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Post-Harvest Physiology and Technology in Orchids

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Abstract

Orchids account for a large share of global floriculture trade and are estimated around 10% of international fresh cut flower trade. They have taken a significant position in cut flower industry due to its attractiveness, diversity in forms, shape and color, high productivity, right season of bloom, and easy packing and transportation. Postharvest life of orchid cut flowers is influenced by pre-harvest factors like varietal or species differences, light intensity, sugar level of flowers, temperature and water loss. It is also affected by harvest factors such as time and stage of harvest and postharvest factors viz. ethylene production, precooling, pulsing, use of preservatives, packaging and storage.

The hybrids of *Dendrobium*, *Vanda* and *Mokara* remain perfect from 7 days to 30 days. The flowers of *Cattleya* and *Phalaenopsis* remain fresh for 1 to 4 weeks whereas *Aranda l*asts for 18 to 28 days. Higher sugar levels of flowers improve longevity of cut flowers. The optimum harvesting stage of commercial orchids is fully open and mature flowers. In *Cymbidium* hyb. 'PCMV', harvest at two buds opened stage had maximum vase life (66.8 days). Ethylene is the main factor responsible for early senescence. In *Cymbidium* hybrid 'Red Princess' pulsing with 5% sucrose increases vase life upto 56 days. Pulsing with 4 mM STS for 10 minutes in *Aranda* and 0.5 mM STS for 24 hours in *Phalaenopsis* blocks the deleterious effect of ethylene.

In tropical orchids like *Dendrobium* and *Oncidium*, $AgNO_3$ (10-30 ppm) and HQS (50-100 ppm) extends vase life and bud opening of cut flowers. In *Cymbidium*, 1-MCP and AVG are superior to STS in prolonging the vase life of cut flowers. In *Cymbidium* 'PCMV', highest per cent of fully opened buds (75%) and maximum vase life (45 days) were recorded with the chemical combination of sugar 4% + salicylic acid 200 ppm.

In orchids, cut spikes are inserted in tube containing water or water with preservatives and bunch of 5 or more or individual spikes are placed inside the CFB box in alternate fashion. Cool growing orchids are stored at lower temperature even at 5°C in cold chambers whereas tropical and subtropical orchids are stored at 7-10°C and 90-95% relative humidity.

Keywords: Orchids; Ethylene; Vase life; Pre-harvest; Post-harvest factors

Introduction

Orchids comprise the largest family of flowering plants with 25,000 to 35000 species belonging to 600-800 genera [1]. They are prized for their incredible diversity in the size, shape and color and attractiveness of their flowers and high keeping qualities even upto 10 weeks. Most of the orchids have originated from tropical humid forests of Central and South America, India, Sri Lanka, Burma, South China, Thailand, Malayasia, Philippines, New Guinea and Australia. Brazilian *Cattleya*, Mexican *Laelia* and Indian *Cymbidium*, *Vanda* and *Dendrobium* have played a major role in developing present day beautiful hybrid orchids which numbers more than 200000. In the international trade, among top ten cut flowers, orchids rank the sixth position and among orchids *Cymbidium* ranks the first position and in floricultural crops it accounts for 3% of the total cut flower production [2].

In India, orchid comprises 158 genera and 1331 species which grow upto an elevation of 5000 m [3]. Indian terrestrials are located in humus rich moist earth under tree shades in North Western India. Western Ghats harbour the small flowered orchids. Epiphytic orchids are common in north eastern India which grows up to an elevation of 2000 m from sea level. Indian orchid species having high ornamental values are *Aerides multiflorum, Aerides odoratum, Arundina graminifolia, Arachnis, Bulbophyllum, Calanthe masuca, Coelogyne elata, Coelogyne flavida, C. corymbosa; Cymbidium aloifolium, C. lowianum, C. devonianum, C. hookerianum, C. lancifolium; Dendrobium aphyllum, D. nobile, D. chrysanthum, D. farmeri, D. chrysanthum, D. densiflorum, D. moschatum, D. fimbriatum, D. jenkinsii; Paphiopedilum venustum, P. spicerianum, P. hirsutissimum, P. insigne, Phaius wallichii, Pleione praecox, Renanthera imschootiana, Rhyncostylis retusa, Thunia alba, Vanda cristata, Vanda coerulea* and *Vanda coerulescens* [4].

In India, some of native genera like *Cymbidium, Paphiopedilum, Vanda, Arachnis* and *Dendrobium* are cultivated on a large scale for cut flower production. The Cymbidium is mainly grown in NEH Region, Sikkim, Darjeeling hills and Arunachal Pradesh. Tropical orchids are cultivated in Kerala and some parts of Tamil Nadu. We should prefer those species which flower during winter and spring months to export flowers to temperate regions from December to May. The orchids have taken a significant position in cut flower industry due to its attractiveness, long shelf life, high productivity, right season of bloom, and easy packing and transportation but lack a complete information module starting from pre-harvest to harvest and subsequently post-harvest techniques including cooling, pulsing, impregnation, bud opening, holding solutions, storage, packaging and transportation of different commercial genera of orchids. In the present investigation, the works on post-harvest physiology and technologies of different orchid genera done by various relevant research workers were reviewed.

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Hybrids and Varieties for Cut Flower

Among the cut flower crops, *Cymbidium, Dendrobium, Phalaenopsis, Odontoglossum, Oncidium, Cattleya, Paphiopedilum, Vanda, Aeridovanda, Aranda, Mokara, Arachnis, Vascostylis, Renanthera, Rhyncicentrum, Rhyncovanda* etc. are important.

A good quality cut flower of an orchid should have the following characteristics [5]:

- Minimum eight standard blooms per stem
- Flowers must be cleaned, evenly colored and free from physiological disorders
- Stem must have flowers evenly arranged and around the stem.
- Two third of the stem should be covered with the flowers.
- Flowers must have a firm texture and a luminescent sheen
- Stems must be firm when held up
- The minimum base diameter of the stem should be of 10mm

Important varieties and hybrids under different genera of orchids for cut flower purposes are listed in Table 1 [6].

Physiology of cut flowers

Vase life or longevity of a cut flower was determined on the basis of attributes like diameter and length of florets, opening of flowers, changes in fresh weight, diameter or length of stem or pedicel, senescence pattern, color of petals, total longevity and foliage burning. In general, cut flowers completed their life cycle in two distinct phases, (i) bud swelling to bud opening and (ii) maturation, senescence and wilting. Flower bud development to swelling involved growth or change in orientation of petals or subtending tissues and may also require abscission of protective structure [7]. When an inflorescence was cut from the plant, a number of physiological processes were affected which included the supply of water, depletion of stored substrates and production of ethylene. The most common symptom of flower senescence was wilting i.e. loss of turgor pressure of the cells due to failure of water uptake [8]. The failure of water uptake as a result of stem blockage might be due to air blockage, microbial growth or physiological plugging. Otherwise senescence was accompanied

Sl No.	Genera	Hybrids/Varieties
1	*Aeridovanda*	Doctor Poyck, Vieng Ping, 'Bensiri', 'Noreen', 'Early Bird', 'Shiv Sidhu', 'New Dawn', Harrison Luke Somsri Sunlight'
2	*Aranda*	'City of Singapore', 'Hilda Galistan', 'Urmila Nandey', 'Christine', 'Thailand Sunspot', 'Millenium Dawn', 'Broga Giant', 'Salaya Red', 'Propine White', 'Propin Spot', 'Lueng Cholburi', 'Ishbel Manisaki', 'Baytown', 'Chao Praya Blue', Chao Praya Dot Com', 'Chao Praya Beauty', ' Ethan Pride', 'Taksari Chandrabir'
3	*Arachnis*	Ishabel, Maggie Oei
4.	*Ascocenda*	Apinantat Red Berry, Pralor Tuyen, Pak-Kred, Bangkok, Surin, Karnada, Crownfox, Sundancer, Laksi 'Red Ruby',Guo Chia Long 'Spotty', Fuchs Angel frost, 'Carol Belk', 'Renuka Angle', 'Joyce Bevins', 'Adisak Blue', 'Renu Gold', 'Tipi Blue Boy', 'Bobs Fortune', 'Rubychai', Shah Rukh Khan', Yang Sophia Firuz', 'Abdul Ghani Othman', 'Chunika', 'Fuch's Star'
5.	*Cattleya and allied*	Lovely Bangkok, Admiration, Bob Belts, General Patton, Joyce Hannington, Little angel, Margaret Stewart, Nillie Roberts, Paerl Harbour, Primma Donna, Queen Sirkhit 'Diamond Crown', Secret Love, Ladda Belle 'Pink Pearl', Maikai, Pastoral, Robert, Prism Palette 'Tricolour Magic', 'Ahmad Seikhi', 'Hsinging Catherine'
6.	*Cymbidium*	Levis Duke Bella Vista, Madrid Forest King, Sparkle Late Green, Angelica December Gold, Sleeping Nymph, Pine Clash Moon Venus, Soul Hunt, Dr. H. C. Aurora, Susan Highes, Tia Gaig Suther Land, Miss Sanders, Amesbury, Kenny Wine, Red Star, Red Princess, Show Girl , Jungfrau 'Snow Queen', Jungfrau 'Dos Pueblos', Lilian Stewart 'Coronation', Lilian Stewart 'Party Dress', Orkney 'Pink Heather', Ensikhan 'Alpha Orient', 'Fire Storm Ruby'
7.	*Dendrobium*	Emma White, Thongchai Gold, July, Erika, Sonia-17, Sonia-28, Kasem White, Madam Pompadour, Bangkok Blue, Ann, Gold Twist, Candy Stripe Pink, Genting Blue, Bengal Beauty, Sakura Pink, Candy Stripe, Burana Charming, Blue Fairy, Channel, Nette White, 'Dang Saard'
8.	*Mokara*	Walter Oumae 'Seksan', Thailand, Sayan, Walter Oumae 'Royal Sapphire', Susan 'Orange', Walter Oumae 'Calypso' , Eng Ling, Madame Panne, Mak Chin On, Bangok Gold, Bibi, Chao Praya Gold, Chark Kuan Orange, Chark Kuan Pink, Chark Kuan Rose, Chark Kuan Super, Dinah Shore, Kelvin Red, Kelvin Orange, Luenberger Gold, Margaret Thatcher, Pink Star, Sayan, Sayang Pink, Walter Oumae, WTO, Jiti, Happy Beauty, Salaya Gold
9.	*Odontoglossum*	Carroll, Ismene, Palnina, 'Italian Job', 'Joyce Stewart', 'Pepe Gerald', 'Purple Rain', 'Katherine Jenkins', 'Roy Wittwer', 'Laguna Blanca', 'Precocious', 'Snow Fall', 'Pesky', 'Queen of Mars', 'Stam Point', 'Holiday Yellow', 'Ronald Norman', 'Bridget Ring Lawless', 'John Hanry Hanson', 'Point Pesky'
10.	*Oncidium*	Aloha Iwanga Dogasima, Goldiana, Gower Ramsey, Golden Shower, Sum Lai Who Jungle Queen, Taka H & R, Sharry Baby Sweet Fragrance AM/AOS, Golden Glow, Popki Red, Irine Gleason Red, Vision Brownish Red, Catherine Wilson x New Calidonia Brownish Red, Robson Orchid Glad
11.	*Paphiopedilum*	Niveum, Concolor, *P. rothschildianum* (3 to 5 flowers), *P. sanderianum* (3 to 5 flowers), Prince Edward of York, Michel Koopwitz, Saint Swithin, Mount Toro, Sorcerer's Apprentice, Grande, Don Wimber, Elizabeth March, Hanne Popow, Jason Fischer, Living Fire
12.	*Phalaenopsis*	Taisuco Crane, Taisuco Kochdian, Cygnus, Yukimai, Sogo Musadian, White Dream, Florida Snow, Nobby's Pink Lady, Minho Valentine, Minho King Beauty, New Cinderella, Taisuco Firebird, Sogo Smith, Carol Campbell, Emil Giles, Brother Lawrence, Taipei Gold, Golden Bells, Sogo Managers, Brother Passat, Be Glad, Cassandra, Vilind, Carmelas Pixie, Zuma's Pixie, Timothy Christopher, Be Tris, Quevedo, Strawberry
13.	*Renanthera*	Brookie Chandler, Manila T-Orchids, Kilauea, Mok Yark-Seng, Poipu, Tom Thumb, 'Red Leopard', 'Scarlet Belle', 'Chanachae', 'Serdang', 'Brady Crocker', '20th WOC Singapore-2011', 'Bart Motes'
14.	*Rhynchovanda*	'Wilton Hill', 'Jammie Harper', 'Apichart', 'Noo Noi', 'Peter Draper', ' Brighton's Albino', 'Prairie Lady'
15.	*Vanda*	Annette Jones, Antonio Real, Golamcos Blue Magic, Fuch's Charmer, Jimmy Millers RF Orchids, Keree Delight, Memoria Lyle Swanson, Motes Indigo x Merrillii, Motes Honeybun, Motes Primerose, Miss Joaquim,V. Rothschidiana, VTMA –Red, Pink, White, Vasco, Johnny Miller,Veerawan, Roberts Delight, Rasriprai, Pat Delight, Pakchong Blue, Mimi Plammer, Manuvade, Lumpini Red, Kultana Gold x Thongchai Gold, Fuchs Delight, Charles Goodfellow, Pine River,Adisak, Doctor Anek, John Club, Bill Sutton, Ellen Noa, Emily Notley, Evening Glow, Honomu, Honolulu, Hilo Blue
16.	*Vascostylis*	Paragon Joy x Kasems Delight, Precious, Veeraphool, Crown Fox 'Red Yen', Aroon Fairy, Viboon Velvet

Table 1: Important varieties and hybrids under different genera of orchids.

Name of Species/hybrids	Vase life (days)
Aerides odoratum, Aerides multiflorum, Cymbidium iridioides, Dendrobium nobile, Renanthera imschootiana	28-56 days
Paphiopedilum hirtussimum, P. wardianum	56 days
Phaius tankervillae	28-42 days
Vanda coerulea, Vanda teres, Zygopetalum intermedium	14-21 days
Cymbidium hybrids	20-55 days
Dendrobium hybrids	14-21 days
Vanda, *Mokara* hybrids	14-30 days
Cattleya hybrids	10- 20 days
Phalaenopsis hybrids	25-30 days
Aranda	18-28 days

Table 2: Vase life of orchids due to species and varietal differences [6].

by a dramatic increase in the leakage of several molecules such as aminoacids, sugars, inorganic ions, anthocyanins and activity of petal ACC synthetase and disintegration of tonoplast and mitochondria [9]. Two major metabolic and biochemical changes occurring in senescing petals were increase in respiration and hydrolysis of cell components. Vase life of cut flowers depends upon the rate of transpiration through open stomata of leaves and solutes present in vase water [10]. Experimental evidences have shown that cuticular transpiration played an important role in the water loss of orchid flowers. The transpiration rate of tropical orchid flowers ranged from 0.15 to 0.17 mg water $cm^{-2}h^{-1}$ or 0.4 to 1.9 g of water per inflorescence per day depending upon the total floral surface area. Halevy [11] classified flowers into climacteric or non-climacteric based on presence or absence of an increased rate of ethylene production associated with petal senescence. In most vegetative tissues, the overall synthesis of ethylene was the conversion of SAM (S-adenosylmethionine) to ACC (1-aminocyclopropane-1-carboxylic acid). Water loss in orchid flowers was considerably lower than that reported for roses and carnation due to the absence of supporting leaves in orchid sprays. It has been found that carbohydrate levels in mature flowers were lower than the levels in the tight buds. Moreover, the level of carbohydrates in the flower decreased markedly with time after harvest as reflected in the decreasing rate of respiration. This problem could be overcome by the exogenous supply of sucrose.

In orchid flowers, ethylene production was an autocatalytic process and ethylene level of 1 ppm caused premature fading of flowers [12,13]. The premature fading of petals might be induced by pollination and by removing pollinia [14]. In Cymbidium, fading of flowers due to pollination was characterized by the formation of anthocyanin in both column and lip, swelling of column, stigmatic closure and wilting of sepals and petals. The anthocyanin level began to decrease with age [15,16]. Developmental processes associated with post-pollination events included senescence of perianth, pigmentation changes, ovary maturation, ovule differentiation and female gametophyte development [17]. Flowers of Dendrobium 'Pompadour' developed premature petal and sepal senescence following pollination. Pollination induced an ethylene climacteric accompanied by a small respiratory climacteric, epinasty and increased flower and inflorescence fresh weight and water uptake [18]. The orchid flowers harvested in the tight bud stage had a lower rate of respiration than open flowers. The respiration rates continuously declined during the post-harvest period until the flower faded [19].

Da Silva, JA Teixeira [20] reviewed the some aspects of changes and programmed cell death occurred in petal senescence.

Cellular structural changes

- Membrane rupturing and increased in cytoplasm debris and loss of permeability and fluidity due to oxidation.
- Invagination of tonoplast and endocytosis of cytoplasmic contents and disappearance of cortical microtubules.
- Reduction in cytoplasm volume, cessation of cytoplasmic streaming and change in proton flux across plasma membrane.
- Degeneration and collapse of organelles and increase in number of peroxisomes.

Biochemical and Structural Molecular Changes

- Increase in proteinases and nucleases; upregulation of phospholipases, acyl hydrolases and lipoxygenase neutral lipids; sterol/phospholipid ratio; lipid peroxidation; reactive oxygen species; water leakage and cell wall cross linking.
- Decrease in phospholipids, chlorophylls, proteins, thiol groups, nucleic acids and RNA.

Post-harvest life of orchid cut flowers is influenced by pre-harvest factor like varietal differences, light intensity, sugar level of flowers, temperature, nutrition and water loss; harvest factors like time, method and stage of harvest and post-harvest factors including ethylene production, pre-cooling, water quality, pulsing, use of preservatives, bud opening, packaging and storage.

Pre-harvest factors

It was estimated that a third of the post-harvest life of flowers is programmed by pre-harvest handling.

Varietal differences: Varietal differences in cut flowers had been reported due to variations in water uptake, fresh weight, flower diameter, stems lignification, vase life and senescence behaviour. Among different species, the vase life ranges from *Lycaste* spp. (9 days), *Phaius tankervillae* (24 days)**,** *Zygopetalum intermedium* (18 days), *Aerides multiflorum, A. odoratum, Cymbidium irridioides, Dendrobium nobile* and *Renanthera imschootiana* (28-56 days), *Paphiopedilum hirtussimum, P. wardianum* (56 days) and *Vanda coerulea, Vanda teres* (28-42 days) (Table 2). Out of nine hybrids of *Cymbidium*, 'PCMV', 'Red Princess', 'White Beauty', 'H.C. Aurora', 'Sun Gold', 'Ensikhan, Florance', 'Valley Legend' and 'Platinum Gold', evaluated at NRCO, Pakyong, Sikkim during 2008-2009, 'Florance' had the highest vase life of 54 days followed by 'White Beauty' (53 days) and lowest in 'Platinum Gold' (22 days) (Figure 1) [21]. The present day orchid hybrids of *Dendrobium*, *Vanda* and *Mokara* remained perfect for 7 to 30 days. The flowers of *Cattleya* and *Phalaenopsis* remained fresh for 1 to 4 weeks whereas *Aranda* lasted for 18 to 28 days.

Light intensity: Light was found to determine the carbohydrate levels before harvest which in turn influence the keeping quality. Flowers containing relatively higher amounts of carbohydrates

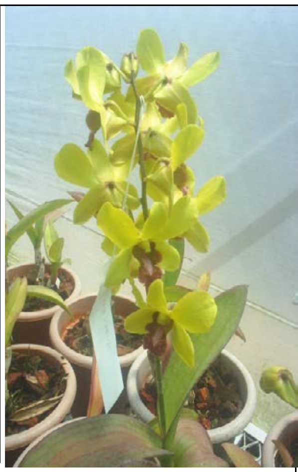
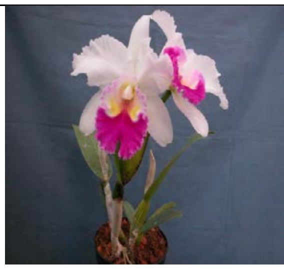
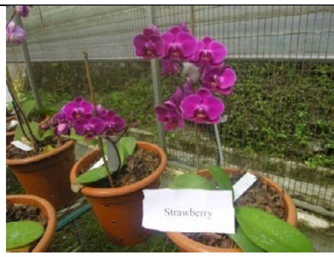
		
Cymbidium, 'Fire Storm Ruby' for cut flower	*Dendrobium*, 'Dang Saard' for cut flower	*Vanda*, 'Roberts Delight Blue' for cut flower
		
Oncidium, 'Sharry Baby Sweet Fragrance' for cut flower	*Blc*, 'Hsinging Catherine' for cut flower	*Phalaenopsis*, 'Strawberry' for cut flower

Figure 1: Varietal differences in cut flowers.

especially mobile sugars lasted longer in the vase. Plants having few leaves, or leather like leaves (like most cattleyas and oncidiums), required a high-light environment. If the leaves are soft and limp (like some phalaenopsis and most paphiopedilum), the plants were probably very light-sensitive, and should not be placed in a sunny south-facing window. Most orchid's prefered indirect or filtered light and 50% shading.

- Low light orchids (1200-2000 f.c.): *Phalaenopsis, Calanthe*
- Medium light orchids (2000-3000 f.c.): *Cattleya, Laelia, Brassovola*
- High light orchids (3000 f. c. or more): *Cymbidium*, Vandaceous groups.

Temperature: Generally, higher temperature resulted in higher level of respiration. Cooling was essential to reduce other metabolic changes such as enzymatic activity and to slow the maturation of flowers. Cooling prior to packaging and transport reduced ethylene production and improved longevity. Based on temperature requirements, orchids were classified into three groups:

- **Warm orchids** (*Aerides, Vanda, Rhyncostylis* and *Dendrobium*): 32.2°C day temperature and 15.5°C night temperature
- **Intermediate orchids** (*Cattleya, Laelia, Oncidium, Miltonia*): 26.6°C day temperature and 12.8°C night temperature
- **Cool orchids** (*Cymbidium, Odontoglossum, Cypripedium*): 24°C day temperature and 10°C night temperature

Humidity: As a thumb rule, orchids required 80-85% humidity for satisfactory growth. Monopodial orchids required higher humidity than sympodial ones. Many sympodial orchids like *Cattleya, Oncidium* and *Dendrobium* form pseudo bulbs, which were swollen shoots that store water and nutrients to help the plant survive periods during prolonged drought. Insufficient humidity during summer might lead to shriveling of pseudo bulb. Excessive humidity during winter might lead to spotting of flowers usually caused by *Botrytis.* Most orchids preferred water of pH 5.0-6.5. Watering with lower or higher pH or with high levels of dissolved minerals could hamper nutrient uptake. Rain water was the best. Regular watering was essential under high sunlight and high temperature conditions. Sprinkling or misting might be practiced during hot summer. Watering should be reduced in late summer and keep the plants barely moist during winter. Watering the plants with thick leaved orchids having CAM activities such as *Aranda* and *Dendrobium* in the late afternoon prior to harvesting season improved the keeping quality.

Orchid hybrid	Commercial stage of harvest	Spike length (cm)	No of Flowers
Aranda	50% bloom	45-60cm	8-10
Cattleya	2-4 days before bud open	25-40 cm	1 or more
Cymbidium	75% bloom or two buds open stage	60-90 cm	10-15
Dendrobium	All flowers except top bud	40-60cm	8-12
Oncidium	80 % bloom	60 cm	Many
Paphiopedilum	3 to 4 days after opening of flowers	25-40 cm	1-5
Phalaenopsis	Fully open flowers	40-60 cm	8-10
Vanda	Fully open flowers	50-75 cm	8-15

Table 3: Stage of harvest, spike length and no of flowers of some commercial orchids.

Nutrition: Orchids were light feeders and they required nitrogen from beginning to two-third of their life cycle. During rest period, they did not need any fertilizers. During flower initiation and inflorescence development plant were fed with less nitrogen, more phosphorus and potassium. In orchids, foliar feeding was found to be ideal. Frequent application of fertilizers in low concentrations was 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 were applied for quality flower production. Sometimes, fresh coconut water, diluted cow urine and fish meal emulsions were also useful as foliar spray.

Harvest factors

Time of harvest: Flowers should be harvested in mild temperature because high temperature causes rapid respiration rates and excessive water loss. Flowers should be harvested in the early morning or in the evening. In the early morning, flowers remained turgid due to transpiration at night and higher sugar levels. Similarly, flowering stems retain a higher amount of stored carbohydrates if cut in the afternoon and retained more vase life.

Method of harvest: Sharp tools or secateurs were always used to detach the stem of flowers from the mother plant. The angle of the cut was given in slanting position and the stem was not crushed during harvesting, especially hard wood stems. The spikes were dipped in a bucket containing water immediately after harvest.

Stage of harvest: The optimum harvesting stage of the commercial orchids was fully open and mature flowers. The stage of harvest, spike length and number of flowers of some commercial orchids are given in Table 3.

Out of three *Cymbidium* hybrids namely 'Pine Clash Moon Venus', 'Valley Legend Steff' and 'Pure Inca Gold', flower spikes were harvested at four stages like fully open, 75% open, 50% open and 25% open to standardize the stage of harvesting, and enhanced vase life. Vase life was noticed highest in 75 % open stage. Maximum vase life of 59 days was recorded in 'Pine Clash Moon Venus' and followed by 48.83 days in 'Valley Legend Steff' and 53 days in 'Pure Inca Gold'.

Post-harvest factors

Temperature: Opening of flower buds and rate of senescence accelerated at higher temperatures. At lower temperature, the respiration came down and the flowers produced a lesser amount of ethylene. Temperature played an important role for flowers harvested at the immature stage for full expansion of buds and the flower buds were kept at temperatures as low as 0.5 to 4.0°C in *Cymbidium* and *Paphiopedilum*, 5-7°C in *Dendrobium* and 7-10°C in *Cattleya.*

Light: Light was essential for long distance transport or prolonged storage of cut flowers. Similarly, high light intensity was essential for opening of tight bud cut flowers. Florists had to maintain a light intensity of 2000-3000 lux for 12-24 hours in their shops for illuminations for most of cut flowers.

Humidity: Cut flowers were kept at 90-95% relative humidity for maintaining turgidity. Flowers started showing wilting symptoms when they had lost 10-15% of their fresh weight. The rate of transpiration from leaves was reduced with the increase of high relative humidity.

Water quality: Water quality is defined as pH and EC value, hardness contents of phytotoxic elements and microorganisms causing vascular occlusions affecting longevity of cut flowers. Saline water decreased the vase life of cut flowers. In case of cut gladiolus, the longevity of flowers decreased when the concentration of salts in the water reaches 700 ppm, whereas for cut roses, chrysanthemum and carnations, 200 ppm is harmful. The increase in concentration of salts over 200 ppm shortens vase life by half a day for each 100g per litres increase in salinity. Basic ions like Ca^{++}, Mg^{++} present in hard water were less harmful to flowers than soft water containing sodium ions. Fluorine is very toxic to most of the cut flowers and causes injury to freesias, gladiolus and gerberas at 1 ppm, and chrysanthemums, roses, poinsettias and snapdragons at 5 ppm. Flowers like lilacs, cymbidiums and daffodils are resistant to fluorine ions. Vase life increased in tap or well water passed through a de-ionizer. The importance of low pH of the holding solutions is well known for improving vase life. A holding solution of pH 3.0-5.0 was optimum for increasing vase life of cut flowers.

Ethylene: Ethylene played an important role in the regulation and co-ordination of senescence in climacteric flowers. Production of this hormone was less and stable in floral buds and young flowers. A sharp increase in ethylene evolution was found during flower maturation, opening and senescence. Afterwards, ethylene production decreased and remained static. Basically, ethylene was first produced in the pistil and the evolved ethylene acted on the petals and induces expression of genes for ACC synthase, ACC oxidase and cysteine proteinases, resulting in the auto-catalytic ethylene production from the petals, in-rolling of petals and wilting of flowers [22]. The gynoecium has been shown to produce a significant amount of ethylene before its production in the petals possibly induced by the factors like ABA or IAA suggesting its importance in controlling ethylene production in the flower during natural and pollination induced senescence, with emasculation hastening the release of ethylene [23]. A wide range of flowers was affected by ethylene with showing of some typical symptoms such as sleepiness of carnation and kalanchoe petals, fading and in-rolling of the corolla of *Ipomoea*, fading and wilting of sepal tips in orchids and induction of anthocyanin formation in female reproductive parts and abscission of flowers and petals. Orchid flowers were highly sensitive to ethylene. High level of ethylene production was due to herbivore damage, mechanical injuries and pollination. Decapped and emasculated flowers produced more ethylene than untreated ones. Sometimes, forced unfolding of flower buds in orchids reduced vase life.

Diseases and insect pests: Fungi, bacteria and insects affected the quality of cut flowers by producing higher amounts of ethylene. Microbes accelerated flower senescence by the plugging of xylem vessels with pectin degraded products, by producing ethylene and toxic compounds. Among bacteria genera, *Alcaligenes, Pseudomonas, Enterobacter, Erwinia, Bacillus, Corynaebacteria, Aeromonas, Acetinobacter* and *Flavobacterium* were commonly found in vase water. Some fungal species *Botryris cinerea*, *Fusarium oxysporum*, *Mucor*, *Penicillium* spp, *Rhizopus*, *Aspergillus* spp, *Alternaria alternata* and

Acremonium strictum were responsible for early senescence of flowers and wilting and decaying of potted plants [24,25].

Treatments for Improving Longevity of Cut Orchid Flowers

Physical treatments

Pre-cooling: It was an important operation in post-harvest handling and transport of cut flowers for the fast removal of field heat wherever flowers were held dry pack. All flowers were pre-cooled immediately after harvest by placing them in cold storage without packing or in open boxes until they reach the desired temperature [26]. It varied with the species and cultivars: *Cattleya* (7-10°C), *Cymbidium* and *Paphiopedilum* (0.5 to 4°C), *Dendrobium* (5-7°C). Precooling lowered respiration rate and decreased the breakdown of nutritional and other stored materials in the stems, leaves and petals; delays bud opening and flower senescence. It also prevented rapid water loss and decreased flower sensitivity to ethylene. Several pre-cooling techniques such as room cooling, forced air cooling, hyder-cooling, vacuum cooling and ice bar cooling etc. were available.

Vase life of cut flowers as affected by stem cut ends: The resistance to water flow through stem segments increased predominantly in the lower most one to two centimeter of the cut stems. Re-cutting stems under water improved longevity due to elimination of air from the conducting vessels.

Chemical treatments

Conditioning: Conditioning or hardening was a simple process where flowers were kept standing loosely in a big container so that air can circulate around the stems. The purpose of the treatment was to restore the turgidity of cut flowers with water stress during storage and transport. Conditioning was achieved by treating the flowers with de-mineralized water supplemented with germicides and acidified with citric acid to pH 4.5 to 5.0 but with or without sugar. Hydration was improved when water was de-aerated or acidified or when a wetting agent like Tween 20 at the rate of 0.01 to 0.1 % was added. Flower stems were placed in warm water or in a preservative solution in plastic jars at a depth of 2-4 cm and held at room temperature or in cold storage for several hours.

Impregnation: Sometimes, the cut ends of the flower stems were impregnated for a short time with chemicals. This treatment protected the blockage of the water vessel in the stem by microbial growth and stem decay. Impregnation of cut bases of flowers with high concentration (1000 ppm-1500 ppm) of silver nitrate, nickel chloride or cobalt chloride for 10-15 minutes improved the longevity of several flowers such as aster, gerbera, gladiolus, carnation, chrysanthemum, phalaenopsis and snapdragon. In *Cymbidium* 'Baltic Glaciers Mint Ice', highest longevity was recorded with $CoCl_2$ (1000 ppm) for 15 minutes (46 days) followed by $CoCl_2$ (1500 ppm) for 15 minutes (44 days) over control (39 days).

Pulsing: The absorption of chemical solutions containing sugars and germicides through the lower cut bases of flower stems was known as pulsing. Pulsing could be used by growers, wholesalers or retail florists in order to enhance the cut flowers subsequent vase life in water. Pulsing was employed with higher concentrations of sugar, mainly sucrose, the percentage of which varies with species and cultivars. Other chemicals used in the pulsing treatments were STS, $AgNO_3$, HQ, MH, AOA, $CaCl_2$, $CoCl_2$, nickel sulphate, aluminium sulphate and benzyladenine. Pulsing was found to be of great value in prolonging life, promoting opening and improving the color and petal size of petals through osmo-regulation. In *Cymbidium* hybrid 'Red Princess' pulsing with 5% sucrose increased vase life (56 days) followed by sucrose @ 8% (54.78 days). In *Cymbidium*, 'Baltic Glaciers Mint Ice' pulsing of flowers with 5% sucrose followed by 150 ppm 8-HQS increased the vase life of flowers with pollina (49.33 and 46.33 days) and without pollinia (44.00 and 41.67 days), respectively. In *Aranda*, pulsing with 4 mM STS for 10 minutes and in *Dendrobium* hybrid 'Pompadour' with 25 ppm $AgNO_3$ + 135 $Na_2S_2O_3$, $5H_20$ for 30 minutes increased vase life of cut flowers [27,28]. In *Oncidium* 'Goldiana' cut sprays pulsing with $AgNO_3$ for 30 minutes improved vase life [29]. In *Phalaenopsis*, pulsing with 0.5mM STS for 24 hours blocked the deleterious effect of ethylene. In *Dendrobium* cv. 'Sonia' pulsing with 4% sucrose + 400 ppm HQ recorded the highest vase life of 21.33 days. Inflorescences pulsed with 6% sucrose + 400 ppm HQ recorded the highest sugar content in the flowers (27.64%) [30].

Bud opening: It was a procedure of harvesting flowers at a stage earlier than normally considered as the cutting stage and then opening the buds off the plant. Such types of post-harvest handling could be applied by growers or wholesalers. Bud opening of flowers increased 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 was lower than the concentration of pulsing and the optimum temperature is kept lower. In *Dendrobium* hybrid, 'Thongchai Gold' opened flowers had 29%, half opened flowers had 28.25 % and buds had 16.17% reducing sugars. In *Dendrobium* hybrids, HQS or $AgNO_3$ (50 ppm) was effective for opening of tight bud cut flowers.

Ketsa et al. [31] reported that a preservative solution containing 225 ppm HQS, 30 ppm $AgNO_3$ and 4% glucose increased bud opening and the time to wilting of the open florets of Dendrobium Cv. 'Ceasar'. In Cymbidium Cv. 'Ensikhan' 4% sucrose + 100 ppm acetyl salicylic acid or 4% sucrose + 100 ppm $Al_2(SO_4)_3$ improved bud opening. In *Cymbidium* hyb. 'PCMV', sugar(4%) + salicylic acid (200 ppm) showed maximum per cent of flower opening (75%) and vase life (45 days) followed by

Treatment	Days to first floret opening	Diameter of first floret (cm)	Per cent of half opened buds	Per cent of Fully opened buds	Vase life (Days)
Distilled water	---	----	0	0	27
Sugar 4%	20	5.1	5.8	44	37.8
Sugar 4% + $Al_2(SO_4)_3$(100 ppm)	21	5.4	0	57	44
Sugar 4% + 8-HQS (200 ppm)	18	5.5	30.7	53.8	44
Sugar 4% + Salicylic acid (200 ppm)	21	6.6	0	75	45
Sugar 4% + Ca $(NO_3)_2$ (1%)	25	4.85	2	22.8	37.8
Sugar 4 % + Boric acid 200 ppm + K_2SO_4 (2mM)	20.5	5.5	6.25	25	36.2

Table 4: Effect of chemicals on bud opening in Cymbidium hyb 'Pine Clash Moon Venus.

sugar (4%) + $Al_2(SO_4)_3$(100 ppm) (57% and 44 days) and sugar (4%) + 8-HQS (200 ppm) (53.8% and 44 days) over control (bud drop and senescence on 27th days), respectively (Table 4). Highest content of carbohydrate (140 mg/g) was estimated at bud stage in fresh condition followed by at bud stage (131 mg/g) at senescence in control. Minimum carbohydrate content (60 mg/g) was observed with Sugar 4% + 8-HQS (200 ppm) followed by Sugar 4% + Salicylic acid 200 ppm) (64 mg/g). In *Dendrobium* hybrid 'Thongchai Gold', per cent of fully opened buds (66%) was recorded maximum with sucrose (4%) + $Ca(NO_3)_2$ (1%) followed by sucrose (4%) + acetyl acetic acid (100 ppm) (60%). Longest vase life (36 days) was found with sucrose (4%) + $Al_2(SO_4)_3$ (100 ppm) followed by sucrose (4%) + acetyl acetic acid (100 ppm) (33 days).

Preservatives: Preservatives were used in the holding solutions in the form of tablets containing a mixture of chemicals such as sugars, germicides, salts, growth regulators etc. Besides, the chemicals were employed during conditioning, pulsing and for making bud opening solutions to improve flower shape, size and opening and color of the flowers.

Sugar, biocide, anti-ethylene compounds and hydrated compounds were used for conditioning. The sugar and biocide solutions were effective for opening of bud cut flowers.

Name of orchid	Holding solution
Oncidium	8-HQC (100-200 ppm) + 4% sucrose
	kinetin (50 ppm) + 4% sucrose
Cymbidium	8-HQC 200 ppm + sucrose 2%,
	1-MCP (500ppb)
	1% Sucrose + STS (1 mM)
Arachnis, Aranda, Aranthera, Cattleya	STS (1mM) + 1% sucrose
Paphiopedilum	8-HQC (200 ppm) +2% sucrose
Vanda	$AgNO_3$ (30 ppm) + 1.5% sucrose
Dendrobium	8-HQC (200 ppm) + sucrose (2%),
	0.5 mM AOA + 4% sucrose,
	$AgNO_3$ (30 ppm) + 4% sucrose
	400 ppm HQ + 30 ppm $AgNO_3$ + 2 % sucrose
	200 ppm 8-HQS + 50 ppm $AgNO_3$ + 8% sucrose

Table 5: Holding solutions for different types of orchids.

Treatments	Loss in wt (g)	Longevity of first floret (days)	Vase life (days)	Solution uptake (ml)
Distilled water	12.6	37.2	44.4	21
$Al_2(SO_4)_3$ (100 ppm)	18.4	45.2	53.4	33
$Al_2(SO_4)_3$ (500 ppm)	21.4	28.4	36.8	21
Ca $(NO_3)_2$ (100 ppm)	16.4	42.0	54.8	27
Ca $(NO_3)_2$ (500 ppm)	29.6	32	35.6	24
8-HQS (100 ppm)	27.4	33.2	45.6	29
8-HQS (200 ppm)	26.8	42.2	49.8	33
BA (25 ppm)	24.0	49.2	48.0	27

Table 6: Effect of chemicals on post-harvest life of Cym 'PCMV'.

Cymbidium	Grades	Flower count	Spike length	Other consideration
Cymbidium Standard	AAA	>12	1.25m	• Strong straight stems, uniform length, no marks on flowers. • Bent crooked spikes but with perfect flowers.
	AA	8	90 cm	
Cymbidium Miniature	XL	>15	65+	
	L	12-14	55-64	
	M	8-11	40-54	
	S	< 5	30-39	

Table 7: Grading of Cymbidium cut flowers.

The vase solution should contain sugars, acidifying agent and a biocide. Citric acids were mainly used for acidifying agent and hydroxy quinoline 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. Among several growth regulators used to increase vase life of cut flowers, BA, IAA, NAA, 2,4,5-T, GA3, B9, CCC are common.

New chemicals that had been found promising as floral preservatives are ethylene inhibitors like amino- oxyacetic acid, 1-amino cyclopropane, aminotriazole, aminoethoxy vinyl glycine, alpha aminoisobutyric acid, diazocyclopentadiene and phenidone.

Different chemicals used in holding solution for improving vase life of orchids are listed in Table 5.

In *Cymbidium* 'PCMV', 2% cane sugar had shown maximum depletion of stored carbohydrates, maximum longevity of first floret (54 days), zero per cent of flower dropping, maximum solution uptake (24ml) and highest vase life (61.2 days) followed by 4% cane sugar. 8% cane sugar had least longevity of first floret (27.2 days) and vase life (36.2 days). Longevity of first floret was recorded maximum with BA (25 ppm) (49.2 days) followed by Al_2 $(SO_4)_3$ (100 ppm) (45.2 days) (Table 6). Maximum vase life (54.8 days) was found with $Ca(NO_3)_2$ (100 ppm) followed by Al_2 $(SO_4)_3$ (100 ppm) (53.4 days). Solution uptake (33 ml) was observed maximum with Al_2 $(SO_4)_3$ (100 ppm) and 8-HQS (200 ppm). In *Cymbidium*, 'Baltic Glaciers Mint Ice', 8HQS 150 ppm increased the vase life of flowers with pollinia (48.33 days) followed by 8 HQS 200 ppm (46.80 days). 8 HQS 200 ppm increased the vase life (36.67 days) of flowers without pollinia.

In another experiment, in Cymbidium hybrid, 'PCMV', out of six treatment combinations, 2% sucrose + 200 ppm 8-HQS had shown maximum vase life (77.6 days) followed by 2% sucrose + 100 ppm $Al_2(SO_4)_3$ (77.4 days) over control in tap water (65 days).

Grading and Packing

Grading

Grading was done based on the basis of parameters like appearance, stage of maturity, blemishes or injuries due to diseases, infestations caused by insect pests, color and size of the bud, straightness, strength as well as length of stem. Flowers were generally grouped into bunches of 5, 10, 12 or 20 stems and loosely tied with rubber bands. Before placing them in the package, individual flower bunches were wrapped with suitable packing materials like cellophane paper, kraft paper, newspaper, tissue paper or corrugated cardboard sheet. For local markets, the bunches were held in buckets containing water or preservative solution. It was advisable that for long distance transport and storage, flower bunches are held in dry cardboard boxes. The minimum length of boxes should be about twice the width and it's width about twice the height. Use of telescope-style boxes made of CFB was ideal.

Grading of cut flowers of orchids was done based upon flower count and spike length of different genera (Tables 7 and 8).

Packaging in orchids

Cut flowers were inserted in tube containing water or water with preservatives or simply wrapped in wet cotton swab and the same was covered with a piece of plastic and tied with rubber band to keep in its place. Flower spikes were bunched into bunch of 5 or 10 or so. Bunches or individual spikes were placed inside the box in alternate fashion. Ethylene scrubbers with $KMnO_4$ or Purafil could also be kept

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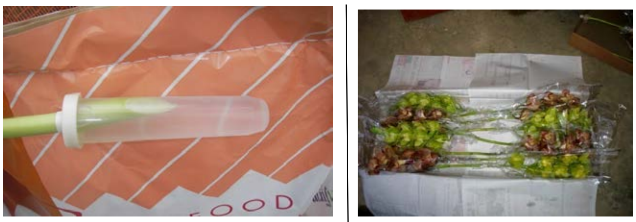
Grade	Spike length	No. of opened flowers
Small (S)	30cm	4-5
Medium (M)	40cm	6-8
Large (L)	45cm	8-10
Extra Large	50cm	>10

Table 8: Grading in Dendrobium Orchids.



Cut flowers are inserted in tube containing Water or water with preservatives

Individual spikes are placed inside the box in alternate fashion

Figure 2: Packaging in orchids.

Name of Orchid	Storage Temperature	Storage period
Oncidium, Phalaenopsis, Odontoglossum, Cattleya	7 - 10°C	2 weeks
Dendrobium	5 - 7°C	10-14 days
Cymbidium	1- 4°C	14 days
Paphiopedilum	-0.5 - 3.0°C	20 days
Arachnis, Aranda, Aranthera Ascocenda, Epidendrum	8-13°C	10-14 days

Table 9: Storage of orchid cut flowers.

in the box. For export purpose, packing of flowers in two piece box was better option. In *Cymbidium*, single flowers backed by a fern leaf were inserted in small flasks containing preservative solution, the flasks were then packed in 3 sided box with a display window. In *Dendrobium* hybrid '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 [32]. In *Cymbidium*, Cilindra - a gift of a glass flute containing a flowering mini *Cymbidium* and Stylish setting- Festive packaging for special occasions like Birthday were common (Figure 2).

Storage of Cut Flowers

Low temperature treatment during storage or shipment period reduced the entire metabolism in the tissues, slowed down the respiration, transpiration and ethylene action and retarded the multiplication of bacteria and fungi.

In general, temperate orchids were stored at lower temperature even at 5°C in cold chambers whereas tropical orchids were stored at 7-10°C. A 90-95% relative humidity was necessary during storage to minimize moisture loss and to prevent wilting.

There are two types of cold storage methods, namely 'Wet storage' and 'Dry storage'. In wet storage, flowers were stored with their bases dipped in water or preservative solution for a short time. Dry storage methods were used for long term storage. In this method, fresh flowers were harvested in the morning, graded and sealed in plastic bags or boxes to prevent the loss of moisture.

In Controlled Atmosphere (CA) storage, cut flowers were kept in gas tight cool chambers equipped with cooling systems at a higher level of CO_2 and lower level of O_2 to reduce the respiration rate and production and action of ethylene. Generally, the concentration of CO_2 was maintained higher than 4% and not below 0.4% in CA storage (Table 9).

Transport

Being short lived and perishable in nature, flowers could be delivered to destination as early as possible immediately after harvest. For long distance markets, cut flowers were transported by cargo planes, merchant ships and trucks. Other modes of transportation were head loads, bicycles, two-three wheelers, cars, vans etc. Hence, for long distance transportation, advanced methods of post-harvest handling like cooling, conditioning, impregnation, pulsing, bud opening and packaging were followed.

Short time pulsing of flowers with optimal concentration of sucrose, $AgNO_3$, STS and growth regulators was important for long term truck and sea shipments. Flowers like standard and spray carnations, chrysanthemum with non-hardy stems of full flowers, gerbera, colored bud lily, miniature and floribunda roses are suited for dry transport over a period of several days; while chrysanthemum with hardy stems and single flowered freesias, iris, orchids, narcissus and H.T. roses are unsuited for dry transportation over a long period. Other than tropical flowers, the best method of transport of most of the cut flowers including temperate orchids is under refrigeration from the grower to final consumers.

Conclusion

The valuable orchid genera which are highly priced in the international flower trade due to their incredible range of diversity in size, colour, shape, forms, appearance and long lasting qualities of flowers include *Cymbidium, Cattleya, Dendrobium, Phalaenopsis, Vanda* and *Paphiopedilum*.

Post –harvest life of orchid cut flowers is influenced by pre-harvest factors like varietal differences, light intensity, sugar level of flowers, temperature and water loss. It is also affected by harvest factors such as time and stage of harvest and post-harvest factors viz. ethylene production, pre-cooling, pulsing, use of preservatives, packaging and storage. Vase life of cut flowers ranges from 18 to 56 days depending upon types of species and hybrids. The optimum harvesting stage of commercial orchids is fully open and mature flowers. Ethylene is the main factor responsible for early senescence. De-capped and emasculated flowers produce more ethylene. There is an obvious increase in flower sensitivity to ethylene following pollination. Pre-cooling of orchids is done by placing the flower boxes in the storage room or in an air conditioned room at 7-10°C in *Cattleya*; 0.5 to 4°C in *Cymbidium* and *Paphiopedilum* and 5-7°C in *Dendrobium*. In *Cymbidium* hybrid 'Red Princess' pulsing with 5% sucrose increases vase life upto 56 days followed by sucrose @ 8% (54.78 days). Pulsing with 4 mM STS for 10 mins in *Aranda* and 0.5 mM STS for 24 hours in *Phalaenopsis* blocks the deleterious effect of ethylene.

In tropical orchids like *Dendrobium* and *Oncidium*, $AgNO_3$ (10-30 ppm) and HQS (50-100 ppm) extends vase life of cut flowers. In *Cymbidium* hybrid, 'Red Princess', 75% open flowers with 200 ppm 8-HQS showed highest vase life along with cent percent opening. Acetyl salicylic acid + sucrose or 8-HQS + $AgNO_3$ wss found beneficial on bud opening of *Oncidium* flowers. In *Dendrobium*, 'Pompadour', 8-HQS or $AgNO_3$ (50 ppm) gave a high percentage of bud opening. In *Cymbidium* 'Ensikhan' 4% sucrose + 100 ppm salicylic acid and 4% sucrose + 100 ppm $Al_2(SO_4)_3$ opened maximum number of buds and maximum longevity. In orchids, cut spikes are inserted in tube containing water or water with preservatives or simply wrapped in wet cotton swabs and then covered with a piece of plastic and tied with rubber band. Flower spikes are then bunched into bunch of 5 or 10 or so and bunch or individual spikes are placed inside the CFB box in alternate fashion. Cool growing orchids like Cymbidiums are stored at lower temperature even at 5°C in cold chambers whereas tropical and subtropical orchids are stored at 7-10°C and 90-95% relative humidity.

Future Research Prospects

- Development of pre-harvest, harvest and post-harvest technologies of major commercially grown orchids for specific target groups like domestic and export market and hybrid/ variety specific technologies.
- Development of packaging for marketing of commercially important fresh and dried produce using locally available materials.
- Development of orchid based technologies for dry flowers and floral arrangement.
- Use of orchid waste for production of phytochemicals including pigments, food, feed, herbal medicines and essential oils.
- Patenting technologies related to species

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