

GOOD AGRICULTURAL PRACTICES OF *DENDROBIUM* ORCHIDS

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Abstract

Dendrobiums are sympodial epiphytic orchids and popular potted flowering plants and cut-flowers around the world due to their floriferousness, wide range in flower colour, size and shape, year round availability, and lengthy vase life. Elite species of *Dendrobium* are used as parents for breeding programmes to develop outstanding hybrids of special merit. Native species are used as genetic resources for crop improvement programmes, potted plants, dry flowers, hanging baskets, tree mounting, and medicinal purposes. *Dendrobium* hybrids are used as cut-flowers, pot plants, in bouquet arrangements, and for display in exhibition. In the present study, agricultural practices including post-harvest management and value addition of tropical, subtropical, and temperate species and hybrids of *Dendrobium* are discussed in details.

Introduction

DENDROBIUMS ARE popular potted flowering plants and cut-flowers around the world due to their floriferousness, wide range in flower color, size and shape, year round availability, and lengthy vase life (Gupta and Saravanan, 2017). Hawaii, California, and Florida are major potted *Dendrobium* growing regions in the United States. In The Netherlands, production of potted orchids is now 40 to 50 million units with *Dendrobium* increasing in popularity. Thailand holds a particularly strong position in *Dendrobium* orchids. It is estimated that 54% of the orchids produced in Thailand are currently exported, while the remaining 46% are consumed in the domestic markets. The export value of orchid cut-flowers has increased sharply to about 60 million USD in 2014. Simultaneously, the export of orchid plants has also rapidly increased to about 22 million USD in 2014.

Botanical Description

Dendrobium comprises 1600 species of sympodial epiphytic orchids. The genera are characterized by long pseudobulbs or canes with soft leaves on entire length or in some species, pseudobulbs are short or swollen terminating in two coriaceous leaves. The pseudobulbs are of four types; a, cane woody; b, cane cylindrical; c, cane clavate fleshy; and d, bulbous round.

The leaf size ranges from 2.5 cm to 40 cm; these are thick, deciduous or evergreen. In some groups, the flowers joined in pairs or group of three on small peduncle on the entire length of the pseudobulbs, with caduceous leaves. In some species, with persistent leaves, the flowers are grouped in pairs or three or alternately closely set forming erect or pendent thyrses. In another group, flowers are generally solitary and small, arising from the axils of

leaves. The *inflorescences* are terminal or sub terminal and arranged with one to several dozens of flowers with extremely diverse dimensions, size, and ranges of flower colour.

Importance and Uses

Dendrobiums are popular for cut-flowers and for interiorscaping. They are also valuable as pot plants or hanging baskets (De and Pathak, 2018). Some species are hanged on the walls or on tree branches to cover the bare area. The dried stems of *Dendrobium nobile* are used for making herbal medicines. *Dendrobium* enhances salivation and used for the treatment of dry mouth, dry coughs, and severe thirst. Flowers could be used to cure eye ailments. The tonic made from *Dendrobium* nourishes stomach, lungs, and kidneys. The plant is effective in treating pulmonary tuberculosis, impotence, and anorexia. The most prominently cited orchids in Chinese Traditional Medicine are several *Dendrobium* spp. which are used to make the drug *shi-hu* from *D. catenatum*, *D. loddigesii*, *D. moniliforme*, *D. nobile*, and *D. officinale* (Leon and Lin, 2017; Teoh, 2016). The pulp of pseudobulb is applied to treat boils and pimples. Juice of the plant is used to relieve fever. *Dendrobium* blossoms are the most common species used in cooking. In Thailand, these edible flowers are dipped in butter and deep fried while many European cooks garnish desserts and cakes with them. The starchy stems of *D. speciosum* are roasted and eaten.

Dendrobium Species for Hybridization Programme

The *Dendrobium* species like *D. aemulum*, *D. affine*, *D. aggregatum*, *D. albertisii*, *D. aries*, *D. canaliculatum*, *D. chrysotoxum*, *D. compactum*, *D. dalhousieanum*, *D. delicatum*, *D. dicuphum*, *D. forbesii*, *D. formosum*, *D.*

goldiei, *D. gracilicaule*, *D. gracillimum*, *D. grantii*, *D. johnsoniae*, *D. kingianum*, *D. laxianthera*, *D. laxiflorum*, *D. leporium*, *D. macrophyllum*, *D. mirbellianum*, *D. nobile*, *D. odoardi*, *D. ostrinoglossum*, *D. phalaenopsis*, *D. primulinum*, *D. superbium*, *D. taurianum*, *D. tetragonum*, *D. toftii*, *D. tokai*, *D. trilamellatum*, *D. undulatum*, *D. veratifolium*, *D. violaceoflavens*, and *D. williamsonii* are successfully utilized for hybridization programme and produce many outstanding hybrids of special characters (De *et al.*, 2014 a,b,c).

Dendrobium Species for Breeding Pot Plants

For producing compact hybrids with short pseudobulbs to breed for potted plants; *D. bigibbum* var. *compactum*, *D. carronii*, *D. canaliculatum*, *D. var. compactum*, *D. phalaenopsis*, *D. 'Mini Gem'* are suitable (Kuehnle, 2006).

Dendrobium Varieties as Proven Parents

Dendrobium 'Agnes', *D. 'Ann'*, *D. 'American Beauty'*, *D. 'Amethyst'*, *D. 'Anouk'*, *D. 'Artur Elle'*, *D. 'Black Bountain'*, *D. 'Caesar'*, *D. 'Carol Ann'*, *D. 'Claire Ayau'*, *D. 'Concert'*, *D. 'Constance'*, *D. 'Dixon'*, *D. 'Endeavour'*, *D. 'Ethreal Kawamoto'*, *D. 'Ewa'*, *D. 'Gold Flush'*, *D. 'Gold Twist'*, *D. 'Helen Fukumara'*, *D. 'Hula Girl'*, *D. 'Jaquelyn Thomas'*, *D. 'Karen Ono'*, *D. 'Khaw Young Hong'*, *D. 'Lady Fay'*, *D. 'Lady Hamilton'*, *D. 'Lady Nui'*, *D. 'Lim Chong Min'*, *D. 'Lynn Takiguchi'*, *D. 'Maloe Kanya'*, *D. 'Manoa Gold'*, *D. 'Margi Thomas'*, *D. 'Main Beauty'*, *D. 'May Neal'*, *D. 'Mustard'*, *D. 'New Hawaii'*, *D. 'Pale Face'*, *D. 'Pompadour'*, *D. 'Rose Chong'*, *D. 'Shangrilla'*, *D. 'Ursula'*, *D. 'Valley King'*, *D. 'Vera Patterson'*, *D. 'Yellow Curls'*, *D. 'Yellow Jacket'* (De *et al.*, 2014 a,b,c).

Dendrobium Species for Pot Culture/Tree Mounting/Hanging Baskets (De *et al.*, 2014 a,b,c)

Dendrobium aggregatum auct. non Kunth.

Distributed in South China, Burma, Thailand, and Laos. The *pseudobulbs* are short clustered, yellowish, furrowed with persistent fleshy solitary *leaves*. *Inflorescence* is pendulous or arching bearing 12 or more flowers. The *flowers* are yellow, 5 cm in diameter, fragrant, long lasting, and are produced in March-April.

Dendrobium aphyllum (Roxb.) C.E.C.Fisch.

Native to Assam and Meghalaya. *Flowers* develop in fascicles of 2-4 at each node of long pendent stem. *Flowers* are soft mauve with a white *lip*, and are produced during April-May.

Dendrobium bensoniae Rchb.f.

Native to Manipur and Mizoram. *Pseudobulbs* are fleshy,

stout, and pale yellow with deciduous linear *leaves*. The *flowers* arise in fascicles of 1-3 flowers from the upper nodes of leafless pseudobulbs. The *flowers* are long lasting, 4-6 cm in diameter, scented, and pure white in colour and *lip* yellow. The *flowers* are produced in May-June.

Dendrobium bigibbum Lindl.

Native to Queensland and New Guinea. The *pseudobulbs* are erect, slender with leathery, evergreen *leaves*. *Inflorescence* is terminal, arching, and arranged with 25 or more flowers. The *flowers* are pure white to rosy mauve and are produced during winter and spring season.

Dendrobium chrysanthum Wall. ex Lindl.

Native to North Eastern states. Golden fragrant *flowers* borne in fascicles of 2 to 4 at each node of pendent *cane*. *Lip* is yellow in the centre with a large double spot of red purple. *Flowers* are produced during July-September.

Dendrobium chrysotoxum Lindl.

Native to Himalayas, Burma, South China, Thailand, and Laos. The *pseudobulbs* are erect, clustered, club shaped with leathery coriaceous *leaves*. The *inflorescences* are arching, 30 cm long, yellow with orange blotched *lip*, and are produced during March-April.

Dendrobium crepidatum Lindl. & Paxton

Native to Bhutan, India, and Nepal. A pendulous orchid with long, curved *pseudobulbs*, and linear lanceolate *leaves*. *Inflorescence* is lateral, leafless at flowering and borne in fascicles of 2 to 4 flowers. *Flowers* are 2-3.5 cm across, white, flushed with pink lilac, and white *lip*. *Flowers* are produced in April-May.

Dendrobium densiflorum Lindl.

Distributed in Himalayas to Burma. The *pseudobulbs* are erect, 4 sided, 30 cm long, green, and club shaped. The *leaves* are coriaceous, dark green, and persistent. Each pseudobulb produces 2 to 3 *inflorescences*. The *inflorescence* is borne from the upper nodes of pseudobulbs, many flowered, pendulous, and cylindrical. The *flowers* are golden yellow with orange *lip*, scented, 5 cm across, and are produced during April-May.

Dendrobium denudans D. Don

Native to Bhutan, India, and Nepal. *Pseudobulbs* are slender, clustered with oblong, sessile *leaves*. *Inflorescence* is terminal and bearing about 10 flowers. *Flowers* are greenish or white and produced during September-October.

Dendrobium devonianum Paxton

This species is native to Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, and Nagaland. *Pseudostems* are slender, cylindrical, pendent with linear-lanceolate leaves. *Inflorescence* is lateral, 1-3 flowered. *Flowers* are 2-5 cm across, white with purple apex, and are produced in May-July.

Dendrobium falconeri Hook.

Native to Arunachal Pradesh, Manipur, Meghalaya, Mizoram, and Nagaland. *Pseudostems* are pendent, branched with bead like nodes and linear leaves. *Inflorescence* is lateral, 1-2 flowered. *Flowers* are 3-5 cm across, white-pale pink with purple tips, and are produced during May-June.

Dendrobium farmeri Paxton

Native to NorthEast India. *Pseudobulbs* are 4 angled, club shaped with 2-3 lance shaped leaves near the apex. *Inflorescences* are borne on cylindrical, pendulous raceme arising from the apices of the mature new growth.

Dendrobium fimbriatum Hook.

Distributed in Himalayas, Burma, Vietnam, Malay Peninsula, and Thailand. The *pseudobulbs* are stem like, slender, terete, stout, erect or arching. The *inflorescence* is 8 to 15 flowered, 20 cm long produced from the top of the ripened stem. The *flowers* are yellow with orange yellow lip, 7.5 cm in diameter, and are produced during March-May.

Dendrobium formosum Roxb. ex Lindl.

Native to Himalayas, Burma to Peninsula, Thailand, and Andaman Islands. The *pseudobulbs* are leafy, erect, pendulous with ovate oblong leaves, persistent. *Inflorescence* is terminal or axillary 3 to 5 flowered in short cluster. The *flowers* are very large, 10 cm in diameter, fragrant, pure white with orange yellow lip.

Dendrobium gibsonii Paxton

Native to Arunachal Pradesh, Meghalaya, Nagaland, and Sikkim. *Pseudostems* are tall, slender, and bearing many ovate-lanceolate sessile leaves. *Inflorescence* is lateral, pendent, slender, and 5-10 flowered. *Flowers* are fragrant, 2-3 cm in diameter, yellow orange, and are produced in July-August.

Dendrobium heterocarpum Wall. ex Lindl.

Native to Bhutan, India, and Nepal. *Pseudobulbs* are stout, erect or pendent, with many oblanceolate leaves. *Inflorescence* is lateral and bearing blooms in fascicles of 1-3 along the nodes. The *flowers* are 5 cm across,

ochraceous yellow to cream in colour, and are produced in March-April.

Dendrobium hookerianum Lindl.

Distributed in Assam and Meghalaya. About 7-11 large golden yellow flowers borne on pendant racemes. Lip is light yellow with two blood red identical blotches. Flowers are produced during August-September.

Dendrobium infundibulum Lindl.

Native to Manipur, Mizoram, and Nagaland. *Pseudostems* are erect, cylindrical with linear lanceolate leaves. *Inflorescence* is terminal or lateral, 2-3 flowered, and borne in raceme. *Flowers* are 7.5 to 10 cm across, pure white, and long lasting with orange yellow lip disc. Flowers are produced during April-May.

Dendrobium jenkinsii Wall. ex Lindl.

Native to India and Bhutan. *Pseudobulbs* are aggregated, oval, compressed, ridged with solitary leaves borne at the apex. The *flowers* are 2 to 4 cm in diameter, orange yellow with a heart shaped lip, and are produced during May.

Dendrobium loddigesii Rolfe

Native to China. The *pseudobulbs* are small, slender, numerous, clump forming with caduceus oblanceolate leaves. The *flowers* are solitary, pale pink with fringed lip, fragrant, long lasting, and 5 cm in diameter.

Dendrobium moschatum (Buch. - Ham.) Sw.

Native to Meghalaya, Assam, and Nagaland. Drooping racemes of 7-15 apricot yellow flowers appear on the upper part of the stem. Lip is slipper shaped, dark orange in colour, and with two identical eye-like maroon blotches. *Flowers* are produced during May-June.

Dendrobium nobile Lindl.

Native to South China, Nepal, Himalayas, Thailand, Vietnam, Laos, and Formosa. The *pseudobulbs* are arching or erect, 60-90 cm tall with caduceus, leathery, and glossy green leaves. *Inflorescence* is 1 to 3 flowered, short, and arises from the upper nodes of the old leafless pseudobulbs. The *flowers* are fragrant, pinkish white, long lasting, 10 cm in diameter, waxy, lip with white margin. The flowers are produced during April-May.

Dendrobium ochreatum Lindl.

Native to NorthEast states. *Pseudostems* are stout, cylindrical, curved with ovate lanceolate leaves. *Flowers* are 5-7 cm across, fragrant, fleshy, golden yellow with maroon purple disc. The flowers are produced during May-June.

Dendrobium parishii Rchb.f.

Native to Manipur and Mizoram. *Pseudostems* are cylindrical, arching to pendent with oblong lanceolate leaves. *Inflorescence* is borne at nodes of leafless pseudostems and 2-3 flowered. The flowers are 3-5 cm in diameter, fragrant, rosy purple, and are produced in June-July.

Dendrobium pierardii Roxb. ex Hook.

Native to Himalayas, Burma, China, and India. The *pseudobulbs* are thin, very elongated, 60-75 cm long, stem like, pendulous or drooping with soft textured deciduous lanceolate leaves. *Flowers* are 5 cm in diameter, scented, short lived, pale pink with yellow lip streaked with red, and are produced during March-April. This species is ideal for covering bare walls and hanging baskets.

Dendrobium primulinum Lindl.

Native to NorthEast States of India. *Pseudostems* are stout, cylindrical, prostrate or pendent with oblanceolate leaves. *Inflorescence* arises from nodes of past season's growth and 1-2 flowered. The flowers are 4-8 cm across, highly scented, rosy pastel pink with cream yellow lip. The flowers are produced during March-April.

Dendrobium speciosum Sm.

A robust species from Australia and New Guinea. *Pseudobulbs* are swollen, conical, and terminated by 2 to 4 leaves. The leaves are apical, persistent, rigid, and leathery. *Flowers* are many and arranged closely in pendent thyrses. Flowers are fragrant and produced during autumn-early winter.

Dendrobium spectabile (Blume) Miq.

Native to New Guinea and Solomon Islands. The *pseudobulbs* are club shaped. The flowers are 7.5 cm across, cream to pale greenish in colour with mottled dull purple veins, and yellow white lip.

Dendrobium superbum Rchb.f.

Native to Indonesia, Malaysia, and the Philippines. The *pseudobulbs* are pendulous, cane like with small, fleshy, glossy green, leathery leaves. The *inflorescence* is 2 flowered. The flowers are highly fragrant, 10 cm in diameter, and are produced in winter-spring season.

Dendrobium thysiflorum B.S.Williams

Native to Himalayas, Burma, and Thailand. The *pseudobulbs* are club shaped with several ridges and cylindrical. The leaves are persistent and coriaceous. *Inflorescence* is pendulous and densely flowered. The

flowers are 5 cm in diameter, white with orange yellow lip, and produced during winter-spring.

Dendrobium transparens Wall. ex Lindl.

Native to Arunachal Pradesh, Meghalaya, Nagaland, and Sikkim. *Pseudostems* are slender, erect or pendent, with linear lanceolate leaves. *Inflorescence* develops laterally and 2-3 flowered. *Flowers* are 3-5 cm in diameter, fragrant, pale rosy mauve to white in colour, and are produced during May.

Dendrobium williamsonii Day & Rchb.f.

Native to Assam, Manipur, and Meghalaya. *Pseudostems* are erect, spindle shaped with velvety lanceolate leaves. *Inflorescence* is 1 to 3 flowered. *Flowers* are 3-5 cm across, fragrant, pale green ivory with brick red lip, and are produced during March-April.

Dendrobium Hybrids for Cut Flowers (De, 2014 a,b)*White*

'Snow White', 'Pagoda White', 'Emma White', 'White Surprise', 'Jacquelyn Concert × Walter Oumae', 'Kasem White', 'Big White 4N', 'Big White Jumbo', 'White 5N', 'Airy White'.

Blue

'Vorawit Blue', 'Lee Chong Blue', 'Kultana Blue', 'Kiyoshi Izumi', 'Blue Fairy', 'Lee Chong Blue', 'Bangkok Blue'.

Pink

'Chiengmai Pink', 'Ekapol Panda', 'Jisu's Star', 'Juree Red', 'Kiilani Stripe', 'Long Champ', 'Penang Sugar', 'Sagura Pink', 'Miss Singapore', 'Madam Pink', 'Sonia-16', 'Ear Sakul', 'Candy Stripe Pink', 'Sonia-17', 'Sonia-28', 'Dr. A. Abraham'.

Yellow

'Sri Siam', 'Swan Lake', 'Thongchai Gold', 'Bonchoo Gold', 'Sarifa Fatima'.

Green

'Daangsaard', 'Kanjana Green', 'Green Mist', 'Little Green Apples'.

Red

'Meike Beauty', 'Pathum Red × Sabin', 'Little Lolita', 'Cleopatra', 'Diamond Star', 'Fireball', 'Little Lolita', 'Kating Daang'.

Interspecific Hybrids

'Australian Lemon Pepper', 'Jiali Paradise', 'Womad', 'Green Elf', 'Memoria Dipper Nishi', 'Falcan', 'First Star', 'Falcan', 'Mini Snowflake', 'Scotts Valentine', 'Dounan

Spicy', 'Black Gold', 'Winter Frost', 'Peng Seng', 'Silver Wings', 'Aminah Khatum', 'Bruce Gorden', 'Green Mist', 'Aussies Queen', 'Sweet Phurichaya', 'Big Alex', 'Carly Hera', 'Pink Glow', 'Molly's Angel', 'Go Secret'.

Inter-varietal Hybrids

'Candy Smile', 'Angel Moon', 'Million Gold', 'Liberty Girl', 'Asian Smile', 'Happy Holiday', 'Happy Smile', 'Pop Eye', 'Sunny Bird', 'Wonder Rabbit', 'Peach Blossom', 'Long river Giant', 'Sally Fiesta', 'Rudkin', 'Ice Storm', 'Genting Melody', 'Hawaiian Twinkle', 'Sea Sky', 'Singa Beauty', 'Arthur Reserve', 'Green Wonder', 'Open Heart Leaf', 'Rising Star', 'Fairy Star', 'Nice Boy Wanda', 'Burbank Candy', 'Burnt Orange', 'Justine'.

Variety-Species Hybrids

'Bright Angel', 'Blue Rain', 'Samson Toy', 'Margaret Thompson', 'Third Eyes Vision', 'Rods Eagle', 'Spider Lily', 'Sylvester', 'Paradise Fortune', 'Sky Mirror', 'Butter Fly Dawn', 'Island Snow', 'Australian Idol', 'Fine Ford', 'Half Moon Bay', 'Special Bride', 'Two Kings', 'Juliette Copper', 'Genting Lipstick', 'Singa Kagoshima', 'Jairuk Spin'.

Selection of Species and Hybrids for Year Round Production (De and Singh, 2018)

Some species and hybrids are used for year round production (Table 1).

Table 1. *Dendrobium* species and hybrids with their flowering time, used for year round production.

Species/hybrids	Flowering time
<i>D. aphyllum</i> , <i>D. chrysotoxum</i> , <i>D. densiflorum</i> , <i>D. jenkinsii</i> , <i>D. kingianum</i> , <i>D. nobile</i> , <i>D. pendulum</i> , <i>D. primulinum</i> , <i>D. ruckeri</i> , <i>D. secundum</i>	February-April
<i>D. densiflorum</i> , <i>D. fimbriatum</i> , <i>D. loddigesii</i> , <i>D. nobile</i> , <i>D. parishii</i> , <i>D. pieradii</i> , <i>D. primulinum</i> , <i>D. thyrsiflorum</i>	May-July
<i>D. acinaciforme</i> , <i>D. aduncum</i> , <i>D. bensoniae</i> , <i>D. candidum</i> , <i>D. chrysanthum</i> , <i>D. chrysotoxum</i> , <i>D. draconis</i> , <i>D. gibsonii</i> , <i>D. moschatum</i>	August-October
'Big White 4N'	September-October
'Bangkok Blue', 'Dang Saard', 'Big White Jumbo', 'Erika', 'Madam Pompadour', 'Ear Sakul', 'Thongchai Gold'	June-November
'Madam Pink', 'Triple Pink'	September-November
'Emma White'	March-November
'Julie', 'Kating Dang'	February-August

Growth and Physiology

Like other flowering plants, orchids also have to attain certain stage of growth and fulfil the energetic demand to initiate flowering. It may vary from 3 years to 7 years depending upon the type of species and hybrids. Orchid pseudobulbs are engaged in the control of physiological processes that are important for growth and survival. The ability to store water, mineral, and carbohydrates in the pseudobulbs has greater impact for survival in the harsh and nutrient limited epiphytic biotope. Pseudobulb photosynthesis recycles respiratory carbon that would contribute positively to whole plant carbon economy. There were significant variations in the content of carbohydrates in pseudobulbs and flowers and chlorophyll content in leaves among different hybrids. Reducing sugar analysis was carried out in *Dendrobium* hybrid 'Thanchai Gold'. Three stages of flowers like opened flowers, partially opened flowers and floral buds were taken for analysis. It was found out that opened flowers contains 29.00% of reducing sugars, whereas partially opened flowers and floral buds contain 28.25% and 16.17%, respectively, for the same.

Propagation

Conventionally, *Dendrobiums* are easy to propagate through keikies which are produced along old canes or by division of pseudobulbs (Gupta and Saravanan, 2017). 10-12 cm long cuttings can also be taken from a healthy, older, and leafless cane keeping three nodes on each cuttings and placed in moist *sphagnum* moss for rootings. Commercially, *Dendrobium* hybrids are usually either seed-propagated or clonally propagated through tissue culture using apical and lateral buds which regenerate protocorm like bodies (PLBs). For seed propagation, green capsules are surface sterilized and seeds are inoculated on a basal salt medium (pH 4.8 to 5.0) containing 15% coconut water and 2% sucrose for germination. Three months after sowing, seedlings are transflasked with 75 to 100 plants per 500 ml flask on a nutrient medium containing 15% coconut water, 2% banana powder, and 1% sucrose.

Cultivation

Temperature

The cool growing *Dendrobium* orchid group thrives well in temperatures ranging between 10-24°C. The intermediate *Dendrobium* orchids prefer a temperature range of 14-26°C whereas the warm growing *Dendrobium* orchids prefer the temperature between 16-30°C. The warmer group species like *Dendrobium antennatum*, *D. biggibum*, *D. discolor*, *D. gouldii*, and *D. phalaenopsis* bloom at night temperatures above 16°C and the cool

growing species such as *D. aggregatum*, *D. anosmum*, *D. chrysotoxum*, *D. densiflorum*, *D. lindleyi*, *D. parishii*, and *D. pierardii* perform well at night temperature of 10°C. Low day temperature causes leaf yellowing, defoliation, and reduces vegetative growth whereas higher temperatures delay flower bud development. Low temperature and short days could change the concentration of endogenous growth regulators leading to the induction of flowering in sympodial orchids (De, 2020 a,b).

Light

Most orchids generally prefer indirect or filtered light. Although it varies from species to species, growth habit and habitat and as the rule of the thumb, 50% shading is always advised for most of the commercial orchids. Under enough light, orchid plants have short, plump stems with bright green leathery leaves and yellowing, stunting, and scorching of plants under too much of light and under too much shade plants have darker green, soft, and succulent leaves with thin and spiny stems. All types of *Dendrobium* orchids require warm bright light (2500-3000 foot candles). They should get at least 12-14 hr of light each day year round.

Atmosphere

Fresh air and good circulation are essential for orchid production. Full of continual light breezes make a good source carbon dioxide for photosynthesis.

Fertilization

Orchids are light feeders and they require nitrogen from beginning to two-third of their life cycle. During rest period, they do not need any fertilizers. During flower initiation and inflorescence development, plants are fed with less Nitrogen, more Phosphorus, and Potassium. During the blooming time, a small level of Nitrogen and phosphorus and high levels of Potassium are maintained. In orchids, foliar feeding is found to be ideal. Frequent application of fertilizers in low concentrations is the best way of feeding orchids. A concentration of 0.2 to 0.3% of 30:10:10 (N:P:K) at vegetative stage and 10:20:20 (N:P:K) at blooming stage are applied for quality flower production. Sometimes, fresh coconut water and diluted cow urine are also useful as foliar sprays.

Potting Mixture

The potting medium of *Dendrobium* orchids should be loose, friable as well as well drained. A potting medium consisting of charcoal, brick pieces, and coconut fibre in equal proportions is ideal for vegetative growth and flowering of epiphytic orchids like *Aerides*, *Dendrobium* etc. Under low humid conditions (30%), plastic pots with

a mixture of bark/perlite/*Sphagnum* moss or *Osmunda* are used. Under average humidity (35-50%), it is advisable to use plastic pots with a mixture of bark and *Sphagnum* moss. Under high humidity (55% and above), clay pots are used with bark, stone culture, charcoal or tree fern. Amongst potting mixtures used, mixture of coco chips + coco peat + leaf mould + brick pieces (1:1:1:1) showed best longevity in plants [*Dendrobium* 'Ear Sakul' (71 days) followed by *D.* 'Triple Pink' (70 days), and *D.* 'Thongchai Gold' (69 days)].

Watering and Humidity

Most orchids are damaged by overwatering rather than under watering. Over watering leads to root rot and many other diseases. Most orchids prefer water of pH 5.0-6.5. Watering with lower or higher pH or with high levels of dissolved minerals can hamper nutrient uptake. Frequent watering is essential under high sunlight and high temperature conditions. Plants in small containers dry out more quickly than in large containers. Plants in earthen pots require more watering than plants in plastic pots. A hanging plant, with better aeration than one in a pot needs more frequent watering. More frequent watering is necessary for fresh potting materials. Watering should be practiced either in the morning or in afternoon time. Potting materials like coconut husk, tree fern etc. having more moisture retention capacity needs less water and less frequently and vice versa. The single dominant factor which affects the cultivation of orchid is humidity which should be as high as 50-75%. It varies species to species depending upon habit of growth, light, temperature, and ecotypes. As rule of thumb, in high temperature, humidity should be kept high. Provisions of misting units or foggers or even humidifiers will ensure adequate humidity. Standing water beneath the benches may be kept to improve humidity.

Repotting

Orchid plants require repotting if there is no space left in the pots for new growths and if the substrate has decomposed or roots are rotting. Timing is the most important part of good repotting. The best time for repotting of an orchid is when new growth and new roots are just beginning to form, before those new roots reach even 1 cm long. In most of the orchids, it occurs right after flowering. It shows that repotting should be done between February and June.

Application of Growth Regulators

Experimental evidences have shown that photoperiod and low temperature modify concentration of endogenous growth regulators. Combined application of GA₃ and BA improves inflorescence length and reduces percentage of abnormal flowers. In *Dendrobium*

'Thongchai Gold', maximum flower spikes were found in drenching followed by morning and evening sprays. Spike length was found maximum in morning spray with GA₃ 200 ppm (46 cm). In the evening spray with GA₃ 100 ppm, spike length was 43.6 cm and in morning spray with GA₃ 100 ppm, spike length was minimum (42 cm). In *Dendrobium* hybrid, 'Emma White', treatment with NPK (20:20:20) with Ca, Mg, and Mn along with BA 10 ppm and GA₃ 100 ppm increased number of leaves (20.06), pseudobulbs (2.73), and pseudobulb girth (1.94 cm). Plant height was highest (59.79 cm) in treatment with NPK (30:30:30) with Ca, Mg, and Mn along with BA (25 ppm) and GA₃ (50 ppm). Treatment with NPK (20:20:20) with Ca, Mg, and Mn along with BA (50 ppm) and GA₃ (100 ppm) gave maximum number of spikes/plant.

Post Harvest Management

Harvest and Economics

Generally *Dendrobium* orchid spikes possess the vase life of 2 to 3 wks. Usually, 40-60 cm long floral spikes with 10-15 flowers are harvested at a stage when all flowers are open except top bud. Harvested sprays should be immediately placed in clean bucket of water with the cut ends submerged about 2-3 inches. Then the sprays are taken in the cool shaded packing area. In *Dendrobium*, it has been reported that flowers harvested early in the morning, generally last longer than those harvested in the late morning. The cost of one *Dendrobium* spike ranges from Rs. 10 to Rs. 25 depending upon the grade. From an area of 500 m² containing 3000 plants, a *Dendrobium* grower can earn 5 lakhs in three years after selling of 3000 number of cut spikes and 3000 mother plants.

Pre-cooling

It varies with the species and cultivars: *Cattleya* (7-10°C), *Cymbidium* and *Paphiopedilum* (0.5-4°C), and *Dendrobium* (5-7°C). Pre-cooling lowers respiration rate and decreases the breakdown of nutritional and other stored materials in the stems, leaves, and petals and delays bud opening and flower senescence. It also prevents rapid water loss and decreases flower sensitivity to ethylene. Several pre-cooling techniques such as room cooling, forced air cooling, hydro-cooling, vacuum cooling, and ice bar cooling *etc.* are available.

Pulsing

Pulsing is found to be of great value in prolonging life, promoting opening and improving the colour and petal size of petals through osmoregulation. In *Dendrobium* hybrid 'Pompador', 25 ppm AgNO₃ + 135 ppm Na₂S₂O₃·5H₂O for 30 min increases vase life of cut

flowers. In *Dendrobium* cv. 'Sonia' pulsing with 4% sucrose + 400 ppm HQ recorded the highest vase life of 21.33 days (Jommy and Sabina, 2002).

Bud Opening

Bud opening of flowers increases longevity of cut flowers by reducing the sensitivity of flowers to extreme temperatures, low humidity and ethylene, saving space during shipment, and extending the useful storage life. The sugar concentration used is lower than the concentration of pulsing and the optimum temperature is kept lower. In *Dendrobium* hybrids, HQS (Hydroxyquinoline Sulphate) or AgNO₃ (50 ppm) is effective for opening of tight bud cut flowers (De *et al.*, 2014 a,b). It has been reported that a preservative solution containing 225 ppm HQS, 30 ppm AgNO₃, and 4% glucose increased bud opening and the time to wilting of the open florets of *Dendrobium* cv. 'Ceasar'. In *Dendrobium* 'Thongchai Gold', per cent of fully opened buds (66%) was recorded maximum with sucrose (4%) + Ca(NO₃)₂ (1%) followed by sucrose (4%) + acetyl acetic acid (100 ppm) (60%). Longest vase life (36 days) was found with sucrose (4%) + Al₂(SO₄)₃ (100 ppm) followed by sucrose (4%) + acetyl acetic acid (100 ppm) (33 days) (De, 2020a,b).

Preservatives

The vase solution should contain sugars, acidifying agent, and a biocide. Citric acids are mainly used for acidifying agent and hydroxyquinoline as biocide. Metallic salts like silver nitrate, cobalt chloride, aluminium sulphate, zinc sulphate, calcium nitrate, and nickel chloride have been found for prolonging post-harvest life of various cut flowers. A combination of biocide, sugar and hormone (8-HQC 100 ppm + sucrose 2% + BA 25 ppm) remarkably enhances the post harvest life of the *Dendrobium* cut flowers. New chemicals that have been found promising as floral preservatives are ethylene inhibitors like aminoxyacetic acid, 1-amino cyclopropane, aminotriazole, aminoethoxy vinyl glycine, alpha aminoisobutyric acid, diazocyclopentadiene, and phenidone. Holding solutions for increased longevity of *Dendrobium* as reported by various workers are 8-HQC (200 ppm) + sucrose (2%), 0.5 mM AOA + 4% sucrose, AgNO₃ (30 ppm) + 4% sucrose, 400 ppm HQ + 30 ppm AgNO₃ + 2% sucrose, 200 ppm 8-HQS + 50 ppm AgNO₃ + 8% sucrose.

Grading

The export quality orchids are graded to maintain high standards of excellence. Sprays are graded according to length, colour, flower size *etc.* The grading is done in four standard sizes, based on spike length and the quality of the stalk for each grade (Table 2).

Table 2. The Grades of the export quality orchids based on their spike length and the quality of the stalk.

Name of the grade	Length of the spike (cm)	Number of opened flowers
Small-S	30	4-5
Medium-M	40	6-8
Large-L	45	8-10
Extra Large-XL	50	>10

Packaging

The flower spikes of dendrobiums are first sleeved in polyethylene sleeves of standard thickness. The standard is to bunch around 5 spikes of the same grade and variety in a pack box. Each stem in the box should be placed in the tube containing water or preservative solution. During shipment, loss of water could be supplemented by employing flowers tube or vials, which could be filled with water or preservative solution. Instead of small tube, cotton wrapping can also be used; in this case cotton pieces should be dipped in water or preservative solution. Then, the piece of polythene can be used to cover the cotton and it should be tied with rubber band. And cushioning materials should be provided in the back side of the sleeve to avoid the damage during transportation.

Then, these graded flowers are packed in suitable size of boxes. In order to check movement of spikes within the boxes during transit the base of the spikes should be tied to the base of the carton by adhesive tapes. *Dendrobium* flower spikes are normally packed in carton of different sizes. The length of the carton varies mainly based on the length of the flower spikes. The carton should be provided with sufficient numbers of holes or vents for aeration. The carton is exclusively designed to ensure better care of the flowers and help reach their destination in pristine conditions. In *Dendrobium* 'Sonia-17', a low gauge polyfilm of 100 gauge thickness the cotton dipped in 8-HQS (25 ppm) covering the base of the spike had maximum vase life and flower quality (Jawaharlal *et al.*, 2006).

Storage

Storage of cut-flowers is an essential part of floriculture industry. Tropical orchids like *Dendrobium*, can be stored at 7-10°C and 90-95% RH (Relative Humidity). The longest vase life of 19 days has been observed in *Dendrobium* hybrid Sonia 28 followed by 15 days in Sonia 17 when stored at 10°C. The orchids stored below optimum temperature cause chilling injury characterized by darkening of labellum. In extreme cases, the sepals and petals also get affected. Orchids are sensitive to ethylene and the storage environment should be free from ethylene which can be effectively accomplished by proper

ventilation and placing ethylene scrubber or absorbent containing potassium permanganate.

Value Addition

Value addition in flower crops can directly or indirectly influence floral market to a great extent (Janakiram and Baskaran, 2018). Value addition in flower crops by employing techniques like colouring in white flowers, flower dehydration, flower processing, advances in flower arrangements *etc.* can add value 5 to 10 times. It is one of the important value addition technique for imparting desired shades of colour to the flowers. It is very useful technique in flower crops where pigments are absent or light and dull. Aesthetic beauty of the cut flowers and dry flowers can be enhanced through tinting. Translocation, immersion, and spraying are methods followed in tinting. Stopping irrigation two days before the harvest of flower improves the flower colour. It can be combined with pulsing solution. Edible dyes of 0.25 to 1% can be used along with pulsing solutions for 30 min to 3 hr. Different dyes and strains such as food colours, feulgen stain, bromocresol blue, bromocresol green, eosin yellow, ammonium purpurate, and phenol red at varying concentrations can be used to get flowers with different shades of colours. Artificial colouring can be done by using edible dyes like apple green, kalakhatta, rose pink *etc.* Employing this technique, the white flowers can be obtained in all shades of red, blue, green, and yellow. Bouquets are prepared with variously coloured *Dendrobium* cut flowers; these are combined according to their colour and are arranged with some foliage plants and subsequently packed in boxes.

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