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ORCHID IMPROVEMENT- AN OVERVIEW

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Abstract

The orchids with its 25,000 to 30,000 species in nearly 700 to 800 genera constitute one of the largest families among flowering plants, and exhibit an almost innumerable hybrids and inexhaustible varieties. Several local species of *Ascocentrum, Calanthe, Coelogyne Cymbidium, Dendrobium, Paphiopedilum, Phalaenopsis Vanda, etc.* are in great demand in international market for breeding materials. Presence of natural hybrids evolved from cross between the species in the wild is known since the early days of orchid collection and cultivation. The orchid hybrids are the offsprings derived from the cross between two genetically non-identical individuals. Intraspecific, intrageneric and inter generic hybrids have been obtained in this group of plants. Polyploidy and introgressive hybridization played a major role in the development of orchid hybrids. Genetic engineering coupled with tissue culture technique provides a useful way to introduce specific genes into orchid plants as evidenced by a successful introduction of improved protein quality, novel flower colour and disease, insect and pest resistance into various crops in the relatively short period of time. More than 3 lakh registered orchid hybrids are available in the world of which *Ascocentrum, Cattleya, Cymbidium, Dendrobium, Oncidium, Phalaenopsis, Paphiopedilum, Rhynchostylis,* and *Vanda* genera are common.

Introduction

THE ORCHIDS are highly priced in international market due to their designed spectacular flowers, brilliant colours, delightful appearance, myriad sizes, shapes, forms, and long lasting qualities. The majesty of nature represents the most highly evolved family, Orchidaceae, among monocotyledons. The orchids with its 25,000 to 30,000 species in 700 to 800 genera constitute one of the largest family among flowering plants, and exhibit an almost innumerable hybrids and inexhaustible varieties. Several local species of *Ascocentrum, Calanthe, Coelogyne, Cymbidium, Dendrobium, Paphiopedilum, Phalaenopsis, Vanda, etc.* are in great demand in international market for breeding materials. In breeding programme, selection of good and healthy plant and flower by visual observation accounts to a great extent. Evidences of natural hybridizations occurring among wild species were reported (Abraham and Vatsala, 1981). Hundreds of natural inter-generic, inter-specific or intra-specific natural hybrids of *Dendrobium* are found in nature. Most of Indian species of *Cymbidium, Dendrobium,* and *Vanda* have been recognized in breeding programme especially to produce primary hybrids due to their inherent attractiveness coupled with their ability to transmit these characters to hybrids.

Cytogenetics

From the beginning of orchid cytology, conceptions of the chromosome numbers in the family of orchidaceae have changed remarkably. Investigations conducted by Guignard (1983) and Strasburger (1888) observed that an orchid plant has a constant number of chromosomes in reproductive cells. They suggested 16 as a common number of chromosomes for orchids and found in reproductive cells of *Gymnadenia conopsea, Himantoglossum hircinum, Listera ovata, Orchis maculata* and *Paphiopedilum barbatum*. Singh and Prakash (1995) reported that the basic numbers and somatic chromosome number show wide variation in orchidaceae, lowest chromosome, number is $2n = 10$ (*Oncidium pusillum*) and highest is $2n = 200$ (*Aeringes* spp.). According to Duncan (1959), in different species and hybrids of orchids, chromosome number in meristem (2n) varies; *Cypripedium* (20-22), *Phragmipedium* (20-32), *Paphiopedilum* (26-70), *Ophrys* (36), *Orchis* (20-80), *Daclyorchis* (20-120), *Platanthera* (16-126), *Gymnadenia* (16-80), *Habenaria* (28-42), *Listera* (32-42), *Epipactis* (24-40), *Cephalanthera* (32-36), *Goodyera* (28-42), *Liparis* (30-42), *Epidendrum* (40-160), *Cattleya* (40-102), *Laelia* (40-60), *Laeliocattleya* (40-100), *Brassocattleya* (40-80), *Dendrobium* (38-80), *Cymbidium* (32-80), *Oncidium* (28-56), *Aerides* (38-40), *Vanda* (28-95), and *Phalaenopsis* (38-114).

Triploids are apparently most satisfactory in commercial *Paphiopedilum* (Duncan, 1947), *Cattleya* (Kamemoto, 1950), and *Vanda* (Storey, 1952). In *Cymbidium,* triploid and tetraploid hybrids account for

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improved flower quality (Mehlquist, 1952; Meninger, 1954; Wells, 1956). A pentaploid (Wimber, 1954) and several polysomic individuals (Wimber and Hernlud, 1955) have also been reported in *Cymbidium*. In *Vanda*, diploid and tetraploid species and their hybrids, as well as polyploidy hybrids which have an origin independent of these species, form an array which extends through pentaploidy (Duncan, 1959).

Pollination and Fertilization

Morphological structure of orchid flower prevents easy fertilization. Moreover, the lumps of pollen can not be carried by wind. In nature, insects are usually the pollinators but birds are also involved in some species. Insects like bees, moths, butterflies, beetles, ants, flies *etc.* enter into the lip, do search for the nectar, release the cap and pollen masses and lodged on the head. While visiting another flower, the pollinia are pressed against the stigmatic surface. The grains germinate, the pollen tube penetrates the ovary and fertilize the ovules. Male bees are responsible for pollination of many orchids, *e.g.*, *Catasetum, Cycnoches, Gongora, Orchis* and others. Butterflies and moths also help in pollination process. *Epidendrum secundatum* is pollinated by butterfly attracted by nectar. Moths usually pollinate white or light coloured flowers which emit strong odour at night (Bose and Bhattacharjee, 1980). *Epipactis consmilis* is reported to mimic the shape and colour of aphids which attracted aphidophagus hover flies for pollination. Flowers of *Oncidium* and *Ophrys* are attracted and pollinated by territory defending male Centries bees. Flowers of *Cypripedium* and *Paphiopedilum* have pouch and if by chance insects enter into the structure, it must disturb the pollens and fertilize before coming out of the flower. Self pollination occurs in *Cypripedium schlmii, Neottia* spp., *Phaius grandiflorus etc.* because of their inherent structural arrangements which facilitates pollination and fertilization (Bose, *et al*, 1999).

Natural Hybridization

Presence of natural hybrids evolved from cross between the species in the wild is known since the early days of orchid collection and cultivation. *Phalaenopsis intermedia* collected from Philippines is one of the oldest natural hybrids between *P. aphrodite* and *P. rosea* described correctly by Lindley in 1853. Natural hybridization within the genus *Platanthera* in North America occurred between the closely related species *P. dilatata, P. hyperborea, P. limosa, P. sparsiflora* and *P. stricta*. Two *Masdevallia* species, *M. splendida* and *M. parlaloreana* are recognized as a natural hybrids developed from cross between *M. veitchiana* and *M. barlaeana* which existed in the Andes of Peru. There are also records of inter-generic hybrids evolved under natural conditions and *Laleliocattleya elegans* is one of such examples (Bose *et al*, 1999).

A natural hybrid population of *Oncidium* arising out of cross between *Oncidium.staevi* and *Oncidium jonesianum* is also reported. A complex of natural hybrids among Mexican and Columbian Odontoglossums was also described. Atleast four different groups of hybrids *i.e* the *crispo-odoratum* group, *crispo-lindleyanum* group, *crispo-luteopurpureanum* group and *triumphante-prescatoria* group are recognized (Abraham and Vatsala, 1981). Natural interspecific hybrids are reported in *Cattleya, Laelia, Miltonia etc. Cattleya guatemalensis*, collected by Skinner from Guatemala in 1861, was later found to be a natural hybrid between two species from different genera. It was developed from a cross between *Epidendrum auranticum* and *Cattleya skinneri*. At present, this natural hybrid is known under generic name *Epicattleya*. In Brazil, *Laelio-cattleya elegans* came into existence from natural cross between *Laelia purpurata* and *Cattleya guttata*. While, *Laeliocattleya scilleriana* is also a natural cross between *Laelia purpurata* and *Laelia intermedia*. Another interspecific natural hybrid *Cattleya intricata* developed from a cross between *C. intermedia* and *C. leopoldii*. One of the most interesting inter-generic natural hybrids spotted in the wild evolved from a cross between *Cattleya warneri* and *Brassovola tuberculata*. Two natural hybrids are also reported in the genus *Ophrys* from central Italy. The earliest known orchid hybrid appears to be *Gymnadenia conopsea* x *Nigritella nigra* found in Alps near Grenoble in 1987 and was described by Villars under the name *Orchis suaveolens*.

Artificial Hybridization

Orchid growers all over the world developed crosses between different species and hybrids with varying degree of success. Mr. John Dominy was the first successful orchid hybridist, who made a cross between *Calanthe masuca* and *Calanthe furcata* which flowered in the year 1856 for the first time. The hybrid was named as *Calanthe* x Domini in honour of its breeder, the first artificially raised hybrid to flower. William Herbert, Dean of Manchester, attempted orchid breeding was the first person to take a crossed capsule to maturity from a cross between *Orchis* and *Ophrys*. He even probably raised few seedlings but they perished after few days (Lenz and Wimber, 1959). John Dominy after his first success later in twenty years actively engaging himself in orchid hybridization could report to develop atleast 25 hybrids. It is only after discovery of Professor Knudson the orchid seeds could be germinated *in vitro*, production of orchid hybrids gained its momentum.

The orchid hybrids are the offsprings derived from the cross between two genetically non-identical individuals. Intraspecific, intra generic and inter generic hybrids have been obtained in these group of plants. These hybrids have been recorded and registered by Messers. Sanders (1946 and addenda). Inter-generic crosses are very common in orchids and large number of crosses involving two genera (bi-generic), three genera (tri generic), four genera (tetra-generic), five genera (penta-generic) hybrids are registered and listed (De and Bhattacharjee, 2011).

Bigeneric Hybrids

Aerdachnis = *Aerides* × *Arachnis*

Aeridocentrum = *Aerides* × *Ascocentrum*

Aredopsis = *Aerdies* × *Phalaenopsis*

Ansidium = *Anselia* × *Cymbidium*

Aredovanda = *Aerides* × *Vanda*

Aranda = *Arachnis* × *Vanda*

Aranthera = *Arachnis* × *Renanthera*

Ascocenda = *Ascocentrum* × *Vanda*

Brassolaelia = *Brassovola* × *Laelia*

Doritaenopsis = *Doritis* × *Phalaenopsis*

Epicattleya = *Epidendrum* × *Cattleya*

Epilaelia = *Epidendrum* × *Laelia*

Laeliocattleya = *Laelia* × *Cattleya*

Miltonidium = *Miltonia* × *Oncidium*

Odontocidium = *Odontoglossum* × *Oncidium*

Odontonia = *Odontoglossum* × *Miltonia*

Renades = *Renanthera* × *Aerides*

Renanopsis = *Renanthera* × *Vandopsis*

Renancentrum = *Renanthera* × *Ascocentrum*

Renantanda = *Renanthera* × *Vanda*

Renanthopsis = *Renanthera* × *Phalaenopsis*

Rhynchovanda = *Rhynchostylis* × *Vanda*

Sophrocattleya = *Sophronitis* × *Cattleya*

Sophrolaelia = *Sophronitis* × *Laelia*

Vandoritis = *Vanda* × *Doritis*

Trigeneric Hybrids

Brassolaeliocattleya = *Brassavola* × *Laelia* × *Cattleya*

Colmanara = *Miltonia* × *Odontoglossum* × *Oncidium*

Dekensara = *Brassovola* × *Cattleya* × *Schomburgkia*

Dialaeliocattleya = *Diacrinum* × *Laelia* × *Cattleya*

Epilaeliocattleya = *Epidendrum* × *Laelia* × *Cattleya*

Hartara = *Broughtonia* × *Laelia* × *Sophronitis*

Laeliocattkeria = *Laelia* × *Cattleya* × *Barkeria*

Laycockara = *Arachnis* × *Phalaenopsis* × *Vandopsis*

Lowara = *Brassavola* x *Laelia* x *Sophronitis*

Lyonara = *Cattleya* × *Laelia* × *Schomburgkia*

Mizulara = *Cattleya* × *Diacrinum* × *Schomburgkia*

Moirara = *Phalaenopsis* × *Renanthera* × *Vanda*

Mokara = *Vanda* × *Arachnis* × *Ascocentrum*

Nakamotora = *Ascocentrum* × *Neofinetina* × *Vanda*

Osmentara = *Broughtonia* × *Cattleya* × *Laeliopsis*

Rhyndoropsis = *Rhynchostylis* × *Doritis* × *Phalaenopsis*

Sappanara = *Arachnis* × *Phalaenopsis* × *Renanthera*

Sophrolaeliocattleya = *Sophronitis* × *Laelia* × *Cattleya*

Trevorara = *Arachnis* × *Phalaenopsis* × *Vanda*

Vascostylis = *Vanda* × *Ascocentrum* x *Rhynchostylis*

Wilsonara = *Cochlioda* × *Odontoglossum* × *Oncidium*

Yapara = *Phalaenopsis* × *Rhynchostylis* × *Vanda*

Tetrageneric Hybrids

Iwanagara = *Brassavola* × *Cattleya* × *Diacrinum* × *Laelia*

Kirchara = *Cattleya* × *Epidendrum* × *Laelia* × *Sophronitis*

Potinara = *Brassavola* × *Cattleya* × *Laelia* × *Sophronitis*

Recchara = Brassavola × Cattleya × Laelia × Schomburgkia

Withnearara = Aspasia × Miltonia × Odontoglossum × Oncidium

Yamadara = Brassavola × Cattleya × Epidendrum × Laelia

Pentageneric Hybrids

Goodlera = Brassia × Cochlioda × Miltonia × Odontoglossum × Oncidium

Hasegawara = Cattleya × Brassavola × Broughtonia × Laelia × sophronitis

Hexageneric Hybrids

Brilliabdera = Aspasia × Brassia × Cochlioda × Odontoglossum × Oncidium × Miltonia

It is not possible to make crosses between any two genera though free breeding is common on orchids. Majority of the success in orchid breeding was brought out by the art of paint breeding, intuition and perseverance of the orchid breeders and on several occasions merely by luck (Arditti, 1992). It requires several years to raise progeny from seeds to flowering stage. Unlike other crops, orchid seeds can not be germinated without special facilities. It takes long time for the seeds to mature. Moreover, the no. of seeds produced in a capsule is so high that to get a representative sample of the progeny that will be required to draw any valid genetic inferences will be very large and may be impossible in most of the occasions. Hence, information on combining ability and inheritance of characters in orchids is scanty.

Mutagenesis

Hybridization technology has proven very reliable and easy to use and has produced wide range of successful cultivars with attractive combinations of spray length, bud number, flower colour and form, vase life, fragrance, seasonality and compactness. By introducing mutagenesis, however, wide variations of flower colours, form, and size can still be obtained in addition to overcoming incompatibility and sterility. In addition, complementary use of molecular techniques will allow breeders to target more specific characteristic changes and cut short breeding time. PCR-based techniques used to analyse the DNA of mutagenic clones found polymorphic fragments that can be developed as molecular markers (Basiran *et al.*, 2002).

Breeding Objectives

The breeders goal is to produce commercially important hybrids having market demand and liked by the consumers. Concept behind development of hybrids in orchids may vary according to the genus and species. The generalized objectives as stated by Bhattacharjee and Das (2008) are given below:

- To breed for better colour, size, and substance of the flower.
- To introduce perfect blending of colours in sepals, petals and lip.
- To create round and full form of sepals and petals with minimum fenestration and twists.
- To increase the length of inflorescence.
- To increase the number of flowers / inflorescence.
- To achieve compactness in flower facing on the spike.
- To develop hybrids showing correct mode of display.
- To extend blooming period.
- To produce miniature forms.
- To produce fragrant varieties.
- To produce flowers with longer vase life.
- To develop types suitable as pot plants.
- To develop hybrids insensitive to strict climatic regime.
- To develop hybrids resistant to biotic stress like diseases particularly to viruses.

Selection of Parents

Healthy parent plants are to be selected so that they can produce healthy seed pod with innumerable seeds in it. Selection of parents depend upon the aim of breeding and genetic affinity of the parental lines. Information on whether the parent performs well as pollen parent or seed parent, as well as the vigour and floriferousness of the parent. Knowledge of compatibility, chromosome number and behaviour of the parents are essential. Known ability of the parents to influence the character in its progeny will also be helpful. Very young plant or seedlings blooming first time should not be selected as mother plant which will bear seed pod. A very healthy and vigorous plant can bear two to three seed pods without affecting the normal health of plant. A cross become successful if two different types of orchids are genetically related.

Compatibility Analysis

A thorough understanding of the compatibility relationships of the genera and as well as species is essential for successful hybrid development. According to Lenz and Wimbler, 1959, many of the cases of the apparent self-incompatibility and cross sterility commonly encountered among orchid hybrids could be due to either of two causes hybrid sterility or polyploidy. The self incompatible orchids always have homomorphic, gametophytic, polyallelic incompatibility with stigmatic inhibition of pollen germination. The failure of fruit development in many reciprocal crosses hints at the operation of a unidirectional incompatibility in orchids (Devi and Deka, 1992).

Breeding of Hybrids

Many Indian species have obtained worldwide recognition in breeding programmes due to their inherent attractiveness coupled with their ability to transmit these characters to hybrids. Some of the leading species are *Aerides multiflorum, Cymbidium devonianum, C. lowianum, C. tracyanum, C. elegans, Dendrobium aggregatum, D. chrysotoxum, D. formosum, D. nobile, Paphiopedilum venustum, Vanda coerulea etc.*(Bose and Bhattacharjee, 1980).

Cattleya

The cattleya species like *aurantiaca, bicolor, bowringiana, dowiana, forbesii, granulosa, guttata, intermedia, labiata, loddigesii, luteola, mossaie, triannaei, warneri etc.* are extensively used for hybridization work. Moreover, the *Cattleya* has also been crossed with several other genera like *Berkeria, Brassavola, Broughtonia, Diacrinum, Domingoa, Epidendrum, laelia, Laeliopsis, Schomburgkia, Sophronitis etc.* and produce multi-generic hybrids. The cattleya cultivars like 'Bob Betts', 'Bow Bells', 'Claesiana', 'Empress Bells', 'Enid', 'Estette', 'General Patton', 'Henrietta Japhet', 'Karae Lyn Sugiyama', 'Margaret Stewart', 'Nellie Roberts', 'Nigritian' 'Pearl Harbour', ' Portica', 'Primma Donna' 'Vesper Bells' are considered famous proven mother plants for breeding work. *Cattleya dowiana* and its variety 'aurea' have been of great importance in the development of the beautiful yellow flowered hybrids. In crosses with the coloured or alba forms of the *Cattleya* species, the yellow colour of *C. dowiana* acts as a recessive and the yellow colour does not appear in the first generation, the flower being coloured with anthocyanin pigments. In certain F_2 population involving *C. dowiana*, the plants segregate to give yellow, cream and white coloured flowers (Fenton, 1951). Mehlquist (1958) studied the inheritance of white flowers with coloured lip. He suggested a gene P to be responsible for this type of colouration due to interact with C and R genes.

The *Cattleya* alliance *Laelia* and *Sophronitis* are known for their bright colours contribution. The redness of many of the orchid hybrids were introduced from *Sophronitis grandiflora*. The flowers of this *Sophronitis* species are small and many of the resulting *Sophrocattleya, Sophrolaelia* and *Sophrolaeliocattleya* have comparatively small flowers. Northern (1949) observed that gene for red is dominant and when present in a homozygous condition it gives a beautiful clear red colour.

Intergeneric hybrids involving *Brassavola* gave very attractive fimbriated lip. The first *Brassocattleya* was bred as early as 1889 by Maron, in which *Brassavola digbyana* was combined with *Cattleya* while first *Laeliocattleya* was bred by Sanders in 1903 from a cross between *Cattleya hardyana* and *Laelia pumilapratens*. The first trigeneric hybrid *Sophrolaeliocattleya* was bred by Holfred in 1907 from a cross between *Laeliocattleya* Aureole and *Sophronitis coccinea*. A hybrid genera *Potinara* which is a tetrageneric hybrid combined *Cattleya, Laelia, Brassavola* and *Sophronitis* was registered for the first time in 1922 (Bhattacharjee and Das, 2008). Introduction of blue colour in *Cattleya* breeding was discussed by Granier, 2002. One of the prominent hybrids used extensively for blue *Cattleya* breeding is *Laeliocattleya* 'Canhamiana', a cross between *C. mossiae* and *Laelia purpurea*. Among *Brassavola, B. cucullata, B. cordata, B. nodosa* and *B. perrinii* are extensively used in hybridization (Mathews, 1996). The large flowered *Cattleya* hybrids are the results of breeding involving fifteen *Cattleya* species, two *Laelia* and *Brassavola digbyana* (Herman, 1997). In *Brassocattleya* the varieties 'Deesse' and 'Hortland' are reported to produce many hybrids in *Cattleya* alliance. The trigeneric hybrid *Brassolaeliocattleya* are also well known for their varieties like 'Edwin Chong', golden Myth', 'Herons Ghyll', 'Jane Helton', 'Malvern', 'Marjorie Frey', 'Mellow Glow', Molflora', 'Norman' Bay', 'Nugget', *etc* which have produced many interesting hybrids. In *Laeliocattleya* are the varieties 'Charlesworthii', Easier Bonnet', 'Edgard Van Belle', Elissa', 'Grandee', 'Harold J Peterson', 'Ishtar', 'Morro Rock', Nugget', 'Pacific' 'Paradasio', 'Princess Margaret', 'S.J. Bracy', 'South Esk', Supervia', Twinkle Star', which are famous proven parent plants for hybridization work.

Cymbidium

Cymbidiums are highly valued as cut flowers as well as pot plants in the international florist trade. Innumerable number of hybrids have been evolved. The species like *Cymbidium devonianum*, *C. ensifolium*, *C. erythrostylum*, *C. grandiflorum*, *C. hoosai*, *C. insigne*, *C. madidum*, *C. pumilum*, *C. tracyanum* are successfully utilized for development of many hybrids. Some of the hybrids like "Balkis', 'Cleo Sheraton', 'Desiree A'logann', 'Early Bird', 'Joan of Arc', 'Kurun', 'Lucy', 'Lustrous', 'Mayfair', 'Miretta', 'Nam Khan', 'October', 'Oiso', 'Ortin', 'Redwood', 'Remus', 'Rio Rita', 'Rosanna', 'Shiraj', 'Stanley Fouraker', 'Swallow', 'Vieux Rose' are outstanding and largely utilized as parent plants for production of many spectacular hybrids.

The species like *C. pumilum*, *C. devonianum* and *C. ensifolium* are small flowered types and cross easily with the large flowered Himalayan species. Most of the hybrids in Cymbidium are evolved through the utilization of the eight of the large flowered species *i.e. Cymbidium iridioides* (syn. *C. giganteum*), *C. eburneum*, *C. hookerianum* (syn. *C. grandiflorum*), *C. sanderae*, *C. lowianum*, *C. tracyanum*, *C. insigne* and *C. erythrostylum*).

Cymbidium 'Alexanderi' a cross between *C.* 'Eburneo-Lowianum' and *C. insigne*, the progenies of the cross were diploid but clone 'Westtonbrit' proved to be tetraploid. In fact this hybrid changed the world of cut flower cymbidiums. *Cymbidium* 'Alexanderi' was producing everything that was required where quality was concerned (Keith, 2000). This hybrid became popular because of its large white flowers and as parent for pestal coloured popular hybrids.

The Japanese and Chinese species of *Cymbidium* are utilized for breeding of miniature types. Miniature hybrids are good as pot plants and slightly tolerant to warmer conditions. The first miniature hybrid in *Cymbidium* was evolved in England in the year 1944, which was a cross between C. 'Lousie Sander' x C. pumilum. The variety 'Lousie Sander' is a cross between 'Alexanderi' x 'Ceres'. *C. munronianum* has been used as parent in several breeding programmes for contributing scent characters to the offsprings.

Dendrobium

Dendrobiums are very popular among the orchids throughout the world for higher productivity and floriferousness. These are well known as cut flowers and potted plants.

The *Dendrobium* species like *aemulum*, *affine*, *aggregatum*, *aries*, *canaliculatum*, *chrysotoxum*, *compactum*, *d albertisii*, *dalhousieanum*, *delicatum*, *dicuphum*, *forbesii*, *formosum*, *goldiei*, *gracilicaule*, *gracillimum*, *grantii*, *johnsoniae*, *kingianum*, *laxianthera*, *laxiflorum*, *leporium*, *macrophyllum*, *mirbellianum*, *nobile*, *odoardi*, *ostrinoglossum*, *phalaenopsis*, *primulinum*, *superbum*, *taurianum*, *tetragonum*, *toftii*, *tokai*, *trilamellatum*, *undulatum*, *veratifolum*, *violaceo-flavens* and *williamsonii* are successfully utilized for hybridization programme and produce many outstanding hybrids of special merit. Vacherot and Lecouffle of France are the pioneers of *Dendrobium* breeding. The nobile type (narrow petals) Dendrobiums of Eastern Himalayas and *D. phalaenopsis* (rounded petals) of Eastern Asia were the most frequently used parents. Kuehnle *et al.* (1997) observed that pigments comprise of cyaniding glycosides are the predominant pigments extracted from the lavender and purple *Dendrobium*. Kamemoto and Amore (1990) reported that a dominant gene P is responsible for lip colour or the semi-alba trait of white petals and sepals with coloured labellum, based on crosses between semi-alba *D. dicuphum* and white *D. affine* or white *D. phalaenopsis* var. *compactum* 'Mauna Kea'. According to Thammasiri *et al* (1986) yellows and greens in *Dendrobium* are due to carotenoids and chlorophylls. Improved yellow cultivars are contributed by triploidy. Kamemoto *et al* (1999) reported inbreeding depression which is expressed as loss in vigour and pollen degeneration in *D. phalaenopsis* and *D. biggibum*, but not found in *D. antennatum*. Several cycles of inbreeding and selection using an amphidiploid *Dendrobium* 'Jaquelyn Thomas' proved to useful to increase flower size and lighten colour (Bobisud and Kamemoto, 1982) and produced valuable stud plants when used subsequently in outcross to restore vigour. Colour has always been of prime importance in *Dendrobium* breeding ranging from chalky white to yellow, brown and intense crimson (Abraham and Vatsala, 1981).

For producing compact hybrids with short pseudobulbs to breed for potted plants *D. carronii*, *D. canaliculatum*, *D. phalaenopsis*, *D.* var. *compactum*, *D. bigibbum* var. *compactum*, *Dendrobium* 'Mini Gem' are suitable (Kuehnle, 2006). Kaiser (1993) suggested one parent of possible interest for breeding fragrant potted plants is *D. d'albertisii*; and out of the 140 species evaluated, 40 per cent produced scents ranging from floral to fruity to herbaceous. Some of the outstanding varieties of *Dendrobium* used in further hybridization program and are recognized as proven parents 'Agnes', 'Ann', 'American Beauty', Amethyst 'Anouk', 'Artur Elle', 'Black Bountain', 'Caesar', Carol Ann', 'Claire Ayau', 'Concert', 'Constance', 'Dixon', 'Endeavour', 'Ethreal Kawamoto', 'Ewa', 'Gold Flush', 'Gold Twist', 'Helen Fukumara', 'Hula Girl', 'Jaquelyn Thomas', 'karen Ono', 'Khaw Young Hong', 'Lady Fay', 'Lady Hamilton', 'Lady Nui', 'Lim Chong Min', 'Lynn Takiguchi', 'Maloe Kanya', 'Manoa Gold', 'Margi Thomas', 'Main Beauty', May Neal', 'Mustard', 'New Hawaii', 'Pale Face', 'Pompadour', 'Rose Chong', 'Shangrilla', Ursula', 'Valley King', 'Vera Patterson', 'Yellow Curls', 'Yellow Jacket' *etc.*

Odontoglossum

This genus produce finest flowers of all cool growing orchids. The *Odontoglossum* species like *cirrhosum, crispum, hallii, pendulum, pulchellum* are used for hybridization work. There are many hybrids of Odontoglossum on record and large number are made with related genera like *Aspasia, Cochlioda, Miltonia* and *Oncidium*. The outstanding hybrids of *Odontoglossum* widely used as parent for production of further hybrids are 'Carroll', 'Ismene', Patnina' *etc.* (Bhattacharjee and De, 2003).

Oncidium

The orchid plants under this genus are known as 'Dancing Ladies' and 'Golden Showers' because of their showy alternatively shaped blossoms. Large number of Oncidium species are utilized for production of spectacular hybrids and most important species in this respect are *henekenii, intermedium, lanceanum, leucochilum, marshallianum, pulchellum, retemeyerianum, splendidum, sylvestre, triquetrum, vericosum* and *variegatum*. The genus is cross compatible with other genera like *Aspasia, Brassia, Cochlioda, Comparettia, Gomesa, Macradenia, Miltonia, Odontoglossum, Rodriguezia, Trichocentrum, Trichopilia etc.* and hence many multi-generic hybrids have been evolved. Some of the outstanding hybrids which have proved as proven parent plants for production of more and more attractive hybrids are 'Angnes Ann', 'Ann Rosa', 'Catherine Wilson', 'Delight', 'Golden Glow', Helen Brown', 'Lovely','organ Mountains', 'St. Anne', and 'Waikiki Sunset' (Bhattacharjee and De, 2003).

Paphiopedilum

This is a remarkable genus of magnificent group of orchids, commonly called as 'Lady's Slipper' orchids. The cut flowers remain fresh in plain water upto six wks. *Paphiopedilum rothschildianum* is one of the most important species which has produced nearly 200 hybrids. Important species used in hybridization programmes are *bellatulum, godfroyae* and *niveum*. One of the most outstanding hybrid in this genus is 'Rolfei' which is a cross between *P. rothschildianum* and *P. bellatulum*. Another important hybrid, *Paph.*'Daisy Barclay' which was evolved from a cross between *P. rothschildianum* and *P. godefroyae*. The cross between *P. rothschildianum* with *P. niveum* created *P. woluwense*. Allelomorph in *P. insignis, P. spicerianum* and *P. boxalli* was reported by Hurst (1925). Rogersen (1991) has suggested that for breeding white coloured *Paphiopedilum*, the species like insigne var. *Sanderae, bellatulum* and *godefroyae* are important and described the general principles governing the inheritance of the white flower colour in orchid and specifically in the genus *Paphiopedilum*. Tu-Fu Philip Liu (2000) stated that the backbone of green and white albino forms was *Paphiopedilum callosum* var *sanderae*; for green breeding, *P.* 'Desert Spring' for yellow breeding promising clones are some hybrids of *P. sukhakuli* var. *album*, such as *P. fairrieanum* var. *album*; for white breeding *P. charlesworthii* var. *album*. *Paphiopedilum* is cross compatible with *Selenipedium* and *Phragmipedium*.

Phalaenopsis

Phalaenopsis is highly valued for its long lasting cut flowers, pot plants and hanging baskets. Several species of *Phalaenopsis* utilized for the production of outstanding hybrids are *amabilis, amboinensis, boxalli, buyssoniane, cornucervi, denevei, equestris, esmeralda, fasciata, fimbriata, fuscata, grandiflora, lueddemanniana, lindenii, mannii, mariae, parishii, schilleriana, serpentilingua, stuartiana* and *violacea*. Hybridization of *Phalaenopsis* mainly evolved around the development of pure whites, pure pinks and white with pink lips. *P. amabilis*, *P. formosana* and *P. aphrodite* were extensively used for production of outstanding white hybrids. For development of pink coloured hybrids like the *lueddemanniana, sanderiana* and *schileriana* figured prominently. White colours with pink lip was achieved in *P. intermedia* due to natural hybridization between *P. aphrodite* and *P. equestris*. According to Thomas (2001), all modern white *Phalaenopsis* are descendents of two species, *P. amabilis* and *P. aphrodite*. *Phalaenopsis* 'Doris' bred in 1940 one of the most influential white hybrid. Yellow and red *Phalaenopsis* breeding started with a cross between *P.* 'Doris', and *P. manni* to produce *P.* 'Golden Louis'. Red *Phalaenopsis* breeding is generally accompanied by problems with fertility, flower size and low flower count. The first fertile and readily available red *Phalaenopsis* is 'Golden Buddha' (Ginsberg, 2000). Another recent trend in *Phalaenopsis* is breeding for blue flowers. The two species that formed the basis of blue *Phalaenopsis* breeding are *Doritis pulcherrima* var. *coerulea* and *Phalaenopsis violacea* var. *coerulea* (Mountford, 2001). Harper (1993) discussed the contribution made by *Phalaenopsis stuartiana* in the development of multiflora *Phalaenopsis* hybrids. Thomas (2001) viewed the requirements for flower forms of commercial growers like strong self supporting erect inflorescences, long duration of blooms, compact plant size, wide temperature tolerance, disease resistance, firm substances and consistency of colours.

Selfing and backcrossing techniques have been found immensely beneficial in breeding for superior hybrids. The long continued inbreeding of *Phalaenopsis sanderiana* is a famous example leading eventually to superior clones. Multi-generic hybrids have been evolved by crossing *Phalaenopsis* with other genera like *Aerides, Arachnis, Doritis, Neofinetia, Rhynchostylis, Renanthera* and *Vanda*. Some of the hybrids of *Phalaenopsis* which are served as parent plants for production of many more outstanding hybrids are 'Aalsmeer Rose', 'Ann lovelace', 'Aristocrat', 'Barbara Bred', 'Big Chief', 'Cassango', 'Cast Iron Monarch', 'Chieftain', 'Cindy Brand', 'Doreen', 'Doris', 'Dos Pueblos', 'Elinor Shaffer', 'Elisa', 'Elwy Middleton', 'Fairway Park', 'Fenton Davis Slover', 'Gladys Red', 'Goleta', 'Grace Palm, 'Hollywood', 'Hymen', 'Intermedia', 'Joanna Magale', ' Junita', 'Judy Karleen', 'Kareen', 'Lachesis', 'Lakme', 'Loius Georgianna', 'Louis Market', 'Luzon', 'Margaret Bean', Marmouset', 'Martha', 'Mild Red Karleen', 'Mrs' J.W. Veitch', 'New Horizon', 'Palm Beach', 'Pasadena', 'Pink Vision', 'Pink Wave', 'Princes Grabce', 'Queen Emond', 'Radiant Glow', 'Reve Rose', 'Rosewell', 'Ruby Lips', Seretiny', 'Shivley Temple', Susan Market, 'Texas Star' 'Zada'.

Vanda

This genus bears attractive flowers which are often large, the colour of flower ranges from pure white to variegated pattern of brown, green, and bright pink to blue to purple. These are commercially important cut flowers used in international flower trade. The *Vanda* species which contributed for production of useful and showy hybrids are *amnesiana, batemanni, coerulea, coerulescens, dearci, denisoniana, hookeriana, insignis, lamellata, loatica, limbata, liouvillei, luzonica, marvillii, parviflora, roeblingiana, rozburghii, sanderiana, spathulata, stuavis, sumatrana, teres* and *tricolor*.

The first Vanda hybrid 'Miss Joaquim' which developed from a cross between *V. teres* and *V. hookeriana* (Teoh Eng Soon, 1998). An albino form of *Vanda* 'Miss Joaquim' was produced by crossing the alba varieties of both the parents. *Vanda* 'Miss Joaquim' is said to have taken the form of *V. hookeriana* and the colour of *V. teres* (Tim Wing Yam, 2001). Fuchs (1997) reported that *Vanda sanderiana* and *V. coerulea*are the two important vandal species found in the background of most of the vandaceous hybrids. *V. sanderiana* gives full form, whereas *V. coerulea* imparts the rich blue violet colouration, lobely tessellation as well as the long inflorescence.

The genus *Vanda* is cross compatible with other allied groups like *Aerides, Arachnis, Ascocentrum, Doritis, Neofinetia, Phalaenopsis, Renanthera, Trichoglottis and Vandopsis*. Some of the important hybrids of Vanda which contributed as parent plant for production of many more hybrids are "Amoene', 'Betsy Summer', 'Bull Sutton', 'Eisenhower', 'Ellen Noa', 'Emily Notley', ' Ernest', Fujinaga', 'Frank Crook', 'Haledena', 'Helen Reynolds', 'Hilo Blue', 'Honolulu', 'Jennie Hashimoto', 'Josephine Van Bero', 'Kapolio', 'Manila', 'Manisaki', 'Miss Joaquim', 'Noel', 'Nora Potter', 'Norbert Alphanso', Onomea', 'Poepoe', 'Rubella', 'Ruby Prince', ' Tan Chay Yan', 'Tatzeri', 'Trimerrill', 'Trisher', 'Venus' and 'Waipuna'.

Polyploidy Breeding

Polyploidy and introgressive hybridization played a major role in the development of orchid hybrids. In some genera like *Cattleya, Cymbidium, Laelia, Paphiopedilum, Phalaenopsis, Sophronitis*, polyploidy coupled with intergeneric compatibility has culminated in formation of hybrid groups which show both greater size and hybrid vigour as compared to parental species. Most orchids have two basic sets (diploid 2x) chromosomes. The most common form of polyploidy is the doubling of the chromosome number from diploid (2x) to tetraploid (4x). Tetraploid plants are more fertile and produce flowers of better texture, bigger size and more intense colouration. According to Abraham and Vatsala (1981), infertility in polyploids often results from pairing abnormalities during meiosis. Sterility is most frequently caused by triploidy, commonly encountered in many of the cultivated orchids. Kamemoto *et al* (1999) has described a strategy in which a triploid yellow, *D. 'Mary Mak'* was crossed to a diploid *D. helix*. Among a population of mostly aneuploids, several tetraploids were obtained for use in subsequently breeding.

Hawaiian breeders produced exciting tetraploid clones by repeated selfing of *V*. 'Miss Joaquim', which is a diploid (2n = 38). Most popular clones produced are 'Atherton', 'Juliet', 'Hula Girl', 'Wood Lawn' and 'Douglas'. Most of the subsequent *V*. 'Miss Joaquim', hybrids are based on these tetraploids. About 450 hybrids have been raised from *Vanda*, 'Miss Joaquim'

(Tim Wing Yam, 2001). In *Phaius tankervilliae*, treatment of protocorms by colchicine treatment (50ppm) induced polyploidy. Doubling of chromosome number was associated with increased guard cell and stomatal size and height and weight of plants (Devi and Deka, 2000). According to Hedren *et al* (2000), diploid members of the genus *Nigritella* have sexual reproduction, whereas polyploidy members are characterized by agamospermy. The AFLP data support the general picture of polyploidy evolution in *Dactylorhiza .i.e.* that allotetraploid derivatives have arisen repeatedly as a result of hybridization between the two parental groups *D. incarnata* and *D. maculata* group (Hedren *et al.*, 2001).

Genetic Engineering

Genetic engineering coupled with tissue culture technique provides a useful way to introduce specific genes into plants as evidenced by a successful introduction of improved protein quality, novel flower colour and disease, insect and pest resistance into various crops in the relatively short period of time. In orchids, the first report on genetic transformation was made by Kuehnle and Sugii (1992). Several gene transferred methods tested with Dendrobium such as particle bombardment (gene gun) (Kuehnle and Sugii, 1992, Chia *et al.*, 1994), protein electro injection, seed imbibation and pollen tube mediated DNA transfer (Nan and Kuehnle, 1995b). Among these micro bombardment (Klein *et al*, 1987) was identified as highly suitable for *Dendrobium* based on high frequency recovery of transgenic plants. A co-cultivation method was standardized for transforming *Phalaenopsis* varieties *in vitro* with *Agrobacterium tumefaciens* using protocorm like bodies as explants (Hsieh *et al.*, 1997). Yang *et al*, 1999 in *Cymbidium* and Yu *et al*, 1999 in *Dendrobium* hybrid exploited the PLBs to transform the orchid using particle bombardment. Protocorm and protocorm like bodies (PLBs) of three genera *Brassica*, *Cattleya* and *Doritaenopsis* were genetically transformed via micro-projectile bombardment (Knapp *et al.* 2000).

Genetically transformed plants can be obtained by co-cultivation of *Agrobacterium tumefaciens* with cell clumps in *Phalaenopsis* orchid (Belarmino and Mii, 2000) and with their rhizome sections in *Cymbidium niveomarginatum* (Chen *et al.*, 2002). A protocol was standardized to obtain stable transgenic orchid (*Dendrobium nobile*) via Agrobacterium mediated transformation of protocorm like bodies (PLBs) (Men *et al.*, 2003b). Transgenic orchids (*Phalaenopsis* cv. White Hikaru) plants were generated by inoculating a needle wounded protocorm like body (PLB) with *Agrobacterium tumefaciens* (Chai and Kim, 2004). The transformation of *Phalaenopsis* cv. Taisuco Crane protocorm like bodies (PLBs) by particle bombardment and *Agrobacterium tumefaciens* mediated transformation with beta-glucuronidase (GUS) fusion protein was studied by Chan *et al* .(2003). Liau *et al.* (2003) indicated that the foreign DNA can successfully be integrated into the orchid genome and expressed transcriptionally and translationally in *Oncidium* orchid plants. Both genome breeding and molecular breeding approaches can be used concurrently in varietal development of *Dendrobium* as cut flowers and flowering potted plants. Chemical survey of *Dendrobium* species and hybrids has shown lavender cyanidin, and peonidin to be the predominant anthocyanidin and orange pelargonidin to be rare. Cloning and characterization of key anthocyanin biosynthetic genes such as of dihydro-flavanol 4-reductase enables more productive hybridization strategies to be implemented (Kuehnle *et al.*, 2004).

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