied on dislocated bones. Powdered root treat cancer and capsule juice are used to treat skin eruptions and ulcers	Perfume workshop (n.d.-c)
77	*Pholidota pallida*	China: Eumaishixiantao	Epiphytic Bhutan, Central Nepal, Northeast India	Root and pseudo bulb	Its powder induces sleep and juice to remove abdominal pain. Root and pseudo bulb paste is used to cure fever	Perfume workshop (n.d.-c)
78	*Platanthera chlorantha*	Greater butterfly-orchid	France, Germany, Great Britain, Albania, Austria, Baltic States, Belarus, Belgium, Bulgaria, Denmark, Finland, Greece, Hungary, Iran, Iraq, Ireland, Italy,	Whole Plant	The whole plant is used in strengthening the kidneys and lungs, and cures sexual dysfunction, hernia, and enuresis affecting children	Perfume workshop (n.d.-c)

			Krym, Netherlands, North Caucasus, Norway, Poland, Romania, Sicilia, Spain, Sweden, Switzerland, Turkey, Ukraine, Yugoslavia			
79	*Rhynchostylis retusa*	Foxtail orchid Blunt Rhynchostylis India: Kopou phool, draupadi mala, panas keli Nepal: ghoge gava	Epiphytic Global Distribution: Indo-Malaysia, India	Leaf, root, flower	Leaves and roots paste are used in rheumatism. Leaf juice is used in constipation, gastritis, acidity, and as an emollient. Root juice is used to heal cuts and wounds, and root is used in menstrual pain and arthritis. Dry flowers are used as an emetic	Basu et al. (1971), Bhattacharjee (1998), Bulpitt et al. (2007), Dakpa (2007) Dash et al. (2008)
80	*Satyrium nepalense*	Nepal Satyrium	Terrestrial Sri Lanka, India, Bhutan, and Myanmar Elevation: 2400–5000 m	Tubers	Treats diarrhea, dysentery, and malaria. Tubers are consumed as an aphrodisiac and used as children's growth supplements. Juice is used in cuts and wounds. The powder is used as a tonic and to treat colds, coughs, and fever	Baral and Kurmi (2006); Behera et al. (2013), Bulpitt et al. (2007), Gutierrez (2010)
81	*Spathoglottis plicata*	Philippine ground orchid, Large purple orchid	Terrestrial Taiwan, Southern India, Indonesia, Japan, Malaysia, New Guinea, Philippines, Sri Lanka, Thailand, Vietnam, Australia, Tonga and Samoa	Pseudo bulb	Treat rheumatic swelling, relieve pain, and uplift blood circulation	Teng et al. (1997), Friesen and Friesen (2012)

(continued)

Table 2 (continued)

Sl. No.	Species	Common Name and Local Name	Habitat and Distribution	Part Used	Therapeutic Importance	References
82	*Thunia alba*	White Thunia	Epiphytic India, China, and Southeast Asia Elevation: 2000 m	Whole plant	Cough pneumonia, bronchitis, bone break treatment, and injury	Xu et al. (2019a)
83	*Vanda coerulea*	Blue Orchid, blue vanda, autumn lady's tresses India: Kwaklei Lawhlei Vandara	Epiphytic Native to: North East India Elevation: 2500–4000 ft.	Flower	Flower juice is used in treating glaucoma, cataract, and blindness	Roy et al. (2011)
84	*Vanda roxburghii*	Rasna	Epiphytic Widely distributed throughout Bangladesh	Root	Treat fever, nervous system disease dyspepsia, snake bites bronchitis, hiccough, piles, rheumatism, allied disorders	Uddin et al. (2015), Uprety et al. (2010)
85	*Vanda spathulata*	Spoon-Leaf Vanda India: Ponnampumaravara	Terrestrial South India and Sri Lanka India: Karnataka, Kerala, and Tamil Nadu	Dried flowers	Dried flower powdered juice is used to treat asthma, and depression, enhance memory, and antioxidant activity, and alleviate chronic disease, and degenerative ailments such as cancer, autoimmune disorders, hypertension, delay the aging process, and atherosclerosis	Decruse et al. (2003), Jeline et al. (2021), Gupta and Katewa (2012)
86	*Vanda tessellata*	Grey orchid or Checkered Vanda		Leaves		Chowdhury et al. (2014)

			Epiphytic India, Myanmar, China, and Sri Lanka		Inflammations, rheumatism, dysentery, bronchitis, dyspepsia, and fever	
87	*Vanda testacea*	Small flowered Vanda	Epiphytic India, Myanmar, and Sri Lanka	Roots, leaves, and flowers	The powdered extract is used in nervous disorders, piles, inflammations, rheumatism, bronchitis, and anticancerous drugs	Kaur and Bhutani (2009)
88	*Vanilla planifolia*	Flat-leaved vanilla	Terrestrial or epiphytic South America Native to: Mexico and Central America	Fruits	Treats intestinal gas and fever, increases sexual desire, used as flavoring syrup and perfume fragrance	Rxlist (n.d.)

and mild uterine diseases (Pant 2013; Perfume workshop n.d.-a; Leander and Lüning 1967; Shanavaskhan et al. 2012; Devi et al. 2015; Panda and Mandal 2013; Nongdam 2014; Mishra et al. 2008). The paste of leaves of *Aerides multiflorum* is used for wounds, cuts, earaches, and consumed as a tonic (Perfume workshop n.d.-a; Baral and Kurmi 2006; Basu et al. 1971; Behera et al. 2013; Raja 2017). The leaf of *Aerides odorata* is applied in cuts, wounds, and tuberculosis, the fruit is used to heal the wound. Leave juice and seeds are used in treating boils in ear, nose, and skin disorders (Pant 2013; Perfume workshop n.d.-a; Leander and Lüning 1967; Baral and Kurmi 2006; Basu et al. 1971; Behera et al. 2013). The whole plant of *Anocetochilus elatus* is used to relief chest and abdominal pain and treats snake bites (Raja 2017; Sherif et al. 2012; Jiang et al. 2015).

The whole plant of *Anocetochilus formosanus* is used as an antipyretic, in detoxification, and treats tuberculosis, diabetes, bronchitis, infections in the kidney, bladder, cramps, snake bites, stomach ache, inflammation, hematemesis, nocturnal emission, nephritis, vaginal discharge, hepatitis, hypertension, and convulsions The plant possesses antioxidant, anti-hyperglycemic, hepatoprotective, anticancerous properties, and pharmacological effects, such as antiosteoporosis, antihyperliposis, and antifatigue (Perfume workshop n.d.-a; Aswandi and Kholibrina 2021; Nandkarni 1976). The leaf and stem of *Ansellia africana* are used for treating madness. Besides it also possesses anti-acetylcholinesterase activity in treating Alzheimer's disease (Saleh-E-In et al. 2021; Bhattacharyya and Staden 2016). The whole plant of *Arundina graminifolia* is used for curing rheumatic, trauma, bleeding, and snake bites. To relieve body aches root is used. In cracks scrapped bulbous stem is applied on the foot-heels (Pant 2013; Aswandi and Kholibrina 2021; Kumar 2002; Dakpa 2007).

Bletilla striata is used for tonic, against leucorrhea; leaves are used in treating lung disease; tubers are used for regeneration of muscle and other tissues, in hemorrhage dyspepsia, dysentery, fever, malignant ulcers, gastrointestinal disorders, anthrax, malaria, eye diseases, ringworm, tumors, necrosis, silicosis, traumatic injuries, coughs, chest pain, cures tuberculosis, sores, scaling, chapped skin, blood purification, strengthening, and lungs consolidation, malignant swellings, breast cancer, pustules ulcers, demulcent, and expectorant (Perfume workshop n.d.-a; Kong et al. 2003; Bulpitt et al. 2007). The *Bulbophyllum odoratissimum* plant is used to cure fractures, pulmonary tuberculosis, hernia pain, infusion, or decoction is used to treat tuberculosis and chronic inflammation (Perfume workshop n.d.-a; Chen et al. 2008; Bhattacharjee 1998). The entire plant of *Calanthe discolor* is used for improving blood flow, circulation, abscesses, scrofula, rheumatism, bone pain, and traumatic injuries, treating skin ulcers and hemorrhoids (Perfume workshop n.d.-a; Yoshikawa et al. 1998). *Changnienia amoena* plant cools the blood, acts as anti-heat and antitoxic, cures coughs, blood-streaked sputum, sores, and furuncles (Teoh 2016). The pseudo bulbs of *Coelogyne cristata* are used in constipation and aphrodisiac (Pant and Raskoti 2013; Subedi et al. 2011; Pamarthi et al. 2019). *Coelogyne stricta* pseudo bulb paste cures headaches and fever (Pamarthi et al. 2019; Yonzone et al. 2012). *Coelogyne flaccida* pseudo bulb paste cures headache and fever, juice helps in indigestion (Teoh 2016; Pant and Raskoti 2013; Pamarthi et al. 2019).

The rhizome paste of *Cymbidium aloifolium* is applied on fractured and dislocated bones. Bulbs are used as demulcent agents (Pamarthi et al. 2019). The root of *Cymbidium ensifolium* decoction used to treat gonorrhea and flower decoction used in eye sore disorders (Tsering et al. 2017). The leaves of *Cymbidium giganteum* are applied over wounds (Bulpitt 2005; Fonge et al. 2019; Linthoingambi et al. 2013). The seed of *Cymbidium goeringii* is used to treat cuts and injuries; entire plant parts are used in curing fractures (Teoh 2016). The leaf juice of *Cymbidium iridioides* is used to cease blood; its powder as a tonic; pseudo bulbs and roots are consumed in diarrhea (Aggarwal and Zettler 2010; Medhi and Chakrabarti 2009; Arditti et al. 1982; Arditti and Ernst 1984). The whole plant of *Cymbidium kanran* is used in heart purification, cures cough and asthmatic problems, and its roots are used to cure ascariasis and gastroenteritis. The whole plant of *Cymbidium lancifolium* is used in the treatment of rheumatism, improves blood flow, and traumatic injuries. The whole plant of *Cymbidium sinense* is used in purifying the heart, lungs; treat cough and asthma (Perfume workshop n.d.-a). The dried powdered pseudo bulb of *Cymbidium longifolium* is consumed on an empty stomach and fresh shoot is used for nervous disorders, madness, epilepsy, hysteria, rheumatism, and spasms. Salep used as demulcent (Zhan et al. 2016; Teoh 2016; Yonzone et al. 2013).

The powdered roots of *Cypripedium calceolus* promote sleep and reduce pain and tea prepared by the roots cures nerves and headaches (Singh and Dey 2005). The whole plant of *Cypripedium debile* is used for improving blood flow, swellings, pain, and diuretic. Likely, *Cypripedium formosanum* is used to improve blood flow, menses, expels gas, pain and itching whereas roots along with stems are used in treating malaria, snake bites, traumatic injury, and rheumatism. The roots and leaves of *Cypripedium guttatum* are used in treating epilepsy (Perfume workshop n.d.-a). The rhizomes, roots, and stems of *Cypripedium macranthos* are used to treat skin disease, promote dieresis, swelling, and pain and improve the flowing of blood; dried flowers are used to stop blood (Shimura et al. 2007). The rhizome of *Cypripedium parviflora* helps to treat insomnia, fever, headache, neuralgia, emotional tension, tumors, delirium, convulsions, anxiety, menstruate pain, and child birth (Moerman 1986; Grieve 1998; Kumar et al. 2005). The whole plant of *Cypripedium pubescens* is used as antispasmodic, diaphoretic, hypnotic, sedative, tonic, diabetes, diarrhea, dysentery, paralysis, and malnutrition, also in cases of nervous irritability, functions of the brain and promotes sleep. The dry powder roots are used as drugs for joint pains and treating stomach worms (Singh and Duggal 2009; Khory 1982).

The tubers of *Dactylorhiza hatagirea* are used as food and tonic and help in healing wound and fever and control burns and bleeding (Arditti 1992, 1967, 1968; Aggarwal and Zettler 2010; Arditti et al. 1982; Arditti and Ernst 1984). The leaves and pseudo bulb paste of *Dendrobium amoenum* are applied on skin diseases, burnt skin, and dislocated bones (Venkateswarlu et al. 2002). The leaf paste of *Dendrobium aphyllum* is applied on deformed abnormal head of a new born baby in order to form a normal shape (Pant 2013). The leaves of *Dendrobium candidum* are used to treat diabetes (Wu et al. 2004). The stem of *Dendrobium chrysanthum* is used as a tonic, enhances the immune system, and reduces fever. Leaves are used as antipyretic and mild skin diseases, which benefit the eyes (Bulpitt 2005; Jalal et al.

2008, 2010; Li et al. 2016). The whole plant of *Dendrobium chrysotoxum* possesses antitumorous and anticancerous properties, stem and flower extract is used as tonic and leaf extract as antipyretic (Bulpitt et al. 2007; Sood et al. 2006; Joshi et al. 2009). The pseudo bulb paste of *Dendrobium crepidatum* is used in fractured and dislocated bones. Stems are used as a tonic, in arthritis and rheumatism (Joshi et al. 2009; Reddy et al. 2001; Joshi and Joshi 2001). The leaves of *Dendrobium crumenatum* are used to cure boils and pimples (Joshi and Joshi 2001). The pseudo bulb pulps of *Dendrobium densiflorum* are used to cure boils, pimples, and various skin eruptions, leaf paste is applied upon fractures bones, sprains, and inflammations (Arditti 1992; Arditti et al. 1982; Arditti and Ernst 1984). The dried stems of *Dendrobium devonianum* is used as an enhancer for the immune system (Cakova et al. 2017). The stem of *Dendrobium draconis* are used in antipyretic and hematinic (Perfume workshop n.d.-b). The whole plant of *Dendrobium fimbriatum* is used during upset of the liver and severe anxiety; leaves are used in bone fracture and as a tonic, the pseudo bulbs are used in fever (Aggarwal and Zettler 2010; Arditti et al. 1982). The pseudo bulb paste of *Dendrobium heterocarpum* is used in treating fractured and bone dislocate (Arditti and Ernst 1984). The root, stem, and leaf of *Dendrobium lasianthera* act as anticancer (Utami et al. 2017).

The whole plant juice of *Dendrobium longicornu* is added to lukewarm water to bath for fever; roots are boiled to feed the livestock, to remove cough; stem juice is used to treat fever (Perfume workshop n.d.-b). The tender shoot tip juice of *Dendrobium macrostachyum* is used for earaches (Zhan et al. 2016). The pseudo bulb paste of *Dendrobium moschatum* is used for dislocated and fractured bone (Reddy et al. 2001). The pseudo bulb extracts of *Dendrobium nobile* are used in treating burns, and eye infections; the plant is used to cure pulmonary tuberculosis, fever, general debility, flatulence, dyspepsia, reduce salivation, parched, thirsty mouth, night sweats, antiphlogistic, and tonic. Seeds are used to heal wounds; stems to cure fever and tongue dryness; stems are used in longevity, aphrodisiac, stomachic, and analgesic (Aggarwal and Zettler 2010; Arditti et al. 1982; Arditti 1967). Whole plant juice of *Dendrobium ovatum* cures stomach aches, excites bile, and is a laxative for the intestines, curing constipation (Kirtikar and Basu 1981; Caius 1986). The dried stem of *Dendrobium primulinum* acts as an enhancer for the immune system (Pant and Thapa 2012). The pseudo bulb paste of *Dendrobium transparens* is used in treating fractures and dislocated bones (Arditti and Ernst 1984). The stem of *Dendrobium trigonopus* is used to cure fever and anemia (Perfume workshop n.d.-b). *Doritis pulcherrima* leaf is used to treat ear infections (Perfume workshop n.d.-c).

The whole plant of *Eria bambusifolia* is used in treating hyper acidity and various stomach aches (Zhan et al. 2016). The tubers of *Eulophia dabia* tubers are used as a tonic and aphrodisiac help to cure stomach aches, and stimulate blood flow, also used for consumption mixed with milk, sugar, and flavored species (Panwar et al. 2022). The tuber of *Eulophia epidendraea* is applied upon boils; controls pain in breast feeding mother; cures tumor and diarrhea; acts as an appetizer, anthelmintic, aphrodisiac, stomachic, worm infestation, stimulate appetite and purifies blood during heart troubles (Narkhede et al. 2016). The whole plant of *Eulophia nuda* is used in stomachache and snake bites; the stems are used to stop bleeding and trauma pain; a thick paste of tuber is applied on the stomach to kill intestinal worms, cures rheumatoid arthritis, bronchitis, scrofulous glands, tumors, purifies blood, used as a tonic, acts as anti-aphrodisiac, demulcent, and anthelmintic. The leaf is used as a vermifuge (Hada et al. 2020). The tuber of *Gastrodia elata* is used to cure stroke, tetanus, migraine, headaches, backache, skin boils, ulcers, and pain in the lower extremities; for generalized dermatitis dizziness, sleepiness, insomnia, high blood pressure, blood circulation, rheumatism, numbness, and paralysis (Chen et al. 2014). The root paste of *Geodorum densiflorum* is applied on insect bites and wounds; the root paste by mixing with ghee and honey to correct menstrual disorders and the poultice made from pseudo bulbs is used as a disinfectant (Sheelavantmath et al. 2000). The stem of *Gymnadenia conopsea* helps the kidney, treats cough, lactation failure, sexual dysfunction, traumatic injuries, thrombosis, and chronic hepatitis (Gustafsson 2000).

The leaves and roots *of Habenaria edgeworthii* act as cooling and spermopiotic; the pseudo bulb of *Habenaria pectinata* is used during diathesis bleeding, burning sensation, fever, and phthisis (Singh and Duggal 2009). The root of *Herminium lanceum* is beneficial for the lungs and kidneys, strengthens muscles, bones, stops bleeding, and treats tuberculosis (Perfume workshop n.d.-d). The whole plant of *Liparis odorata* is soaked in wine for external use; tubers are used during stomach disorders (Perfume workshop n.d.-e). The pseudo bulb of *Malaxis acuminata* is used as a tonic, aphrodisiac, styptic, antidysentery, and febrifuge (Pushpa et al. 2011). The stem and leaves of *Papilionanthe teres* are used for improving blood flow and reducing swellings. The whole plant of *Pholidota articulata* is used to remove gas and reduce swelling, treat coughs, headaches, dizziness, ulcers, sores, traumatic injuries, uterine, and menses problems. The roots and pseudo bulb paste of *Pholidota pallida* are used to cure fever and induce sleep and juice to remove abdomen pain. The whole plant of *Platanthera chlorantha* is used to strengthen the kidneys and lungs, hernia, and sexual dysfunction (Perfume workshop n.d.-c).

The leaves and roots paste of *Rhynchostylis retusa* are used in rheumatism, leaf juice is used in constipation, gastritis, acidity, and as emollient; root juice is used to heal cuts and wounds; root is used to treat menstrual pain and arthritis; dry flower is used as emetic (Basu et al. 1971; Dakpa 2007; Bulpitt et al. 2007; Bhattacharjee 1998; Dash et al. 2008). Tubers of *Satyrium nepalense* are used to treat diarrhea, dysentery, and malaria, consumed as an aphrodisiac, and used as a children's growth supplement. Juice is used in cuts and wounds (Gutierrez 2010; Baral and Kurmi 2006; Basu et al. 1971; Behera et al. 2013; Bulpitt et al. 2007). The pseudo bulb of *Spathoglottis plicata* is used in rheumatic swelling; the hot fomentation is pressed on to draw out pus from the infected part, helps in proper blood flow and reduces pain (Friesen and Friesen 2012). The whole plant of *Thunia alba* is used in treating cough, pneumonia, bronchitis, bone break treatment, and injury (Mathew 2013).

The flower juice of *Vanda coerulea* is used in treating glaucoma, cataract, and blindness. The root of *Vanda roxburghii* is used to treat fever, dyspepsia, bronchitis, cough, piles, snake bites, rheumatism, allied disorders, and nervous system disease (Uprety et al. 2010). The dried flower powdered juice of *Vanda spathulata* are used to treat asthma, depression, enhance memory, antioxidant activity, and alleviate chronic disease, and degenerative ailments such as cancer, autoimmune disorders, hypertension, delay in aging process, and atherosclerosis (Jeline et al. 2021). The leaf of *Vanda tessellata* is used in inflammation, rheumatism, dysentery, bronchitis, dyspepsia, and fever (Chowdhury et al. 2014). The leaf, root, and flower powdered extract of *Vanda testacea* is used in nervous disorders, piles, inflammations, rheumatism, bronchitis, and anti-cancerous drugs (Kaur and Bhutani 2009). The fruit of *Vanilla planifolia* is used to treat intestinal gas and fever, increase sexual desire, used as flavoring syrup and perfume fragrance (Rxlist n.d.).

The phytochemicals such as alkaloids, flavonoids, and glycosides made the orchids therapeutically important (Hossain 2011); they are, however, mainly used as nutraceuticals because the active principles responsible for their medicinal properties are yet to be identified with further accuracy.

7 Phytochemistry

Gas Chromatography and Mass Spectrometry (GC/MS) analyzed the essential oil and the oleoresins for various medicinal orchids. In our present study, we accessed and summarized the phytochemicals of 45 orchid species (Table 3).

Major phytochemicals reported in *Ansellia africana* namely n-Hexanal, Mesityl oxide, 4-Heptenoic acid, 3,3-dimethyl-6-oxo-methyl ester, Pentadecanoic acid, Succinic acid, 3,7-dimethyloct-6-en-1-yl pentyl ester, Linoleic acid, Linolenic acid, l-Ascorbyl 2,6-Dipalmitate, Toluene, Ethylbenzene, Mesitylene, Erythro-1-Phenylpropane-1,2-diol, Styrene, Hyacinthin, 2-Ethylbutyric acid, 3-methylbenzylester which possess cytotoxic effect against cancerous cell line (Saleh-E-In et al. 2021). Gramniphenol, a potent marker reported in *Arundina graminifolia* showed anti-tobacco mosaic virus activity (Gao et al. 2012). Phytochemicals of *B. striata* showed major biological activity in aiding hemostasis, cytotoxicity, antimicrobial, anti-inflammation, anti-oxidation, immunomodulation, anti-fibrosis, antiaging, and anti-allergy (He et al. 2017). Densiflorol B, the most active compound reported from *Bulbophyllum odoratissimum* exhibit cytotoxic activity against the five tested cell lines (Chen et al. 2008). Major stilbenoids, flaccidin, oxo flaccidin and isoflaccidin were reported in *Agrostophyllum callosum, Coelogyne flaccida (*Majumder and Maiti 1988, 1989, 1991*;* Majumder et al. 1995*)*. 5-hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1 → 6)]-β-D-glucoside, an alpha-glucosidase inhibitor reported from *Dendrobium devonianum (*Sun et al. 2014*)*. Sesquiterpene such as alloaromadendrene, emmotin, and picrotoxane from *Dendrobium nobile* possesses immunomodulatory potential (Ye et al. 2002). Dendroparishiol a marker reported from *Dendrobium parishii* exhibited antioxidant and anti-inflammatory activity against RAW264.7 cells (Kongkatitham et al. 2018). 9, 10-dihydrophenanthrene, a novel marker reported from *Eria bambusifolia* showed anticancer activity against the human cell line (Rui et al. 2016). Major aromatic phytochemicals were reported in *Platanthera chlorantha* namely β-Ocimene, Lilac

Table 3 Screening of phytochemicals in some medicinal orchids

Sl. No.	Species	Phytochemicals	References
1	*Anacamptis pyramidalis*	Disaccharide, Citric acid, Parishin G isomer-1, Parishin G isomer-2, Gastrodin derivative, Parishin B, Gastrodin derivative, Parishin C, Dihydroxybenzoic acid derivative, Caffeic acid derivative, Acacetin derivative, Oxo-dihydroxy-octadecenoic acid, Trihydroxy-octadecenoic acid	Fawzi Mahomoodally et al. (2020)
2	*Ansellia africana*	2,4,4-Trimethyl-1-hexene, 2-Hexene, 2,5,5-trimethyl, 2,3-Dimethyl-2-heptene, Cyclopentane, 1,2,3,4,5-pentamethyl, pentane, 1,2,3,4,5-pen, Nonane 4,5 dimethyl, Octane 5-ethyl-2-methyl, n-Decane, 1-Undecane, 4-methyl, Dodecane, Cyclohexane, (1,2,2-trimethylbutyl), tetradecane, pentadecane, Hexadecane 4-methyl, heptadecane, Nonadecanol, Lignoceric alcohol, cis-4-Hexen-1-ol, n-Hexanal, Mesityl oxide, 4-Heptenoic acid, 3,3-dimethyl-6-oxo-methyl ester, Pentadecanoic acid, Succinic acid, 3,7-dimethyloct-6-en-1-yl pentyl ester, Linoleic acid, Linolenic acid, l-Ascorbyl 2,6-Dipalmitate, Toluene, Ethylbenzene, Mesitylene, Erythro-1-Phenylpropane-1,2-diol, Styrene, Hyacinthin, 2-Ethylbutyric acid, 3-methylbenzylester	Saleh-E-In et al. (2021)
3	*Arundina graminifolia*	graminibiben-zyls A, 5,12-dihydroxy-3-methoxybibenzyl-6-carboxylic acid, dihydropinosylvin, 2,5,2′,5′-tetrahydroxy-3-methoxybibenzyl, rhapontigen, pinosylvin, bauhiniastatin D, arundinaol, coelonin, cucapitoside, blestriarene A, isoshancidin, obovatin, kaempferol-β-3-O-glycos, dihydropinosylvin, 4′--methylpinosylvin, 3-(γ,-γ-dimethylallyl)resveratrol, 5-(γ,γ dimethylallyl)oxyresveratrol, 3-hydroxy-4,3′,5′-trimethoxy-trans-stilbene, gramniphenol, 9'-dehydroxy-vladinol, vladinol F,	Gao et al. (2012), Hu et al. (2013), Zhang et al. (2021)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		9-O-β-D-xylopyranoside-vladinol F, 4,9-dihydroxy-4',7-epoxy-8',9'-dinor-8,5'-neolignan-7'-oic acid	
4	*Bletilla striata*	3,3′-dihydroxy-5-methoxybibenzy, gigantol, 5,4′-dimethoxybibenzyl-3,3′-diol, 3′-hydroxy-5-methoxybibenzyl-3-O-β-D-glucopyranoside, 5-hydroxy-4-(p-hydroxybenzyl)-3′,3-dimethoxybibenzyl, bulbocol, gymconopin D, bulbocodin D, blestritin B, 4,7-dihydroxy-2-methoxy-9,10-dihydrophenanthrene, 9,10-dihydro-4,7-dimethoxyphenanthrene-2,8-diol, blestriarene A, 2,4,7-trimethoxy-phenanthrene, 7-hydroxy-2-methoxyphenanthrene-3,4-dione, 3′,7′,7-trihydroxy-2,2′,4′--trimethoxy-[1,8′-biphenanthrene]-3,4-dione, cyclomargenone, β-sitosterol, stigmasterol, protocatechuic acid, cinnamic acid, p-hydroxybenzaldehyde, 3,7-dihydroxy-2,4,8-trimethoxyphenanthrene, 9,10-dihydro-4,7-dimethoxyphenanthrene-2,8-diol, 9,10-dihydro-1-(4'-hydroxybenzyl)-4,7-dimethoxyphenanthrene-2,8-diol, 3',4"-dihydroxy-5',3",5"-trimethoxybibenzyl, batatasin III	He et al. (2017), Woo et al. (2014)
5	*Bulbophyllum odoratissimum*	Moscatin, 7-hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene, coelonin, densiflorol B, gigantol, batatasin III, Tristin, vanillic acid, syringaldehyde, 3,7-Dihydroxy-2,4,6-trimethoxyphenanthrene, Bulbophyllanthrone	Chen et al. (2008), Sharifi-Rad et al. (2022)
6	*Coelogyne cristata*	Coelogin, coeloginin, 3,5,7-trihydroxy-1,2-dimethoxy-9,10-dihydrophenanthrene, 3,5,7-trihydroxy-1,2-dimethoxyphenanthrene	Majumder et al. (2001)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
7	*Coelogyne flaccida*	Callosin, flaccidin, oxoflaccidin, 2,7-dihydroxy-6-methoxy-5H-phenanthro [4,5-bcd] pyran-5-one	Majumder and Sen (1991), Majumder and Maiti (1988, 1989), Majumder et al. (1995)
8	*Cymbidium aloifolium*	1,2 diarylethanes, 9,10 dihydrophenanthrene, 6-0-methylcoelonin, batatasin III, coelonin, gigantol, 5-hydroxy-3-methoxy-1,4-phenanthraquinone, Friedelin, sitosterol, n-hexadecanoic acid, 9,12-octadecadienoic acid, 9,12,15-octadecatrienoic acid, octadecanoic acid, phytol; 2-butyne; 2-cyclopenten-1-one; and 1,4-benzenedicarboxylic acid	Juneja et al. (1987), Barua et al. (1990), Rampilla and Khasim (2020)
9	*Cymbidium ensifolium*	Cymensifins, cypripedin, and gigantol	Jimoh et al. (2022)
10	*Cymbidium finlaysonianum*	1-(4-Hydroxybenzyl)-4,6-dimethoxy-9,10-dihydrophenanthrene-2,7-diol, Cymbinodin-A	Lertnitikul et al. (2018)
11	*Cymbidium giganteum*	1,2-diarylethane, gigantol, 4ξ-(β-d-glucopyranosyloxymethyl)-14-α-methyl-22ξ, 24ξ, 25,28-tetrahydroxy-9,19-cyclo-5α,9-β-ergostan-3-one	Juneja et al. (1985), Dahmén and Leander (1978a)
12	*Cymbidium goeringii*	Gigantol	Won et al. (2006)
13	*Cymbidium kanran*	Vicenin-2, Schaftoside isomer, Schaftoside, Vicenin-3, Vitexin, Isovitexin	Jeong et al. (2017)
14	*Dendrobium amoenum*	3,4′-dihydroxy-5-methoxybibenzyl and 4,4′-dihydroxy-3,3′,5-trimethoxybibenzyl, 3,4,5-trimethoxybenzaldehyde, picrotoxinin, aduncin, 9,10-dihydro-5H-phenanthro-(4,5-*b*,*c*,*d*)-pyran, amoenumin, (E)-13-docosenoic acid; oleic acid; 11-octadecenoic acid, methyl ester; and hexadecanoic acid, 2,3-dihydroxypropyl ester, aphyllone B, (R)-3,4-dihydroxy-5,4′,α-trimethoxybibenzyl, 4-[2-[(2S,3S)-3-(4-hydroxy-3,5-dimethoxyphenyl)-2-hydroxymethyl-8-methoxy-2,3-dihydrobenzo (Stewart and Griffith	Venkateswarlu et al. (2002), Majumder et al. (1999), Dahmén and Leander (1978b), Veerraju et al. (1989), Paudel and Pant (2017)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		1995; Kaushik 1983) dioxin-6-yl] ethyl]-1-methoxyl benzene, dendrocandin B, 4,4′-dihydroxy-3,5-dimethoxybibenzyl, 3,4-dihydroxy-5,4′--dimethoxybibenzyl, 3-O-methylgigantol, dendrophenol, gigantol, dendrocandin C, dendrocandin D, and 3,3′,4,4′--tetrahydroxy-5-methoxybibenzyl	
15	*Dendrobium candidum*	3,4′-dihydroxy-5-methoxybibenzyl, uridine, sucrose, adenosine	Li et al. (2008, 2009)
16	*Dendrobium chrysanthum*	Denchrysan B, dengibsin, moscatin, dendroflorin, denchrysan A, moscatilin, gigantol, batatasin III, Tristin, 4,9-dimethoxy-2,5-dihydroxyphenanthrene, 3,4-dihydroxybenzoic acid, dibutyl phthalate, stigmasterol, β-sitosterol, daucosterol	Li et al. (2016)
17	*Dendrobium chrysotoxum*	Chrysotoxols A and B, bibenzyls, phenanthrenes, fluorenones, coumarin, flavonoid, gigantol, 3-O-methylgigantol, moscatilin, 4-[2-(3-hydroxy-4-methoxyphenyl) ethyl]-2,6-dimethoxyphenol, crepidatin, chrysotoxine, erianin, isoamoenylin, batatasin III, tristin, nobilin C, moscatin, 2,5-dihydroxy-4,9-dimethoxyphenanthrene, confusarin, nudol, fimbriatone, 1,5,6,7-tetramethoxy-2-hydroxyphenanthrenol, 7-hydroxy-2,3,4-trimethoxyphenanthrene, 1,2,6,7-tetrahydroxy-4-methoxyphenanthrene, 2,4-dihydroxy-7-methoxy-9,10-dihydrophenanthrene, erianthridin, 2,5-dihydroxy-4-methoxy-9,10-dihydrophenanthrene, 1,4,7-trihydroxy-5-methoxy-9H-fluoren-9-one, nobilone, 6-methylesculetin, and homoeriodictyol	Hu et al. (2012), Liu et al. (2022)
18	*Dendrobium crepidatum*	Crepidatuols A, (±)-homocrepidine A, Crepidatin, crepidatumines A and B,	Li et al. (2013), Hu et al. (2016), Xu et al. (2020, 2019b), Ding et al. (2021)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		dendrocrepidine B, crepidatumines C and D, crepidine, isocrepidamine, crepidamine, octahydroindolizine	
19	*Dendrobium densiflorum*	Densiflorol, Dendroflorin	Fan et al. (2001)
20	*Dendrobium devonianum*	Quercetin, Taxifolin, Rutin, Luteolin, Kaempferol, Myricetin, (−)-Epiafzelechin, 5-Hydroxyauranetin, 6-C-Hexosyl-hesperetin O-hexoside, 8-C-Hexosyl-apigenin O-feruloylhexoside, 8-C-Hexosyl-apigenin O-hexosyl-O-hexoside, 8-C-Hexosyl-chrysoeriol O-feruloylhexoside, Isorhamnetin hexose-malonate, Isorhamnetin O-acetyl-hexoside, Isorhamnetin-3-O-rutinoside, Isoschaftoside, Isovitexin, Isovitexin 7-O-glucoside, Jaceosidin, Kaempferide 3-O-β-D-glucuronide, Ladanein, Naringenin, Nepetin, Peonidin 3-O-glucoside chloride, Pinobanksin, Quercitrin, Rhoifolin, Schaftoside, Tamarixetin, Tangeretin, Tricin 7-O-hexoside, Tricin 7-O-hexosyl-O-hexoside, Tricin O-malonylhexoside, Tricin O-saccharic acid, Tricin O-sinapoylhexoside, Violanthin, Vitexin, Vitexin 2''-O-β-L-rhamnoside, Vitexin-2-O-D-glucopyranoside, 5-hydroxy-3-methoxy-flavone-7-O-[β-d-apiosyl-(1 → 6)]-β-d-glucoside	Zhao et al. (2021), Sun et al. (2014)
21	*Dendrobium draconis*	5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone, hircinol, gigantol, batatasin, 7-methoxy-9,10-dihydrophenanthrene-2,4,5-triol	Sritularak et al. (2011)
22	*Dendrobium fimbriatum*	Plicatol B, hircinol, plicatol A, and plicatol C, 1 bibenzyl (3′,4-dihydroxy-3,5′-dimethoxybibenzyl), furostanol, protodioscin, Denfigenin, gigantol-5-O-β-d-glucopyranoside, 9,10-dihydro-aphyllone A-5-O-β-d-	Talapatra et al. (1992), Xu et al. (2017), Favre-Godal et al. (2022)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		glucopyranoside, ficusal-4-O-β-d-glucopyranoside, botrydiol-15-O-β-d-glucopyranoside	
23	*Dendrobium heterocarpum*	Methyl 3-(4-hydroxyphenyl) propionate, 3,4-dihydroxy-5,4'--dimethoxybibenzyl, dendrocandin B, dendrofalconerol A, syringaresinol, batatasin III, 3-*O*-methylgigantol, gigantol, moscatilin, dendrocandin A, (S)-3,4,-α-trihydroxy-4′,5-dimethoxybibenzyl, densiflorol A, dendrocandin I, dendrocandin F, coelonin, carthamidin, 4-hydroxy-2-methoxy-3,6-dimethylbenzoic acid	Warinhomhoun et al. (2022), Xiao-bei et al. (2019)
24	*Dendrobium longicornu*	Longicornuol A, 4-[2-(3-hdroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol, 5-hydroxy-7-methoxy-9,10-dihydrophenanthrene-1,4-dione, 7-methoxy-9,10-dihydrophenanthrene-2,4,5-triol, *erythro*-1-(4-*O-β-D*-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol, Longicornuol B	Hu et al. (2008b, 2010)
25	*Dendrobium nobile*	Vitamin A Aldehyde; Longifolene; 1-Heptatriacotanol; Z,Z6,28-Heptatriactontadien-2-One and Dendroban-12-One, alloaromadendrane, emmotin, picrotoxane, dendronobilate, 4-*O*-demethyl-nobilone, dendronobilate, 4-*O*-demethyl-nobilone	Ye et al. (2002), Cao et al. (2021), Meitei et al. (2019)
26	*Dendrobium ovatum*	Stilbenoid	Pujari et al. (2021)
27	*Dendrobium parishii*	(−)-Dendroparishiol	Kongkatitham et al. (2018)
28	*Dendrobium primulinum*	2,4,7-trihydroxy-9,10-dihydrophenanthrene, denthyrsinol, moscatin, moscatilin, gigantol, batatasin III, tristin, 3,4,5-trihydroxybibenzyl, 3,6,9-	Ye et al. (2016)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		trihydroxy-3,4-dihydroanthracen-1 (2H)-one, -sitosterol, -daucosterol	
29	*Dendrobium thyrsiflorum*	Denthyrsin, denthyrsinol, denthyrsinone, 2,3,5-Trihydroxy-4-methoxyphenanthrene, 3,7-Dihydroxy-2,4-dimethoxyphenanthrene, 2,7-Dihydroxy-1,5,6-trimethoxyphenanthrene, Syringaresinol, Pinoresinol, Ayapin, Scopoletin, and 6,7-Dimethoxycoumarin, 4, 7-dihydroxy-2-methoxy-9, 10-dihydrophenan-threne, syringaldehyde, moscatin, gigantol, batatasin Ill, tristin, stigmasterol	Zhang et al. (2005), Wrigley (1960), Ruixuan et al. (2015)
30	*Dendrobium trigonopus*	Trigonopols A and B, gigantol, tristin, moscatin, hircinol, naringenin, 3-(4-hydroxy-3-methoxyphenyl)-2-propen-1-ol, (−)-syringaresinol	Hu et al. (2008a)
31	*Eria bambusifolia*	Erathrins A and B, bambusifolia, batatasin III, tristin, 3-hydroxy-5-methoxy bibenzyl, gigantol, 3′,5-dimethoxy-9,9′-diacetyl-4,7′-epoxy-3,8′-bilign-7-ene-4′--methol, and balanophonin	Rui et al. (2016)
32	*Eulophia epidendraea*	β-sitosterol, β-sitosterol glucoside, β-amyrin, lupeol	Maridass and Ramesh (2010)
33	*Eulophia nuda*	Eulophiol, Nudol, 2,3,4,7-tetramethoxyphenanthrene, 9,10-dihydro-4-methoxyphenanthrene-2,7-diol, l,5-dimethoxyphenanthrene-2,7-diol, 1,5,7-trimethoxyphenanthrene-2,6-diol, 5,7-dimethoxyphenanthrene-2,6-diol, 4,4,8,8-tetramethoxy-[1,1-biphenanthrene]-2,2,7,7-tetraol, 2,2,4,4,7,7,8,8-octamethoxy-1,1-biphenanthrene, Lupeol, 9,10-dihydro-2,5-dimethoxyphenanthrene-1,7-diol, 9,10-dihydro-4-methoxyphenanthrene-2,7-diol, 1,5-dimethoxyphenanthrene-2,7-diol, 1,5,7,-trimethoxyphenanthrene-2,6-diol,	Hada et al. (2020), Bhandari et al. (1985), Tuchinda et al. (1988)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		5,7-dimethoxyphenanthrene-2,6-diol, and 4,4′,8,8′-tetramethoxy [1,1′-biphenanthrene]-2,2′,7,7′--tetrol. 4-Hydroxybenzaldehyde, 4-hydroxybenzyl alcohol, 2,7-dihydroxy-3,4-dimethoxyphenanthrene	
34	*Gastrodia elata*	Parishins B and C, gastrodin A, gastrol A	Lin et al. (1996), Li et al. (2007)
35	*Gymnadenia conopsea*	Gymnoside, loroglossin, dactylorhin, daucosterol, dioscin, gymconopin, blestriarene, 2,6-dimethoxy phenol, eugenol, 4-hydroxybenzene, 4-methoxy phenylpropanol, 4-ethoxy phenylpropanol, contra-hydroxybenzyl, dithioether, syringol, syringaldehyde, gastrodin, arabinose, xylose, lupenone, 4,4-dimethyl-5α-cholesta-8,14,24-trien-3β-ol, lupeol, cirsimarin, astragalin, kaempferol-7-O-glucoside, desmethylxanthohumol, isorhamnetin, naringenin chalcone, equol, galangin, 1-((4-hydroxyphenyl)methyl)-4-methoxy-2,7-phenanthrenediol, gymconopin A,9,10-dihydro-2-methoxy-4,5-phenanthrenediol, blestriarene A, gymconopin, blestriarene B	Gustafsson (2000), Shang et al. (2017)
36	*Liparis odorata*	Anodendrosin A, Liparisglycoside, Liparis alkaloid, 4-(O-β-D-Glucopyranosyl)-3,5-bis(3-methyl-2-butenyl) benzoic acid, Adenosine, D-α-2-Alanin, p-Hydroxybenzoic acid	Liang et al. (2019)
37	*Malaxis acuminata*	Catechin, phloridzin, rutin, Caffeic acid, chlorogenic acid, ellagic acid, 3-hydroxy benzoic, 4-hydroxy benzoic, protocatechuic acid, 3-hydroxy cinnamic acid, p-coumaric acid, Stigmasterol and β-sitosterol, Sibutramine, limonene, diethylene glycol, p-cymene, eugenol, benzene, piperitone, glycerol, ribitol, and myo-inositol, 6-octadecenoic acid,	Suyal et al. (2020)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		8-octadecenoic acid, 9-octadecenal, batatasin III, bulbophythrin A, butyl oleate, cerasynt, cis-oleic acid, cyclopentadecanolide, diethyl phthalate, cyclopentanetridecanoic acid	
38	*Phalaenopsis cornucervi*	1,2-saturated pyrrolizidine mono-esters, T-phalaenopsine	Frölich et al. (2006)
39	*Pholidota pallida*	Oelonin, lusianthridin, flavanthrin, batatasin-III, 3′,5-dihydroxy-2-(4-hydroxybenzyl)-3-methoxybibenzyl, gigantol, 3-[2-(3-hydroxyphenyl) ethyl]-2,4-bis[(4-hydroxyphenyl) methyl]-5-methoxyphenol, hydroxytyrosyl butyrate, (24R)-ethylcholest-5-en-3-ol-7-one, taraxerone, friedelin, hydroxytyrosyl	Yu et al. (2021)
40	*Platanthera chlorantha*	β-Ocimene, Lilac aldehyde, β-Elemene, α-Bergamotene, Cedrene, Germacrene D, Pentadecane, b-Bisabolene, b-Sesquiphellandrene, 1,2,3-Trimethoxy-5-(2-propenyl) benzene, Tetradecanal, Benzophenone, Galaxolide, Docosane, Tetradecyl benzoate	D'Auria et al. (2020)
41	*Platanus acerifolia*	5,7,40-trihydroxy-8-(1, 1-dimethylallyl)-30-methoxyflavonol, 5,7,40-trihydroxy-60-prenyl-30-methoxyflavonol, Kaempferol-3-O-a-L-(300-E-p-coumaroyl)-rhamnoside, Quercetin-3-O-α-l-(2″-E-p-coumaroyl-3″-Z-p-coumaroyl)-rhamnopyranoside (E, Z-3′-hydroxyplatanoside, and quercetin-3-O-α-l-(2″-Z-p-coumaroyl-3″-E-p-coumaroyl)-rhamnopyranoside (Z,E-3′--hydroxyplatanoside, 8-methoxy-6-*C*-methyl-5,7-dihydroxyflavonol, 8-*C*-(1,1-dimethyl-2-propen-1-yl)-5,7-dihydroxyflavonol, and 8-*C*-(1,1-dimethyl-2-propen-1-yl)-4′--methoxy-5,7-dihydroxyflavonol	Wu et al. (2022), Kaouadji (1989), Thai et al. (2016)
42	*Thunia alba*	Batatasin-III, lusianthridin, 3,7-dihydroxy-2,4-	Majumder et al. (1998), Ya-ping et al. (2019), Yan et al. (2016)

(continued)

Table 3 (continued)

Sl. No.	Species	Phytochemicals	References
		dimethoxyphenanthrene, 3,7-dihydroxy-2,4,8-trimethoxyphenanthrene, cirrhopetalanthrin and flavanthrin, hircinol, scoparone, β-sitosterol, 3,7-dihydroxy-2,4-dimethoxyphenanthrene, lusianthridin, coelonin, thunalbene	
43	*Vanda coerulea*	Imbricatin, methoxycoelonin, gigantol, phenanthropyrans, bibenzyl, dihydrophenanthrenes	Simmler et al. (2009)
44	*Vanda tessellate*	Tessalatin, Oxo-tessallatin, 2,5-Dimethoxy-6,8-dihydroxy iso-flavone, Gallic acid, 2.7.7-Trimethyl bicycle () heptanes, Octacosanol, Heptacosane	Khan et al. (2019)
45	*Vanda roxburghii*	Stigmasterol, γ-sitosterol, β-sitosterol, β-sitosterol-D-glucoside, tetracosylferulate	Khan et al. (2019)
46	*Vanilla planifolia*	Vanillin	Podstolski et al. (2002)

aldehyde, β-Elemene, α-Bergamotene, Cedrene, Germacrene D, Pentadecane, b-Bisabolene, b-Sesquiphellandrene, 1,2,3-Trimethoxy-5-(2-propenyl) benzene, Tetradecanal, Benzophenone, Galaxolide, Docosane, Tetradecyl benzoate (D'Auria et al. 2020). Quercetin-3-O-α-L-(2″-E-p-coumaroyl-3″-Z-p-coumaroyl)-rhamnopyranoside (E, Z-3′-hydroxyplatanoside and quercetin-3-O-α-L-(2″-Z-p-coumaroyl-3″-E-p-coumaroyl)-rhamnopyranoside (Z, E-3′-hydroxyplatanoside) markers reported from *Platanus acerifolia*. The leaves exhibit antimicrobial activity against *Staphylococcus aureus (*Wu et al. 2022*)*. Phytochemicals reported in genus *Vanda* possess major pharmacological activities, markers such as stigmasterol, γ-sitosterol, β-sitosterol, β-sitosterol-D-glucoside, tetracosylferulate possess anti-aging, antimicrobial, anti-inflammatory, antioxidant, neuroprotective, membrane stabilizing, and hepato-protective activities (Khan et al. 2019).

7.1 Secondary Metabolites

A wide range of secondary metabolites is present in Orchids, of which only a very slight portion was analyzed. Normally several phytochemicals viz., alkaloids, saponins, flavonoids, anthocyanins, carotenoids, polyphenols, sterols, etc. were produced and integrated into in vitro culture of orchids (Mulabagal and Tsay 2004; Yesil-Celiktas et al. 2007; Shinde et al. 2010). Among them, polyphenols were responsible for their crucial role in curing many degenerative and age-linked ailments (Brewer 2011; Procházková et al. 2011). Likely, other bioactive compounds like flavonoids, tannins, and alkaloids were bestowed for the medication of several chronic diseases (Lu et al. 2004; Zhang et al. 2005; Harris and Brannan 2009).

7.1.1 Bioactive Compounds

Various plant parts (leaf, root, and pseudobulb) of orchids possess a group of important phenolic acids such as gentisic acid, gallic acid, salicylic acid, protocatechuic acid, syringic acid, caffeic acid, sinapic acid, ferulic acid as well as flavonoids viz., catechin, apigenin, myricetin, naringin, rutin, quercetin, kaempferol, and alkaloids viz., chysine, drobine, dendronine, grandifolin, crepidine, and vanilin in higher concentration. In in vitro raised plants, bioactive compounds were more dominant than in wild plants of medicinal orchids (Fig. 2).

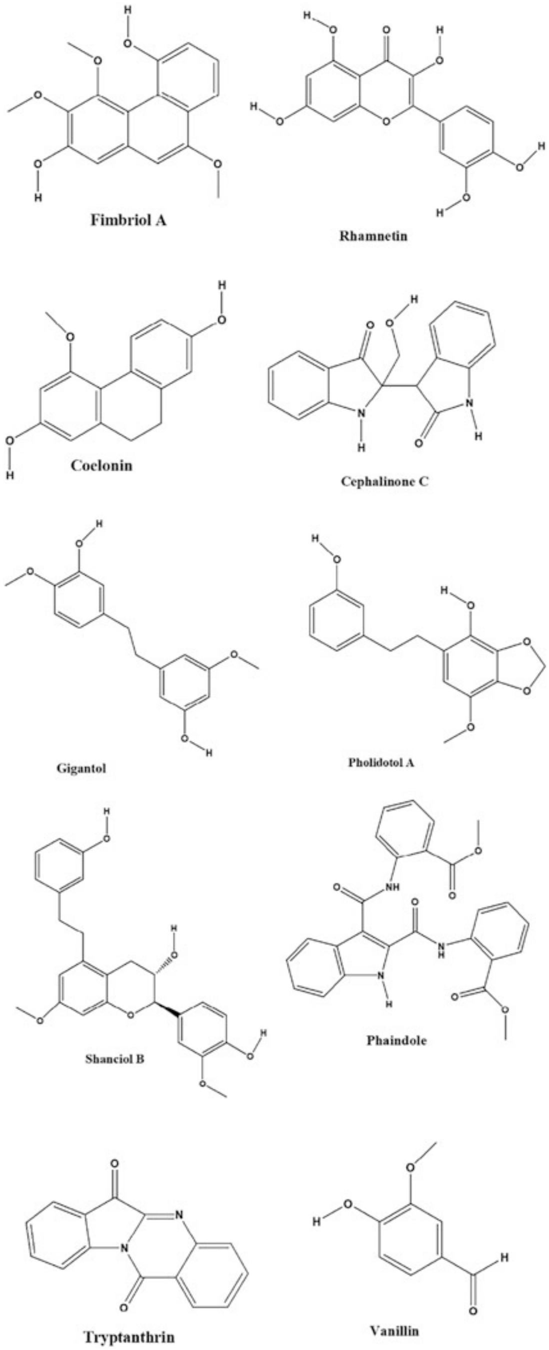
The majority of bioactive compounds viz., ayapin, n-octastylferulate, crepidatin, confusarin, physcion, scopolin, rhein, fimbriatone, and β-sitosterol were reported in *Dendrobium fimbriatum* which were important for pharmacological point of view (Paul et al. 2017; Bi et al. 2003; Shailajan et al. 2015). However, studies on the phytochemical analysis of medicinal orchids raised in vitro are very few (Bhattacharyya et al. 2014, 2015, 2018, 2016a,b; Bhattacharyya and Staden 2016; Giri et al. 2012b; Bose et al. 2017). A bioactive compound such as bisbenzyl erianin was isolated from the callus culture of *Dendrobium chrysotoxum* which was the potential as an antioxidant, antitumor, and antiangiogenic agent (Zhan et al. 2016). The presence of polyphenols was reported in *Habenaria edgeworthii* culture (Giri et al. 2012a). Different biochemical constituents like total phenolic, flavonoid, alkaloids, and tannins contents were analyzed and comparisons were reported between the various parts of mother plants and micropropagated plants of *Dendrobium nobile* (Bhattacharyya et al. 2014). Compounds with higher concentrations are reported in micropropagated plants of *Herminium lanceum* (Singh and Babbar 2016) and *Habenaria edgeworthii* (Giri et al. 2012a) than in wild plants. The phytochemical evaluation of various parts of the mother plant and in vitro propagated plants of *Bulbophyllum odoratissimum* was performed by using HPLC (Prasad et al. 2021). Extracts of *Dendrobium crepidatum* contained bioactive compounds like tetracosane, hexadecanoic acid, triacontane, phenol derivatives, and tetradecanoic acids are responsible for antioxidant and cytotoxic activities (Paudel et al. 2019).

7.1.2 Biological Activity

Antioxidant Activity

Bioactive components exhibited vigorous antioxidant properties in divergent in vitro methods which showed high scavenging potentiality to various Reactive Oxygen

Fig. 2 Chemical structure of bioactive molecules of medicinal orchids (Drawn in Chemdraw 8.0)



Species (ROS) viz. hydroxyl radical, peroxynitrite, superoxide anion, and hypochlorous acid (Halliwell 2008). Unlike synthetic antioxidants, vigorous studies were conducted on antioxidants present in natural fruits, vegetables and medicinal plants, which are considered less toxic due to their effective free radical scavenging activity.

1,1- diphenyl-2-picrylhydrazyl (DPPH) and Ferric Reducing Antioxidant Power (FRAP) assay were used for the analysis of the antioxidant activity of the plant extracts of mother and micropropagated *Dendrobium nobile* plants (Cao et al. 2021). Both the assays describe the antioxidant response of *Dendrobium nobile* determining the high antioxidant potential in samples of leaf due to its high content of polyphenols, alkaloids, and flavonoids. Among the different solvents and plant parts of the tested species, the DPPH activity of the methanolic leaf extraction was the highest (89.8 ± 2.9%), but the activity of radical scavenging of the chloroform leaf extraction was the lowest (28 ± 2.9%) of the micropropagated plant. *D. nobile* plantlets grown through tissue culture reported higher levels of free radical scavenging activity than mother plants (Bhattacharyya et al. 2014). Total phenol content (TPC), radical scavenging activity DPPH and ABTS (2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid), Total Flavonoid Content (TFC) as well as total reducing power ability is being reported from all plant material extracts of mother plants and in vitro-cultured plants of *Bulbophyllum odoratissimum* (Prasad et al. 2021). DPPH radical scavenging activity was studied in some of the following orchid species viz. *Acampe papillosa, Aerides odorata, Bulbophyllum lilacinum, Arundina graminifolia, Cymbidium aloifolium, Dendrobium aphyllum, Papilionanthe teres, Luisia zeylanica, Dendrobium tortile, Rhynchostylis retusa* (Rahman and Huda 2021); *Rhynchostele rossii* (Gutiérrez-Sánchez et al. 2020); *Dendrobium candidum (*Wang et al. 2016*)*; *Dendrobium chrysanthum (*Aswandi and Kholibrina 2021*)*; *Dendrobium draconis (*Sritularak et al. 2011*)*; *Pholidota articulata* (Singh et al. 2016a); *Papilionanthe teres* (Mazumder et al. 2010); *Geodorum densiflorum* (Keerthiga and Anand 2014). DPPH assay measures the total phenolic, alkaloid and flavonoid content by using Folin-Ciocalteu, spectrophotometry and modified acid-alkalimetry methods in *Dendrobium crumenatum* (Topriyani 2013). DPPH radical, column chromatography Diaion HP-20 or reverse-phase silica gel column chromatography was studied in *Gymnadenia conopsea* (Shang et al. 2017). A DPPH radical, spectrophotometric method, Liquid Chromatography Mass Spectrometry (LC-MS) was studied in *Paphiopedilum villosum* (Khamchatra et al. 2016). DPPH and ABTS assay were studied in *Cymbidium kanran* (Axiotis et al. 2022); *Dactylorhiza hatagirea* (Kumari et al. 2022); *Dendrobium moschatum* (Robustelli della Cuna et al. 2018); *Geodorum densiflorum* (Keerthiga and Anand 2014); *Gastrodia elata* (Song et al. 2016). DPPH, ABTS radical scavenging assays and reducing capacity assays have been studied in *Dendrobium aphyllum* (Liu et al. 2017) and *Dendrobium macrostachyum* (Sukumaran and Yadav 2016). DPPH, ABTS, and metal chelating in *Malaxis acuminata* (Bose et al. 2017) and in *Dendrobium nobile* hydroxyl radicals scavenging assay was also studied (Luo et al. 2010). MTT (3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide) assay in *Dendrobium aphyllum* (Liu et al. 2018) and

DPPH assay in *Dendrobium densiflorum* (Pant et al. 2022), and in *Dendrobium crepidatum* by using GC–MS (Gas Chromatography and Mass Spectrometry) was used to identify the compounds (Paudel et al. 2019). DPPH, ORAC, and deoxyribose assays in *Dendrobium parishii* (Raja 2017); DPPH scavenging activity, reducing power and chelating activity against iron ions (Fe^{2+}) in *Dendrobium candidum* (Ng et al. 2012). DPPH and FRAP assay were studied in *Dendrobium devonianum* (Wang et al. 2018) and *Dendrobium fimbriatum* (Paul and Kumaria 2020). Deoxyribose assays, non-site-specific scavenging assays, or antioxidants and iron ions, also known as site-specific scavenging assays have been studied in *Dendrobium chrysotoxum* (Zhao et al. 2007) (Table 4).

Antimicrobial Activity

Five different multidrug resistance (MDR) bacterial clinical isolates were used for testing the antibacterial activity of the epiphytic orchid *Pleione maculata* which includes *Escherichia coli* (2461), *Enterococcus* sp. (2449), *Staphylococcus aureus* (2413), *Serratia* sp. (2442), and *Acinetobacter* sp. (2457) along with antimycobacterial activity with *Mycobacterium tuberculosis* strain (H37Rv) (Bhatnagar and Ghosal 2018). Likely methanolic extracts of tubers of *Satyrium nepalense* were studied against both Gram-negative and -positive food pathogenic bacteria namely *Staphylococcus mutans, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Klebsiella pneumonia* and 6 mg/100 μL concentration was responsible for the minimal effect against all the tested microorganisms (Mishra and Saklani 2012).

Ethanolic and hexane extracts of *Coelogyne cristata* and *Coelogyne fimbriata*, leaves and pseudobulbs were explored against human pathogens like Gram-positive *Bacillus cereus* (ATCC 14579), *Staphylococcus aureus* (ATCC 12600), and Gram-negative *Escherichia coli* (ATCC 10798), *Yersinia enterocolitica* (ATCC 9610), and *Klebsiella pneumonia* (ATCC BAA-3079) bacteria. Only 70% of ethanolic leaf extracts inhibited the growth of the investigated human pathogens (Pyakurel and Gurung 2008; Subedi 2002; Wati et al. 2021; Subedi et al. 2013). Methanolic and water extract of *Peristylus densus* showed better antimicrobial activity against bacterial and fungal strains with an inhibition zone of 8–10 mm when tested against *S. typhi, P. aeruginosa, S. aureus, E.coli, and Aspergillus niger* (Jagtap 2015). Methanolic and ethanolic extract of *Malaxis acuminata* revealed strong antimicrobial activity against *P. aeruginosa* and *S. aureus* strain in Minimum Inhibitory Concentration (MIC) assay and Butanol extract showed a strong inhibition zone of 32 mm compared to control 28 mm against *Candida albicans* (Suyal et al. 2020). Ethyl acetate extract showed significant antimicrobial activity against bacterial strains *K. pneumoniae, S. enteric* and *E. coli* with an inhibition zone of 14–18 mm in *Pholidota articulata (*Singh et al. 2016b*)*. Whereas ethanolic extract of the species showed antimicrobial activity against microbial strains *S. aureus, Vibrio cholerae, B. subtilis, E. coli,* and *K. pneumoniae* with inhibition zone ranges from 9 to 12 mm. No activity was observed in *V. cholerae (*Marasini and Joshi 2012*)*. Ethanolic extract

Table 4 Testing of antioxidant activity of some medicinal orchids

Sl No.	Species	Antioxidant activity	References
1	*Cymbidium kanran*	DPPH and ABTS assays	Axiotis et al. (2022)
2	*Dactylorhiza hatagirea*	DPPH and ABTS assays. Further, UPLC-DAD analysis	Kumari et al. (2022)
3	*Dendrobium aphyllum*	DPPH and ABTS-free radical scavenging assays and the reducing power assay. MTT assay	Liu et al. (2017)
4	*Dendrobium candidum*	DPPH scavenging activity, 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity, reducing power, and ferrous ion (Fe^{2+}) chelating activity	Wang et al. (2016), Ng et al. (2012)
5	*Dendrobium chrysanthum*	DPPH radical scavenging activity	Xiao-Ling et al. (2014)
6	*Dendrobium chrysotoxum*	Deoxyribose assay, non-site-specific scavenging assay) or antioxidants and iron ions (referred as a site-specific scavenging assay)	Zhao et al. (2007)
7	*Dendrobium crepidatum*	DPPH (2, 2-diphenyl-1-picrylhydrazyl) and MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assays	Paudel et al. (2019)
8	*Dendrobium crumenatum*	1-1 Diphenyl-2-picrylhydrazyl (DPPH) method, measurement of total phenol, flavonoid, and alkaloid content using Folin-Ciocalteu method, spectrophotometry method, and modified acid-alkalimeter method	Topriyani (2013)
9	*Dendrobium draconis*	DPPH-free radical assay	Sritularak et al. (2011)
10	*Dendrobium densiflorum*	DPPH and MTT assays	Pant et al. (2022)
11	*Dendrobium devonianum*	DPPH Radical-Scavenging Assay, Ferric Reducing Antioxidant Power (FRAP) Assay	Wang et al. (2018)
12	*Dendrobium fimbriatum*	DPPH and FRAP assay	Paul and Kumaria (2020)
13	*Dendrobium macrostachyum*	DPPH, ABTS radical scavenging, and reducing power activity	Sukumaran and Yadav (2016)
14	*Dendrobium moschatum*	DPPH assay and ABTS assay	Robustelli della Cuna et al. (2018)
15	*Dendrobium nobile*	Free radical scavenging activity assay; ABTS assay; DPPH assay; hydroxyl radicals scavenging assay	Luo et al. (2010)
16	*Dendrobium parishii*	DPPH, ORAC, and deoxyribose assays	Kongkatitham et al. (2018)
17	*Gastrodia elata*	The DPPH and ABTS radical scavenging activities	Song et al. (2016)
18	*Geodorum densiflorum*	DPPH method (1,1-diphenyl-2-picrylhydrazine)	Keerthiga and Anand (2014)
19	*Gymnadenia conopsea*	Diaion HP-20 column chromatography (reverse-phase silica gel column chromatography, DPPH radical	Shang et al. (2017)

(continued)

Table 4 (continued)

Sl No.	Species	Antioxidant activity	References
20	*Malaxis acuminata*	DPPH, metal chelating, and ABTS	Bose et al. (2017)
21	*Paphiopedilum villosum*	Anti-free radical activity (DPPH), spectrophotometric methods, liquid chromatography coupled to mass spectrometry (LC-MS)	Khamchatra et al. (2016)
22	*Papilionanthe teres*	DPPH assay	Mazumder et al. (2010)
23	*Pholidota articulata*	DPPH radical scavenging	Singh et al. (2016a,b)

of *Pholidota imbricata* showed effectiveness against *S. aureus, V. cholerae, B. subtilis, E. coli,* and *K. pneumonia* microbial strains with inhibition zone ranges from 8 to 14 mm (Marasini and Joshi 2012). *Rhyzopus stolonifer, Candida albicans,* and *Mucor* sp. were tested with the different orchid species. No activity against fungal organisms reported in *Coelogyne stricta (*leaf), *Coelogyne stricta* (Pseudobulb), and *Dendrobium amoenum.* Whereas *Pholidota imbricata* and *P. articulata* extracts showed fine activity. *Dendrobium nobile, Eria spicata, Rynchostylis retusa, Bulbophyllum affine*, and *Vanda cristata* showed very weak to moderate activity against selected fungal pathogens (Marasini and Joshi 2012).

Cytotoxic Activity

The cytotoxic activity of crude extracts from *Dendrobium longiflorum* plants was determined by the Mean Transit Time (MTT) assay (Mosmann 1983; Sargent and Taylor 1989). This study tested tumor cells of the human brain (U251) and cervical cancer cells (HeLa). The cytotoxicity results of *D. longicornu* acetonic extract showed a significant cell growth inhibitory effect on the U251 cell line which may be due to high levels of flavonoids, while ethanolic extract had no significant cytotoxic activity on U251 cells. Similarly, the higher flavonoid levels in the ethanolic extract of *D. longicornu* showed significant results on the cytotoxic activity of the HeLa cell line. The cytotoxic activity of flavonoids has been described by previous researchers (Patel and Patel 2011; Awah et al. 2012; Jeune et al. 2005).

Methanolic extract of the whole plant of *Pleione maculata* was tested for cell cytotoxicity and found to be within permissible limit, i.e., 7% at MIC assay. This supports scientific evidence in favor of folk medicinal utilization of *Pleione maculata* for various ailment treatments (Bhatnagar and Ghosal 2018). However, no cytotoxic effect was observed at an extract dosage of 50–100 μg/mL in the methanolic extract of *Pholidota articulata*, whereas 200–400 μg/mL of the extract showed better activity in HeLa cells (IC50 673.04) compared to U251 cells (IC50 3170.55). The control showed a better cytotoxic effect (Joshi et al. 2020). Similarly in *Papilionanthe uniflora* no cytotoxic effect was observed at a methanolic extract dosage of 50–100 μg/mL, whereas 200–400 μg/mL of the extract showed better activity in HeLa cells (IC50 781.85) compared to U251 cells (IC50 2585.88) and control showed better cytotoxic effect (Joshi et al. 2020).

The cytotoxic activity of *Dendrobium crepidatum* was determined against HeLa (Human Cervical Cancer) and U251 (Human Glioblastoma) cell lines. The extract contains bioactive compounds like tetracosane, tetradecanoic acid, triacontane, phenol derivatives, and hexadecanoic acid which cause cytotoxic activity. The percentage of growth inhibition of HeLa cells for extraction of hexane (DCH) at 100 g/mL and chloroform extract (DCC) at 800 g/mL was found to vary from 19.84 to 4.31% and 81.49–0.43%, respectively. Whereas higher growth inhibition percentage was recorded in DCC at 800 μg/mL and in the extraction of acetone (DCA) at 400 μg/mL (74.35–0.59%) of HeLa cell, which was significantly different compared to other extracts. Likewise, ethanol extracts (DCE) at 100 μg/mL and methanol extracts (DCM) at 200 μg/mL showed significantly higher growth inhibition percentages of HeLa cells (Paudel et al. 2019).

8 Economics

Orchids are popular due to their attractive and long-lasting flowers, with unique shapes and forms. This is a flowering plant consisting of diverse genera and species. Nowadays using the micropropagation technique it has become easy to multiply some of the rare medicinal orchids. Flowers have bagged a significant position in present-day contemporary society. Therefore, a potential pressure for flowers was created especially in terms of the orchid flower as they have a plethora of flower forms and colors. As Orchid reproduction is in a very germinal stage in India, different medicinal orchid varieties can be reproduced by adopting a well-planned Orchid augmentation strategy for the cut-flower trade.

Orchids were the first horticultural crop mass multiplied successfully through the micropropagation technique and the commercial aspects of this group were being increasing day by day for their medicinal importance. Commercial Tissue Culture laboratories around the globe have aided the orchid's mass multiplication and helped the orchid industry revolutionize in the form of cut flower business in several countries. The Indian flower market is expected to grow to INR 661 billion by 2026. North East India, along with Sikkim, Arunachal Pradesh, and Himachal Pradesh, is the orchid-rich state in the country. In southern India, Kerala and Tamil Nadu have high humidity, low temperatures, abundant rainfall, and a pleasant climate suitable for commercial orchid cultivation. The orchid industry in India is in its infancy in terms of in vitro micropropagation or commercial cultivation. This is due to inappropriate or unsuitable planting material for large-scale cultivation, a deficit of technology for commercial mass propagation techniques, a lack of post-harvest commercial techniques for the cut-flower market for international trade, export policies, inappropriate commercial planting methods, etc. However, in India, it can be possible to grow commercially viable orchid varieties such as

Cattleya, Cymbidium, Dendrobium, Oncidiums, Phalaenopsis, Paphiopedilum, and *Vandaceous* for cut flower production. Presently, the inward demand for orchid cut-flower is mainly refilled through imports from outside India. However, with the installation of in vitro propagation technology, cost-effective greenhouses, and post-harvest and storage technology, the orchid cut-flower industry can commence in other parts of India also.

According to the National Horticultural Database released by the National Horticultural Administration, in 2020–2021, the flower planting area in India is 322,000 hectares, producing 2152 thousand tones of scattered flowers and 828,000 tones of cut flowers. Growing orchids is more than just a pleasure these days. This is an international trade that accounts for about 8% of the world's horticultural business and has the potential to change a country's economic outlook.

According to Biotech Consortium India Limited (Biotechnology Division) and Agri-Business of Small Farmers' Consortium, Indian Tissue Culture Market Research, 2005, *Dendrobium* sp. as cut flowers and *Vanilla* as spice are the most important plants in India which are suitable for micropropagation. Growing orchids in India, different agro-climatic regions, low labor costs, and accelerating high-end customer markets create a successful impact on society (Singh et al. 2008). But, the orchid cut flower business is consistently retarded by the unruly condition in airports; large numbers of infected and deserted cut flowers; moreover chemically processed flowers are rejected in Indian cities for violation of bio-safety norms (De 2008).

Presently, worth millions of dollars industry of orchid cut flower are flourishing in different countries such as Malaysia, Australia, Thailand, and Singapore among the top ten cut flowers of the world, the cut flower grasps sixth position and 3% *Cymbidium* orchid alone contributes in this list (De and Debnath 2011).

9 Conclusion

Biotechnological interventions and plant tissue culture techniques are accelerating the large-scale reproduction of the delicate and rare medicinal orchid for its potential uses as therapeutics. Since orchids are exotic breeders, they propagate by seed to produce hybrid plants. Therefore, protocols that allow regeneration from different vegetative parts of the plant are needed to achieve suitable types of micropropagation of medicinal orchids, which have shown amazing developments in germplasm conservation in recent years. Hardening and acclimatization of in vitro-propagated orchids have maintained in different ratios of the organic medium before ex vitro survivability. In recent years, as a research tool addition to being used, plant tissue culture techniques have also been of great industrial significance in the plant propagation field, plant improvement, and secondary metabolites production.

Furthermore, testing of clonal fidelity of micropropagated medicinal orchids by using markers like RAPD, ISSR, and SCOT can be adequately utilized in the sustainable implementation of plant genetic resources by identifying and eliminating the difficulties of somaclonal variations. However, from various parts of the in vitro-raised medicinal orchid many compounds have been isolated which are a good source of bioactive molecules as well as phytochemicals. Antioxidant activities and ethnomedicinal properties have been offering better possibilities for the occurrence of value-added products, for the treatment of diseases with herbal medicines to boost health benefits.

Similar to micropropagation technology, synthetic seed technology has attracted much attention in recent years due to its broader application of germplasm conservation in natural habitats. Although little progress has been made in proving the feasibility of synseeds, their successful implementation in the conservation of orchid ornamental/medicinal genetic resources is achievable.

Emphasis on eco-rehabilitation study provides a new gateway for ex situ conservation of in vitro-raised medicinal orchids in their natural habitats. The host tree and orchid species symbiosis still maintains a proper balance for further reintroduction and population enhancement for the practical conservation of important orchids. Orchids have both flower value and medicinal value and are more demanding in the international market. Endemic and rare orchids have a plethora of flower shapes and colors that require scientific attention for their use in the cut flower industry.

Comprehensive research is still necessary to extensively study the different orchid species for various ailments. However, due to limited understanding and knowledge about the therapeutic values of these locally available plants, the use of orchids in the traditional healing process is restricted. For commercial scale, very less effort has been made for medicinal orchid cultivation due to its small size population and restriction in distribution. Different precious orchid species that have reached either the threatened or extinct category can survive with biotechnological interventions and human support for their mass propagation. Therefore, to meet the current need for medicinal orchids and to reduce the pressure on its natural population, plant tissue culture can be an acceptable alternative for its sustainable utilization which is the need of the hour.

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