J. Orchid Soc. India, 32: 81-91, 2018 ISSN 0971-5371

CONSERVATION, MANAGEMENT, AND UTILIZATION OF ORCHID GENETIC RESOURCES

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Abstract

Orchidaceae is one of the largest families of flowering plants and orchids are one of the most threatened plants due to habitat destruction and climate change, but many of them are also threatened by illegal harvest for horticulture, cultural use, food and medicine. In this review paper, trade related activities, economic importance of valuable orchid species and conservation measures are discussed in detail with a view to developing approaches that may allow us to address the threats on a broader scale to complement focused approaches for the species that are identified as being at the highest risk.

Introduction

ORCHIDACEAE IS one of the largest families of flowering plants (Chase *et al.*, 2015; Willis, 2017) and are almost globally distributed. Till date, 28,484 species have been identified and accepted (Govaerts *et al.*, 2017). By the end of 2017, the IUCN Global Red List included assessments for 948 orchid species, of which 56.5% are reported to be, threatened (IUCN, 2017). In addition to their geographical and taxonomic diversity, orchids are also widely used for a variety of reasons, both legally and illegally, sustainably and unsustainably (Fay, 2015a). One of the best-known plant groups in the global horticultural and cut flower trades (De, 2015; FloraHolland, 2015), orchids are also harvested, grown and traded for a variety of purposes, including as ornamental plants, medicinal products and food. Most popular global orchid trade is in artificially propagated cut flowers and plants grown under controlled conditions. During the period of 1996 to 2015, Taiwan and Thailand were the largest exporters, with most plants sent to South Korea (40%), the U.S.A (27%) and Japan (20%) (UNEP-WCMC, 2017).

Orchids are mostly vulnerable due to over-harvesting because many of them occur at low densities due to a variety of interacting factors such as recent speciation, specialized pollination mechanisms, habitat specificity, and the restricted distribution of mycorrhizal symbionts (McCormick and Jacquemyn, 2014; Swarts and Dixon, 2009a). The limited ecological studies on the conservation impacts of wild collection of epiphytic orchids indicate a low tolerance to harvest (Hu *et al.*, 2017; Mondragón, 2009).

Conservation Status

The family Orchidaceae is divided into five subfamilies (Apostasioideae, Cypripedioideae, Vanilloideae, Orchidoideae, and Epidendroideae). Orchids account for nearly 8% of angiosperm species diversity (Chase *et al.*, 2015; Willis, 2017). Major threats include habitat destruction, illegal harvesting, and because of their complex life histories, orchids are thought to be particularly vulnerable to the effects of global climate change (Fay and Chase, 2009; Gale *et al.*, 2018; Swarts and Dixon, 2009a). All species of subfamily Cypripedioideae (the slipper orchids) were assessed for the Global Red List in a recent project, and due to a combination of habitat degradation and, in some cases, ruthless harvesting, nearly 90% of species were assessed and reported to be threatened (Fay and Rankou, 2016). Slipper orchids had expected a high level of threat, but even the family-wide figure of 56.5% showed that many orchid species are threatened of extinction. Their conservation should be regarded as urgent, if these unique plants are not to decline further.

Threats

Globally, both habitats and the species are under increasing pressure. There is also an increasing evidence that global climatic change may also be influencing species distribution (Fay, 2015b), and benefits and problems associated with assisted migration and translocations to climatically suitable localities are increasingly being discussed in relation to orchids (Ramsay and Dixon, 2003; Swarts and Dixon, 2009a). Like all plants, orchid species with their often complex interactions with pollinators, mycorrhizal fungi and host trees, are likely to be at a greater risk as they are dependent on other organisms that are also being affected by habitat or climatic change. Therefore, orchids face greater challenges than many other plant groups. Another aspect of threat relating to orchids is illegal harvesting; indiscriminate collection for horticultural

Received: August 19, 2018; Accepted: October 30, 2018

purposes, has also been documented as having a major impact on some orchids, notably species of *Cattleya*, *Laelia*, *Renanthera* and some slipper orchids (*Cypripedium*, *Paphiopedilum*, *Phragmipedium*), and in some cases, these have been systematically stripped from the wild to the habitat of extinction. However, many orchids are not collected for horticulture or are collected in such small numbers that there is unlikely to be a much impact (Cribb *et al.*, 2003; Fay, 2015a). As a result, these desirable orchids and because of perceived problems with their identification, all orchids were placed on the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Cribb *et al*., 2003), and orchids account for more than 70% of the species listed on CITES. However, it is being observed that many orchid species are still being collected and transported across international borders, for use as medicine and food in addition to the horticultural trade, without the permits required under CITES (Fay, 2015a; Hinsley *et al.*, 2018). The extent of the illegal trade is difficult to manage, but attempts are being made to estimate the extent of non-compliance with CITES regulations (Ghorbani *et al*., 2014; Hinsley *et al*., 2018). Notable examples of poorly documented trade relates to orchids collected for traditional medicine in East Asia and for production of the foodstuff, salep in the Eastern Mediterranean and the Middle East (de Boer *et al*., 2017; Kreziou *et al*., 2016) and Chikanda in South-Eastern Africa (Veldman *et al*., 2014); the development of novel DNA-based barcoding techniques (Huda *et al.,* 2017, Ramudu and Khasim, 2016) is now opening up the opportunity to identify the orchid species in these processed foodstuffs. In addition, due to illegal trade, an unintended consequence of the listing of all species of orchid in CITES has led to the reduction in the collection of orchids for scientific purposes, including conservation research (Roberts and Solow, 2008).

Conservation Measures

About 70% of the world's orchids are epiphytic and/or lithophytic; 25% are terrestrial and 5% of the world's orchids grow in mixed substrates (lithophytic, epiphytic and terrestrial) (Arditti, 1992). These also occur as saprophytes. Pedersen *et al.* (2018) stressed the close link between collection based research and conservation. Approaches addressing conservation of process (rather than individual species) may be appropriate in groups which are relatively undergoing evolution due to hybridization and/or polyploidization (Ennos *et al*., 2012). There are three prominent methods of conservation of genetic resources of orchid species namely, legislative measures, *in situ* conservation in Sanctuaries/Reserves, and *ex situ* conservation in Orchidaria/Botanic gardens by cultivation (Hegde, 2012).

Legislative Measures

Renanthera imschootiana (Red Vanda) and *Vanda coerulea* (Blue Vanda) are now included in schedule VI of Wildlife Protection Act (1972) of Government of India as amended in 1992. As a result, all orchids are protected plants under Wildlife Protection Act. The International Union for Conservation of Nature (IUCN) has a Species Survival Commission (SSC) with a well defined preservation programme for the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). Under this provision, orchids are treated as protected species. In India, three genera and eleven species are being treated as protected under Schedule-VI of Wild Life Protection Act, 1972 and simultaneously under CITES Appendix-I. All other species of India have been included in Appendix-II of CITES. The following species have been kept under CITES Appendix-I and Schedule-VI of Wild Life Protection Act of Govt. of India: *Paphiopedilum charlesworthii, P. druryi, P. fairrieanum, P. hirsutissimum, P. insigne, P. spicerianum, P. venustum, P. wardii, Renanthera imschootiana,* and *Vanda coerulea.* However, except *P. druryi,* which is reported from Kerala, all other species of *Paphiopedilum* belong to North East India. As per laws, no wild orchids can be traded with and so the plants listed above cannot be allowed for export. However, under CITES rules and regulations, whenever CITES Appendix-I species are cultivated, then these can be allowed for export, subject to condition that proper permit for possessing and growing these scheduled plants is obtained from the concerned State, provided the nursery is registered under Wild Life Preservation Office, Government of India.

Appendix-I includes threatened and extinct species. In fact, no trade in wild plants is allowed. Trade is allowed in cultivated and artificially propagated plants subject to licensing. Appendix-II covers species which may be threatened unless trade is strictly regulated. Infact, the whole family Orchidaceae is listed on Appendix-II. Trade in wild and propagated specimen is allowed subject to licensing. Further, all cultured orchid seedlings/plantlets in flasks or those aseptically raised from seeds and tissues are now exempted from CITES control *w.e.f.* April 16, 1993.These legislations have helped in checking illegal collection of orchids from the wild as non importing countries also accept plants of wild origin. In this regard, the Proceedings of the Seminar on CITES Implementation for Plants (1997), illustrates the method of recognizing the wild plants at the port and the procedure to deal with the same.

In Situ Conservation

It refers to the maintenance of the germplasm in its natural habitat allowing continual adaptation to the environment without any human interference.

Biosphere Reserves

These are versatile protected areas to preserve the genetic diversity in the representative ecosystem which are internationally recognized. The proposal for development of biosphere reserve was initiated by UNESCO in 1971 under the ‘Man & Biosphere’ (MAB) programme. The first biosphere reserve of the world was established in 1979. Presently, 564 biosphere reserves have been developed in 109 countries across the world. India has 17 biosphere reserves namely, Achanakamar-Amarkantak, Agasthymalai, Cold Desert, Dihang-Dibang, Dibru Saikhowa, Great Nicobar, Gulf of Mannar, Kachchh, Khangchendzonga, Manas, Nanda Devi, Nilgiri, Nokrek, Pachmarhi, Seshachalam Hills, Simlipal and Sunderbans for conservation of endemic, endangered and vulnerable orchid species.

National Parks

This is an area of adequate natural biological and geo-morphological interest owned by a sovereign state having one or several ecosystems where conservation of wild life (both flora and fauna) is practiced along with educative and recreative interest, designated, created and protected by legislation. Hailey National Park, presently known as Jim Corbett National Park is the first developed National Park in India, in 1936. Presently, there are 98 National Parks in India. 96 different species of orchids are found in Simlipal National Park of Orissa and 150 different species of orchids are conserved in Buxa Tiger Reserve of West Bengal.

Sacred Groves

A sacred groove is a special type of area where all forms of life particularly the sacred tree species related to any particular culture are protected by a particular human community, race or tribe in the name of their respective deity. Himachal Pradesh, Karnataka, Kerala, Maharashtra, Andhra Pradesh, West Bengal and Chhattisgarh are very prominent states for sacred grooves. About 13,270 sacred grooves presently exist in India (Kumar *et al.,* 2016) and these may be important areas for *in situ* conservation of orchids of that particular locality.

Gene Sanctuary

Gene sanctuary is a protected area where broad spectrum of genetic variability is conserved to act as a reserve for future use and crop improvement. At present, India has 480 wildlife gene sanctuaries. Sessa Orchid Sanctuary of Arunachal Pradesh with 100 sq. km area conserves about 200 species of orchids. Similar types of sanctuaries have also been created in Sikkim at Deorali and Singtam.

Individual Trees

The epiphytic orchid species are conserved on tree species in their natural habitat where they attach themselves to the bark of trees, or the surface of other plants. Some of the host trees of orchid species are *Lyonia ovalifolia, Benthamidia capitata, Quercus leucotricha*, *Diploknema butyracea, Berberis asiatica, Myrica esculenta, Castanopsis indica, Persea odoratissima, Pinus roxburghii, Rhododendron arboreum, Berberis cristata, Engelhardia spicata, Pyrus pashia, Shorea robusta, Mioromeles rhamnoides, Alnus nepalensis* and *Prunus cerasus* (De *et al.*, 2013). Their white thick roots are specially adapted to absorb moisture and dissolved nutrients. Because these tropical orchids usually grow high on the trees, rather than on the forest floor, they are accustomed to good air circulation and plenty of light.

Ex Situ Conservation

It refers to the preservation of germplasm outside the natural habitat. In India, Botanical Survey of India (BSI) is maintaining three National Orchidaria and Experimental Gardens, one each at Yercaud (Tamil Nadu), Howrah (West Bengal), and Shillong (Meghalya) where representative species of the region are being cultivated. Similarly, Arunachal Pradesh State Forest Research Institute is maintaining a large number of orchid species at Orchid Research Centre, Tipi, Itanagar, Sessa, Dirrang, Jenging and Roing as a measure of *ex situ* conservation of orchids. In Karnataka, three *ex situ* conservation centres have been established, one in Kodagu, another in Kudremukh and the third in Dhandeli (Rao and Sridhar, 2007).

Field Gene Banks

In this area, germplasm is collected from natural habitat or from other sources including commercial houses and nurseries and are maintained in the field or protected structures. In this connection, it is worthwhile to mention that in the field gene banks of TBGRI, Trivandrum, nearly 600 different species and 150 hybrids of orchids are maintained; NRC for Orchids, Pakyong, Sikkim has nearly 90 different genera and a number of hybrids of commercial orchids, and Orchid house at Panjab University, Chandigarh maintains nearly 100 species of orchids and some hybrids of commercial importance.

Botanical Gardens

These are protected areas where living plant specimens are conserved in fields or in protected structures providing significant information regarding mode of perpetuation, reproductive biology, taxonomical characters and propagation technique. At present, there are 13 botanical gardens in India maintaining a number of orchid species. About 43 species of orchids are collected and displayed in the orchid house of Lloyd Botanical garden, Darjeeling, West Bengal. Swarts and Dixon (2009b) focused on the role of botanic gardens in supporting orchid conservation scientifically and horticulturally.

Herbal Gardens

In these areas, medicinal plant genetic resources are reared in a protected area for maintaining them, generation after generation. Government of India has sanctioned funds for development of herbal gardens in 16 SAU's and research institutions in different agro-climatic regions of the country with a view to conserving and maintaining regional medicinal plants and endangered species (Gupta, 1993). In India, a networking among the herbal gardens is already developed at the Directorate of Medicinal and Aromatic Plants Research (DMAPR), where 83 such gardens with details of their species are registered.

Orchid Seed Gene Bank

Million of seeds are produced in a single capsule of orchid. However, they lack the functional endosperm and require specific mycorrhizal association for germination under natural conditions and consequently, the percentage of germination is low. Many orchids have been germinated through asymbiotic technique where germination is found as high as 90%. The seeds of orchids are orthodox in nature and provide a great scope for long term storage through low temperature.

In Vitro Conservation

This technique can be used for revitalization of orchid germplasm affected by virus and virus-like diseases through apical meristem culture, as a matter of fact, orchids are first plants to be tissue cultured, in this connection (Pritchard, 1989). Further, though attempts have been made to propagate orchid species *in vitro* using various explants (seeds, stem, root *etc.*) (Anuprabha *et al.,* 2017; Arora *et al*., 2014, 2016; Bhattacharjee and Hossain, 2015; Bhatti *et al.,*2017; Borah *et al*., 2015; Chauhan *et al*., 2015; Hoque *et al*., 2016; Kaur and Pathak, 2014; Kaur *et al.,* 2017; Pathak *et al*., 2016; 2017; Sibin and Gangaprasad, 2016; Sibin *et al*., 2014) so as to develop effective protocols for their *in vitro* propagation, the data is meager in terms size of the orchid family. There is a need for studies on genetic stability to avoid the somaclonal variants and slow growth cultures for longer storage duration to avoid frequent transfers.

Cryopreservation

Cryopreservation means long term storage or conservation of plant parts and reproductive materials at a very low temperature, in the laboratory condition either in liquid nitrogen (-196^{o}C) or in vapour phase (-150^{o}C). Tissues/explants of orchids can be cryopreserved in liquid nitrogen cylinders as a long term storage procedure after proper treatment of cryoprotectants and plant vitrification solutions. In our country, National Bureau of Plant Genetic Resources (NBPGR) has created the facility of cryobank where 2.5 lakhs of germplasm lines can be stored (Singh, 2005).

Systematics and Conservation Genetics

Many groups of orchids are distributed in tropical regions, and phylogenetic studies are required so as to identify the number of species especially those that are phylogenetically isolated and consequently of high conservation value. Li *et al.* (2018) studied the use of phylogenetic measures as a mean for prioritizing members of Orchidaceae for conservation in the Indo-Burma Biodiversity Hotspot, revealing Thailand, South China and Vietnam as the areas with highest phylogenetic diversity and *Tropidia curculigoides*, *Thaia saprophytica* and *Risleya atropurpurea* as accounting for disproportionately great evolutionary distinctiveness. At the population level, genetic studies may be useful to identify regions or populations that should be treated as high priority for conservation. Earlier, development of markers was time consuming and expensive, but new technologies are speeding up marker development and allowing more loci to be studied than previously possible, and as a result, the quality of the information to be used in conservation planning will improve (Gargiulo *et al.,* 2018).

Molecular genetic tool aids are used for species-level orchid identification. Techniques include Sanger sequencing-based DNA 'barcoding' techniques, which for plants typically compare two or more DNA regions (or 'markers') from each specimen with a library of verified reference samples (Hollingsworth *et al.,* 2016). They also include the so-called next-generation sequencing techniques that use the whole genome or a much larger number of markers from across the entire genome to compare with a reference library. Barcoding approaches have been exploited for the monitoring of ornamental orchid trade (Phelps, 2015), so as to identify constituent species, in processed medicinal products (Wu *et al.*, 2009; Yao *et al.*, 2009), and most recently, to identify species in edible orchid products (Ghorbani *et al*., 2017; Veldman *et al*., 2017).

Conservation of Habitats

Habitat alteration, including total destruction, modification, and fragmentation, is widely recognised as the main threat to biodiversity in tropical regions where orchid diversity is the greatest. The relationship between epiphytic orchids and their host trees, calls for further research into the mechanisms controlling distribution of orchids on different species of trees (De *et al*., 2013; Rasmussen and Rasmussen, 2018). Some orchid conservation organisations such as the Orchid Conservation Alliance (OCA), which state that "preservation of natural orchid habitat preserves the orchids, their pollinators, their genetic diversity, and other fauna, as well as the birds, frogs, insects, reptiles, and mammals in the forests where they live" (OCA, 2017). A combination of creating new habitats, transplantation, and *ex situ* conservation in seed banks and living collections will meet these challenges. Conserving orchids in isolation from their pollinators, fungal associates and host plants means that the complexity of their biology is lost, even though the species still survives as has also been indicated earlier by Vanlalruati *et al.* (2016). For this reason, orchid conservationists suggest "integrated conservation", using *ex situ* techniques to support *in situ* conservation as an appropriate method.

Pollination Mechanisms, Pollinators, and Conservation

Orchids are popular for the wide range of pollination mechanisms and syndromes (Darwin, 1862; Micheneau *et al*., 2009) and the species diversity has been attributed, in part, to the diversity of pollen mechanisms (Cozzolino and Widmer, 2005). Because of the diversity of pollination mechanisms, Roberts (2003) revealed the importance of understanding pollination biology for effective orchid conservation, stating that "orchid conservation will require a case by case, functional ecosystem approach", and stated the need to conserve not only the orchid and the pollinator, but also in some cases the "pollinator food source, nesting site, larval host species, and in the case of parasitic pollinators, the larval host plant of its host species". Hutchings *et al*. (2018) studied that climate change can decouple the phenology of pollinator and orchid species, potentially leading to reproductive failure of the orchid. Recent papers have reviewed birds (Micheneau *et al*., 2006; van der Niet *et al*., 2015), crickets (Micheneau *et al*., 2010), fungus gnats (Phillips *et al*., 2014) and biting midges (Bogarín *et al*., 2018), as specialized pollinators. Many orchid species attract pollinators with the forms of deception including food deception, brood-site imitation, shelter imitation, rendezvous attraction and sexual deception (Buragohain and Chaturvedi, 2016; Jersáková *et al*., 2006), and recent discoveries of dual deceive (pseudopollen lacking food value; Davies *et al*., 2013), carrion mimicry (van der Niet *et al*., 2011), and production of fruit fly aggregation pheromones (Karremans *et al*., 2015) demonstrate that the understanding of the full complexities of orchid pollination is yet to be understood.

Mycorrhizal Associations and Conservation

Seed and protocorm development, including discussion of mycorrhizal associations and the survival of orchid seeds and plantlets in their natural habitats were reviewed by Yeung (2017). It is well known, the role of mycorrhizal fungi is crucial to the survival of self-sustaining populations of orchids (Hajong and Kapoor, 2016), but there is much research still to be conducted before understanding the mycorrhizal associations, especially with epiphytic orchid species. Even with temperate terrestrial species, the techniques including measurement of isotope enrichment of carbon, nitrogen and hydrogen now allow us to demonstrate the contribution that the fungi make to the nutrition of orchids, even when the plants are apparently capable of photosynthesis (Gebauer *et al*., 2016). Recently, techniques are used to demonstrate that reintroduced seedlings of *Cypripedium calceolus* had established mycorrhizal associations after planting out, despite being produced axenically (Fay *et al*., 2018).

Utilization of Genetic Resources

Horticultural Use

Over the last half a century, importance of orchids in floriculture has been amply highlighted by various workers (Hegde, 2014, 2016; Pathak *et al.,* 2001) and agencies in India. These plants have been commercialized as ornamental plants in the horticultural and floricultural trade, which is unsurprisingly, dominated by species with attractive flowers, but it also includes species admired for their unusual growth habits (*e.g*. leafless orchids, such as species of *Dendrophylax* and *Chiloschista*), miniature size (*e.g*. species of *Platystele* and *Bulbophyllum moniliforme*), scent (*e.g.* species of *Cattleya* and *Dendrochilum glumaceum*), patterned leaves (*e.g.* jewel orchids in the genera *Anoectochilus*, *Goodyera*, *Ludisia* and *Macodes*) and as cut flowers (*Renanthera imschootiana*, *Vanda coerulea*). The principal orchid trade involves artificially propagated plants and cut flowers cultivated in commercial greenhouses. Reported Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) trade in live artificially propagated plants is dominated by a small number of genera with huge number of hybrids (*e.g. Cymbidium*, *Dendrobium* and *Phalaenopsis*, *Cattleya*, *Oncidium*). Orchids are consistently ranked among the best sellers in the global potted plant trade (FloraHolland, 2015; USDA, 2016) and also has nearly 10% of all fresh cut flowers traded internationally (De, 2015). This represents an economically significant global trade, with exports of potted orchids from the Netherlands alone valued at almost 500 million in 2015 (FloraHolland, 2015). The largest areas of production are found in Thailand, Taiwan, The Netherlands and Japan, with demand for both potted and cut flowers growing in economic value annually (Griesbach, 2002; Hanks, 2015). Thailand, for example, sells roughly half of the orchids, it produces in the domestic market (Thammasiri, 2015). Important orchid genera used as potted plants in the international market are *Ascocenda, Brassia, Cattleya, Cymbidium, Dendrobium, Epidendrum, Miltonia, Oncidium, Paphiopedilum, Phalaenopsis,* and *Vanda* (Lopez and Runkle, 2005). Several local species of *Ascocentrum, Calanthe, Cymbidium, Dendrobium, Paphiopedilum* and *Vanda etc.* are in great demand in international market for breeding materials (Kumar and Sheela, 2007). They can also be preserved by drying for their use in flower arrangement and dried flower craft. These can be dried best using silica gel or borax for microwave drying, embedded drying or by freeze drying. Drying orchids is a challenging task as these flowers are considered difficult to be preserved. Dried orchids are used for different purposes such as these are used in vases and baskets and sometimes in shadow boxes. Bright flowers of orchid genera like *Cattleya, Cymbidium, Dendrobium, Paphiopedilum,* and *Pholidota etc*. can be used for drying (De *et al.,* 2017).

Cultural and Ornamental Use

In Assam, the flowering spike of *Rhynchostylis retusa,* known as *Kopou Phul* is used by the girls to adorn their hair during the spring festival. The flowers of some other orchids like *Coelogyne nitida* and *Vanda roxburghii* are also used to adorn hair of girls of Assam and Arunachal Pradesh, in local festivals. The flowers of *Papilionanthe teres* are offered to Lord Buddha and spirits by the Khamtis and other Tai ethnics of Assam and Arunachal Pradesh. In Kameng district of Arunachal Pradesh, *Dendrobium hookerianum*, *D. nobile* and *D. gibsonii* are considered as the symbol of purity and sanctity by the local people. Monpas consider the flowers of *Cymbidium grandiflorum* important for holy worship. The young naga women of Manipur wear the orange flowers of *Dendrobium densiflorum,* behind their ears. Similarly, the flowers of *Vanda coerulea* are used by the women of Manipur, in hair during the autumn puja festival. In several countries, orchid species and hybrids are used as National Flowers. For example, *Vanda* Miss Joaquim in Singapore, *Peristeria elata* in Panama, and *Lycaste skinneri* var*. alba* in Guatemala. Orchids are depicted on stamps of several countries like Venezuela, USA, New Zealand, Australia, Indonesia, India, Singapore, Japan, Russia, Thailand, Malaysia, and many others (Bhattacharjee and Das, 2008). As the orchids symbolize wealth, beauty and social status, orchid flower arrangements are used for good table decorations and venue decorations during weddings. Amongst orchids, *Cymbidium, Dendrobium* and *Phalaenopsis* are excellent for wedding counter pieces. An arch decorated with chic white silk combined with white orchids can be considered as an admirable orchid flower arrangement. In home, they can be displayed in three ways *i.e.,* single flower vases, plants in pots and traditional mixed flower arrangements. In Philippines and New Guinea, the stem of some *Dendrobium* species is used to make baskets and bracelets. In some tribes, *Cattleya labiata* var. *autumnalis* sap is used as glue for musical instruments. In Central America, the schomburgkias empty pseudobulbs are used to make horn (De and Pathak, 2015). Orchid flowers have historically been and continue to be traded for their ornamental value in a wide range of cultural and religious ceremonies. For example, flowers of *Dendrobium maccarthiae* are used as special temple offering in Sri Lanka, and flowers and pseudobulbs of species of *Laelia* are used in Mexican Day of the dead ceremonies (Duggal, 1971).

Use as Food

Orchids used for human consumption include globally important products, such as Vanilla flavourings (extracts of *Vanilla*), and other edible products used on national and regional levels. Leaves, tubers, and pseudobulbs of different species are used for edible purposes. Vanilla, a major spice crop and source of vanillin comes from *Vanilla planifolia*. Salep is made from the polysaccharide-rich tubers of wild orchids that were traded predominantly in Turkey as far back as 1850 (Landerer, 1850). After collection, the orchid tubers are boiled in water, milk or ayran (a yoghurt-based drink) to render the enzymes in them, inactive and prevent tubers from re-growing (Tamer *et al.,* 2006). They are then dried and ground into a powder which is used to make the drink called salep and ice cream called maras dondurma (Kasparek and Grimm, 1999). At least 35 species of orchids are used to make salep, including species from the genera *Anacamptis*, *Dactylorhiza*, *Himantoglossum*, *Ophrys*, *Orchis*, *Serapias* and *Steveniella* (Kasparek and Grimm, 1999; Kreziou *et al.*, 2016; Ghorbani *et al.*, 2017). The tubers of terrestrial orchids are used in several african countries in the production of chikanda, a large cake with a meat-like structure, made of ground orchids and peanuts baked with ashes or baking soda (Bingham, 2009; Kaputo, 1996). Chikanda is a traditional dish eaten by the Bemba tribe in Northern Zambia (Richards, 1939) and by a tribe in the Katanga province of the Democratic Republic of Congo (Malaisse and Parent, 1985), the Sumbawanga region in Tanzania (Davenport and Ndangalasi, 2003; Nyomora, 2005), Malawi (Kasulo *et al.,* 2009) and the Bayam people in Cameroon, where the dish is prepared in a similar way with tubers of two species of *Habenaria* and is called *napssié* (Menzepoh, 2011). Predominant orchid species used for chikanda, generally belong to three genera *i.e. Disa*, *Habenaria* and *Satyrium* (Bingham and Smith, 2002; Bingham *et al.*, 2003; Challe and Struik, 2008; Challe and Price, 2009; Davenport and Ndangalasi, 2003; Hamisy, 2007; Nyomora, 2005). *Anoectochilus* leaves are used as vegetables in Indonesia and Malaysia. Pseudobulbs of *Cymbidium madidum* and *Dendrobium speciosum* and tubers of *Microtis uniflora* and *Caladenia carnea* are eaten. The popular beverage called as *Faham* or *Madagascar Tea* on the islands of Mauritius and Madagascar is prepared from an orchid *Jumellea fragrans*. In Bhutan, the inflorescence or the flowers and pseudobulbs of *Cymbidium* spp. are eaten.

Medicinal Use

Many orchids are rich in alkaloids. Experimental evidences have reported the isolation of a number of alkaloids like anthocyanins, stilbenoids and triterpenoids from orchids. Orchinol, hircinol, cypripedin, jibantine, nidemin and loroglossin have been reported from orchids. Subsequently, orchids are also used in traditional medicine systems around the world, from subsistence to commercial levels. Some of the commercial medicinal uses of orchids include Chinese and South Asian Ayurvedic traditional medicine (Leon and Lin, 2017; Teoh, 2016). They are also known to be utilized in some African traditional medicine, *e.g. Vanilla madagascariensis* in Madagascar (Randriamiharisoa *et al*., 2015), North American folk medicine, *e.g. Cypripedium acaule* and *C. parviflorum* (Henkel, 1906) and the Unani medicine system, *e.g. Dactylorhiza hatagirea*, *Vanda tessellata*, *Cymbidium bicolor* and *Ipsea speciosa* (Khajuria *et al.*, 2017; Thakur and Dixit, 2007). Medicinal orchids are also traded widely around the world, including Europe as various traditional medicines and health supplements (Brinkmann, 2014).

Use in Chinese Traditional Medicine

The medicinal value of orchids was reportedly first recognized in the 28th century BC by Shennong, China's founding emperor and patron deity of agriculture (Bulpitt, 2007; Hong, 2004). The most prominently cited orchids in Chinese Traditional Medicine are various *Dendrobium* spp. used to make the drug *shi-hu* from *D. catenatum*, *D. officinale*, *D. loddigesii*, *D. moniliforme* and *D. nobile* (Leon and Lin, 2017; Teoh, 2016). In addition, tubers of *Gastrodia elata* (from which *tian-ma* is prepared), rhizomes of *Bletilla striata* (from which *bai-ji* is derived), the rhizomes and stems of *Anoectochilus* spp. (*jin-xian-lian*) and the corms of *Cremastra appendiculata*, *Pleione bulbocodioides* and *P. yunnanensis* (from which *shan ci gu* is prepared) are all used (Leon and Lin, 2017; Teoh, 2016).

Use in Ayurvedic Medicine

The concept of Ayurvedic medicine originated in the Indian Subcontinent and has become globally practised, as part of complementary and alternative medicines. It includes a wide range of medicines, including Asthavarga preparations (Dhyani, *et al.*, 2010) used to treat a variety of ailments. Nepal's Ayurvedic trade has been reported to involve nearly 94 orchid species (Acharya and Rokaya, 2010; Subedi *et al.*, 2013), including *Crepidium acuminatum*, *Habenaria intermedia*, *Herminium edgeworthii* and *Malaxis muscifera* (Dhyani *et al.*, 2010; Hossain, 2009; Khajuria *et al.*, 2017). *Eulophia* spp. are also widely used medicinally across large parts of India [*E. dabia*, *E. spectabilis* (= *E. nuda*): Jalal *et al.*, 2014], and *D. hatagirea* is used to treat a range of ailments (Pant and Rinchen, 2012). Estimates suggest that 6200-31,000 kg of *D. hatagirea* are harvested annually in the north-eastern Himalayan region of Sikkim (Rai *et al.*, 2000; Uniyal *et al.*, 2002), with each kilo having nearly100 individuals (Pant and Rinchen, 2012). *Paphiopedilum druryi*, an IUCN-listed Critically Endangered species endemic to Kerala, also continues to be collected for medicinal use and horticulture (Maridassa *et al.*, 2008; Rankou and Kumar, 2015).

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