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MORPHOLOGICAL DIVERSITY IN *CYMBIDIUM* ORCHIDS

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Abstract

Orchids constitute one of the largest families of flowering plants and are distributed throughout the world. The family Orchidaceae is divided into five subfamilies (*Apostasioideae, Cypripedioideae, Vanilloideae, Orchidoideae,* and *Epidendroideae*). The orchids are evergreen or deciduous herbaceous plants and show a wide range of diversity both in vegetative and reproductive characters for climatic and physiological adaptations. The present study was conducted using all vegetatively propagated 12 species and 30 hybrids of commercially grown orchid genus *i.e.*, *Cymbidium*. Using 62 descriptors, morphological diversity of species and hybrids of *Cymbidium* was studied based upon the International Union for the Protection of New Varieties of Plants (UPOV) guidelines. Amongst different morphological descriptors, their diversity, diversity in shape of pseudobulbs and leaves, inflorescence variations, and floral characteristics were studied in detail.

Introduction

THE FAMILY Orchidaceae is one of the largest families of flowering plants (Willis, 2017) and is distributed throughout the world. Orchids account for *ca.* 8% of angiosperm species diversity (Chase *et al.,* 2015). Till date, 29,481 species have so far been identified and accepted (WFO, 2023), although several hundred new species are added each year. 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). Orchids may be epiphytes, terrestrials, subterranean, and lithophytes. 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). 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, 2015). One of the best-known plant groups in the global horticultural and cut flower trades (De, 2015), these plants are also harvested, grown and traded for a variety of purposes, including as ornamental plants, medicinal products, and as food. Several local species of *Ascocentrum, Calanthe, Cymbidium, Dendrobium, Paphiopedilum,* and *Vanda etc.* are in great demand in international market for breeding materials (Kumar *et al*., 2007; Roy, 2023). Globally, the trade on artificially propagated live plants is dominated by orchid hybrids (28.7%), *Cymbidium* species (26.9%), *Phalaenopsis* hybrids (10.1%), *Phalaenopsis* species (4.4%), *Dendrobium* species (3.4%), *Cymbidium* hybrids (3.3%), *Dendrobium* hybrids (2.3%), *Cattleya* species (0.4%), and *Oncidium* species (0.2%) (UNEP, 2017). Orchids occupy good rank amongst the best sellers in the global potted plant trade (Flora Holland, 2015; USDA, 2016) and also comprise *ca.* 10% of all fresh cut flowers traded internationally (De, 2015; Prakash and Pathak, 2020, 2023). Cymbidiums are amongst the most popular winter and spring blooming semi-terrestrial orchids grown in Australia, New Zealand, Japan, the Netherlands, the USA, and England. In the international trade, amongst top ten cut flowers, orchids rank at the sixth position and amongst orchids, *Cymbidium* ranks at the first position and in floricultural crops, it accounts for 3% of the total cut flower production (De and Debnath, 2011). The Netherlands is the top most orchid exporting country (39. 67%) followed by Thailand (28.41%), Taiwan (10%), Singapore (10%), and New Zealand (6%), respectively. Importing countries are mainly Japan (30%), UK (12%), Italy (10%), France (7%), and the USA (6%), respectively (Cheamuangphan *et al.,* 2013). In India, its cultivation is limited to Sikkim and the surrounding region of West Bengal covering Kalimpong, Darjeeling, and Mirik hills. Other NorthEastern states like Nagaland and Arunachal Pradesh are also promoting these plants. Higher elevations of (1500-2000m) with cool summer nights and monsoonal summer rain are ideal for *Cymbidium* cultivation (De and Singh, 2018).

Material and Methods

Presently, the experiments were conducted using all vegetatively propagated species of *Cymbidium* and its commercially grown hybrids. For all the varieties and species, full grown 20 plants with at least two pseudobulbs/shoot were selected for the present study. Usually, healthy and insect, pest and disease free plants are required for testing for taking morphological observations without any chemical and bio-physical treatment. The experiments were conducted for two

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similar flowering seasons at two different places under greenhouse conditions ensuring satisfactory growth for the expression of the relevant characteristics of the variety and species. All observations were taken by measuring or counting made on 10 plants or parts taken from each of 10 plants. Normally, growth regulators were not applied. Observations were taken of the vegetative parts (pseudobulbs and leaves), inflorescence and the flowers at the time when 50% of the flowers on the inflorescence have opened. Observations were also taken for the most recently fully opened flowers on the inflorescence before fading of their colour; and also of the length and width of the flowers along with other floral parts (colour of sepal, petal, lip, and column on the inner side) in the spread out position. For the assessment of colour characteristics, the Royal Horticultural Society (RHS) colour chart was followed.

Results and Discussion

A variant, clone, extant variety or farmers variety can be registered if it fulfills essentially the criteria of Distinctiveness, Uniformity, and Stability which means the candidate variety must be distinguishable by at least one essential characteristic from a variety which is sufficiently uniform in its expression of its essential characteristics which should remain fixed even after repeated propagation. The variety should also have a single and distinct denomination (Henke, 2008). In the present investigation, morphological diversity of 12 *Cymbidium* species *i.e., Cymbidium aloifolium, C. dayanum, C. devonianum, C. elegans, C. erythraeum, C. gammieanum, C. iridioides, C. lowianum, C. mastersii, C. pendulum,* and *C. tigrinum* and 30 elite *Cymbidium* hybrids were studied with 62 morphological descriptors based upon UPOV guidelines. The species like *Cymbidium devonianum, C. ensifolium,* and *C. pumilum*, are small flowered types and cross easily with the large flower Himalayan species. Most of the hybrids of *Cymbidium* are evolved through the utilization of the eight of the large flowered species *i.e.*, *C. eburneum*, *C. erythrostylum, C. hookerianum* (syn. *C. grandiflorum*), *C. insigne, C. iridioides* (syn. *C. giganteum*), *C. lowianum*, *C. sanderae*, and *C. tracyanum*).

Table 1. Pseudobulb shapes in *Cymbidium* orchids.

Shape	*Cymbidium* species/ varieties
Round	*Cymbidium dayanum, C. eburneum, C. tigrinum C.* 'Lucky Rainbow'
Ovoid	*C. erythraeum, C. giganteum, C. hookerianum C. lowianum, C. pendulum, C. tracyanum*
Conical	*C. elegans, C. gammieanum, C. 'Luna Pink', C. mastersii*

Table 2. Leaf types in *Cymbidium* orchids.

Shape	*Cymbidium* species/ varieties
Linear	*Cymbidium gammieanum, C. mastersii, C. pendulum*
Linear-oblong	*C.* 'Soul Hunt', *C.* 'Fire Storm', *C.* Bob Marlin 'Lucky', *C.* 'Winter Beach Sea Green', *C.* 'Madrid Forest King'
Lanceolate	*C. tigrinum*
Ob-lanceolate	*C. devonianum, C. lancifolium*

Table 3. Inflorescence variations in *Cymbidium* orchids.

Inflorescence characteristics		*Cymbidium* species/ varieties
Number of inflorescences /pseudobulb	One	*C. tracyanum, C.* 'Jungfrau Snow Queen', *C.* 'Fire Storm', *C.* Bob Marlin 'Lucky', *C.* 'Winter Beach Sea Green'
	Two	*C. elegans, C.* 'Sleeping Nymph', *C.* 'PCMV'
	More than two	*C. lowianum, C.* 'H.C. Aurora',
Orientation of the Inflorescence	Erect	*C. eburneum, C.* 'Jungfrau Snow Queen', *C.* 'Sleeping Nymph', *C.* Red Star', *C.* 'Valley Legend Steff'
	Arching/ Horizontal	*C. erythraeum, C. hookerianum, C. tracyanum*
	Drooping/ pendulus	*C. aloifolium, C. dayanum, C. devonianum, C. elegans, C. lowianum*
Length of the Inflorescence	Short (<30cm)	*C. devonianum, C. ebuneum, C. erythraeum, C. tigrinum*
	Medium (30-60cm)	*C. elegans, C. ensifolium*
	Long (>60cm)	*C. aloifolium, C. gammieanum, C. lowianum, C. tracyanum*

Table 4. Number of flowers/inflorescence in *Cymbidium* orchids.

Number of flowers/inflorescence	*Cymbidium* varieties and species
<12	*C. ensifloium, C. erythraeum, C. irridoides, C. mastersii, C. tracyanum, C.* 'September Sunset'
12-20	*C. devonianum, C.* 'Ensikhan', *C.* Madrid Forest King, *C.* 'Red Star', *C.* 'Red Beauty Evening Star'
>20	*C. aloifolium, C. gammieanum, C. lowianum*

Morphological Characteristics of Cymbidium

Stem and Pseudobulbs

Cymbidiums are sympodial orchids which are characterized by short and stout pseudobulbs ensheathed by encircling leaf bases. Leaves are long, ribbon shaped, leathery or soft and lanceolate. The flower spikes develop from the base of the pseudobulbs. A plant has three types of bulbs. Old back bulbs without leaves which act as a reserve food supply for emergencies. Back bulbs can make new plants but they may take years to flower. Old bulbs with leaves which support the new growth and may produce flowers for a number of years depending on the variety. New leads or bulbs are the youngest bulbs on the plant that produce flowers. When dividing, at least one old bulb and one back bulb must be retained with this bulb to ensure that the plant may flower the following year. Being sympodial epiphytes, the base of the stem may be thickened to form what is called a pseudobulb that contains nutrients and water for drier periods. In *Cymbidium sinense,* pseudobulbs are able to retain about 64% of their water content after 42 days of water stress conditions (Zheng e*t al*., 1992). Pseudobulbs may be conical, round to ovoid in *Cymbidium* (Table 1). The pseudobulbs of *Cymbidium* accumulate massive amounts of carbohydrates during vegetative development. These carbohydrate reserves are subsequently remobilized to support new shoot and inflorescence development (Hew and Ng, 1996; Ng and Hew, 2000). In backbulbs, carbohydrate content ranges from 70 mgG^{-1} in *Cymbidium;* 'Pink' to 152 mgG^{-1} in *Cymbidium* 'Fire Storm Blaze' whereas in flowering pseudobulbs, it varied from 88 mgG^{-1} in *Cymbdium* 'Pink' to 180 mgG^{-1} in *Cymbidium* 'Fire Storm Blaze' (De, 2020a).

Table 5. Predominant colour variations in *Cymbidium* orchids.

Characteristics of floral parts		*Cymbidium* species/ varieties
Petal main colour	Green	*C. lowianum*, *C.* 'Nonina Paleface', *C.* 'Concerto'
	White	*C.* 'Jung Frau Snow Queen'
	Yellow	*C. pendulum, C. gammieanum, C. elegans, C. erythraeum, C.* 'Pine Clash Moon Venus', *C.* 'Sun Gold', *C.* 'Sunny Moon'
	Pink	*C.* Rocky Creek "Pebbles"
	Red	*C.* 'Fire Storm Blaze', *C.* 'Bob Marlin Lucky', *C.* 'Red Beauty Evening Star'
	Purple	*C. devonianum, C.* 'Arabian Night'
	Brown	*C. pendulum*
Lip main colour	White	*C. tigrinum*
	Yellow	*C. elegans, C. gammieanum*
	Red	*C. aloifolium, C. irridoides*
	Purple	*C. dayanum, C. pendulum, C.* 'Soul Hunt-6'
Lip colour pattern	Uniform	*C.* 'Sungold'
	Spotted	*C. hookerianum, C. tigrinum*, C. 'Jungfrau Dos Pueblos', *C.* 'Takarjoke', *C.* 'Fire Storm', *C.* Bob Marlin 'Lucky'
	Blotched	*C. devonianum, Cymbidium irridoides, C. pendulum*, *C.* 'Pine Clash Moon Venus', *C.* 'H.C. Aurora'
	Shaded/Striped/ Streaked	*C. dayanum, C. mastersii, C.* 'Red Star'
	Mixed	*C. aloifolium*, *C.* 'Hazel Fay -Tangerine', *C.* Fire Storm "Blaze"

Leaf

Orchids generally have simple leaves with parallel veins, although some Vanilloideae have a reticulate venation. These may be linear, linear-oblong, ovate, lanceolate, or orbiculate, and very variable in size. Epiphytic orchids are characterized by thick and succulent leaves with thick cell walls, cuticles, and small substomatal chambers whereas those of terrestrial species are thin (Sailo *et al*., 2014). Usually mature leaves are photosynthetically active. Leaves are sites for reduction of transpiration, water storage organs, retention of rain or condensed water and absorption of water as liquid or vapour. In *Cymbidium*, number of leaves vary from 5 to 10 and linear, linear-oblong and lanceolate in shape (Table 2). Chlorophyll content in linear leaves varies from 51.7 mg/100g in *Cymbidium mastersii* to 66.5 mg/100g in *C. pendulum* whereas in linear-oblong leaves, it is from 45.6 mg/100 mg in *C.* 'Bartha Peterson' to 88.9 mg/100g in *C*. 'Fire Storm Blaze'.

Inflorescence

Orchids are arranged with flowers on an inflorescence, which is a spike, a raceme or a panicle. In *Cymbidium*, spike initiates from base of young pseudobulbs or mature pseudobulbs with leaves. These species usually produce arching or drooping inflorescences whereas hybrids give out erect inflorescences and number of inflorescences per pseudobulb ranges from 1 to 3 (Table 3).

Flowers

Orchids are monocotyledonous plants bearing flowers with seven floral parts- three sepals, three petals and the column or gynostemium. The two lateral petals are alike and the other one, called the lip or labellum, is highly modified and enlarged. The labellum is the most prominent and distinctive part of the orchid flower. The lip is attached to the base of the column loosely or firmly. The colour pattern, size, and shape of the lip vary in different genera. The most fascinating aspect of the lip is its habit of mimicry to facilitate pollination. The column or gynostemium located at the center of the flower, is the unique structure distinguishing the orchids from all other kinds of plants. It is the reproductive part of the flower formed by the union of the male and female organs. It bears one to three movable or rigidly attached anthers at its tip or on the sides. The anther contains a mass of pollen called pollinium which is varying from 2, 4, and 6 to 8. The

Table 6. Variation of sepal, petal and lip shape in *Cymbidium* orchids.

Variations in shapes of floral parts		*Cymbidium* species/ varieties
Dorsal sepal	Linear	*C. aloifolium*, *C. iridoides*, *C.* 'Yankilla',
	Lanceolate	*C. dayanum, C. devonianum*
	Elliptic	*C.* 'H.C. Aurora', *C.* Bob Marlin 'Lucky',
	Oblong	*Cymbidium aloifolium*, *C. hookerianum*, *C. lowianum, C. mastersii, C.* 'Winter Beach Sea Green', *C.* 'Madrid Forest King'
	Obovate	*C.* 'Soul Hunt', *C.* 'W.W. Wondrous'
	Ovate	*C.* 'Hazel Fay –Tangerine'
Petal	Linear	*C. dayanum, C. mastersii, C. iridoides, C.* 'Red Star'
	Lanceolate	*C. ensifolium, C. lowianum*, *C.* 'Madrid Forest King', *C.* 'Ensikhan'
	Elliptic	*C. devonianum, C. lancifolium,*
	Oblong	*C. aloifolium, C. iridoides*
	Obovate	*C. hookerianum*, *C.* 'Soul Hunt', *C.* 'H. C. Aurora', *C.* Bob Marlin 'Lucky', *C.* 'Winter Beach Sea Green'
	Ovate	*C.* 'Hazel Fay –Tangerine', *C.* 'Caripepper Peachy Keen'
Lip	Oblanceolate	*C. elegans*
	Elliptic	*C.* 'Arabian Night'
	Ovate	*C. gammieanum, C. iridioides* , *C.* 'Jungfrau Dos Pueblos'
	Obovate	*C. devonianum, C. mastersii*
	Sub-orbicular	*C. aloifolium*
	Orbicular	*C.* 'Pine Clash Moon Venus', *C.* 'Sungold'

pollinia are contained in a cavity called the clinandrium. Just below the anther, on the ventral surface of the column, is a hollow cavity of sticky and viscid mass known as stigmatic surface. It is formed by the fusion of two fertile stigmas. The anther and stigmatic surface is separated by the structure called rostellum, which is actually the third stigma. The rostellum serves to prevent from self-pollination. In *Cymbidium*, the spikes are erect, arching or pendulous and arranged with 2 to 15 flowers. *Cymbidium* hybrids are classified into three groups-Standard, Intermediate, and Miniature hybrids. Standard and Intermediate hybrids produce 90 to 120 cm long spikes with 8 to 15 flowers per spike (Table 4). Miniature hybrids produce green, yellow or brown coloured flowers, 30 cm tall and each spike contains 30-40 flowers of 2.5 to 8.5 cm across. Novelty or Intermediate hybrids have been evolved by crosses between Miniature and Standard hybrids, and produce flowers of white, green, yellow, pink, maroon, red, and brown colour (Table 5). Shape of the sepal, petal, and lip varies depending upon species and varieties (Table 6).

Conclusion

Morphological studies are essential for conservation and utilization of endangered orchids. Native species can be effectively utilized for development of inter-generic, inter-specific or intra-specific natural hybrids of commercially important orchid genera like *Cymbidium* and their compatible alliances which would be market driven having export value as well as tolerant to biotic and abiotic stresses. Investigations on morphological diversity could open up avenues for identification of new and elite germplasm for pot culture, cut flowers, dry flowers, herbal preparations, smart packs, and exhibits for market displays.

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