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Improvement of Ornamental Plants - A Review

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Abstract Ornamental crops provide better income from a unit area with higher profitability. There is huge untapped flower production potential in our country which could benefit a large segments of the weaker sections of the society. Both the domestic market and the export potential of flowers and ornamentals are tremendous. Besides, earning foreign exchange and improving the national income, the floriculture business being labour intensive generates gainful employment to rural youth. Ornamental plants are appreciated by their ability to please the eye of consumers as garden or pot plants or when sold as cut material. The main emphasis in ornamental plant breeding is to improve variety traits, novel colour, form, size, number of flowers, flower vase life, repeat blooming, disease resistance, nutrient uptake capacity and growth habit. Various types of new varieties of ornamental crops have been produced for many years by cross hybridization and mutation breeding techniques, separately or in combination. Many ornamental plants have been originated from inter-specific and inter-generic crosses, which leads to high degree of heterozygosity in the resulting hybrids, often polyploidy and aneuploidy also occur. In the present review, origin, modes of reproduction, introduction, selection, hybridization, mutation and polyploidy breeding of various ornamental plants are discussed in details.
Keywords Varieties; Flowers; Hybrids; Hybridization; Polyploidy; Selection

1 Introduction

Ornamental plants include woody and herbaceous as well as annuals, bi-annuals and perennials. Ornamentals are grown as both seed propagated and vegetative propagated cultivars. A general characteristic of ornamentals is assessed by their quantitative capacity for production of seeds or other plant organs. Utilization of polyploidy both auto-polyploidy from spontaneous or induced chromosome doubling and allo-polyploidy from spontaneous or artificial interspecific hybridization is widely used among ornamentals to rapidly combine traits and to create giant type of flowers and leaves. In seed propagated ornamentals, with a considerable seed marked, cultivars will normally be bred as hybrids based on inbred parental lines.

Ornamental plants are appreciated by their ability to please the eye of consumers as garden or pot plants or when sold as cut material. For these reasons, cultivars or ornamentals must fulfill aesthetic criteria in demand. The main emphasis in ornamental plant breeding is to improve variety traits, novel colour, form, size, number of flowers, flower vase life, repeat blooming, disease resistance, nutrient uptake capacity and growth habit. Recently, many spectacular shades and forms like dwarf hollyhocks, dwarf delphiniums, uniform perfumed cyclamen, red and white marigolds, blue roses and carnation, yellow antirrhinum, fragrant gladioli, coloured tuberose etc. have great demand in ornamental trade (Raghava, 1999).

2 Origin of Ornamental Plants

The origin of a crop is determined by the collection of existing forms of cultivated and wild species in a particular area.

Indian origin: The important flowers which are natives of India cultivated in different parts of the world are orchids, rhododendrons, musk rose (*Rosa moschata*), begonia, balsam (*Immpatiens balsamina*), globe amaranth(*Gomphrena globosa*), gloriosa lily (*Gloriosa superba*), foxtail lily (*Eremerus himalicus*), primula (*Primula denticulata P.rosea*), blue poppy (Meconopsis), lotus (*Nelumbo nucifera*), water lily (*Nymphaea* spp.), clematis (*Clematis montana*- a climber) and the wild tulip of the Himalayas (*Tulipa stellata* and *T.aitchisonii*).The important native ornamental flowering trees, mentioned in ancient literature are Kachnar (*Bauhinia variegata*), Amaltas (*Cassia fistula*), Pink cassia (*Cassia nodosa*) Dhak or Flame of the Forest (*Butea frondosa*), Indian coral tree (*Erythrina blakei*, Pride of India (*Lagerstroemia flos-reginae,L. thorelli*), Lal Lasora or Scarlet Cordia (*Cordia sebestena*), Yellow silk cotton (*Cochlospermum gossypium*), Karanj (*Pongamia glabra*), Rugtora or Wavy-leafed Tecomella (*Tecomella undulata*), tulip tree or Bhendi (*Thespesia populnea*), *Crataeva roxburghii*, *Sterculia colorata*, chalta (*Dillenia indica*), Ashoka, Kadamba and rhododendrons. Among the shrubs and climbers originated from India are the jasmine (*Jasminum sambac*, *J.pubescens*, *J.auriculatum*, *J.humile*, *J.officinale*, *J.grandiflora*) and madhavi (*Hiptage medablota*), which have been mentioned by Kalidasa in his plays. The other indigenous species are *Bauhinia acuminata*, *Mussaenda frondosa*, *Ixora spp.* (*I. coccinea*, *I. parviflora*, *I.barbata*, *I.undulata*), *Hamiltonia sauveolens*, *Holmskioldia sanguinea*, *Clerodendron inerme*, *Crossandra infundibuliformis*, *Plumbago rosea*, *Plumbago zeylancia*, *Tabernaemontana coronaria*, *Trachelospermum fragrans*, *Osmanthus fragrans*, *Passiflora leschenaulti*, *Clitoria ternatea*, *Porana paniculata*, *Gloriosa superba and Clematis montana*.

Globally, most of ornamentals are confined to north-eastern Eurasia. There are about 8000 species of ornamentals in world trade for commercial purposes. Amongst them, *Gladiolus, Iris, Narcissus, Rosa, Tulipa* are grown over large areas. Out of 120 perennial plants, paeony, phlox, iris, lily, tulip and daffodil and 100 annual species, china aster, petunia and marigold showed greater diversity. Basilevskaya (1960) first investigated the geographical origin of garden plants. Coats (1968) who first traced out the ornamental herbs whereas Hui-Lin Li (1974) wrote first introduction of woody plants. There are altogether thirteen centres of origin of identified for ornamental plants as given below.

The Mediterranean Centre: It covers about 1000 ornamental species i.e. 20% of garden plants and amongst them, daffodil, hyacinth, cyclamen, stock, iris, garden pansy, oleander, cornflower, windflower, paeony are common.

The North American Centre: It envisages about 650 native species or about 13% of garden plants of the world. Popular ornamentals include white acacia, *Phlox paniculata*, perennial lupin (*Lupinus polyphyllus*), cone flower (*Rudbeckia hybrida*), coreopsis, evening primrose (*Oenothera* spp.), purple coneflower (*Echinacea purpurea*).

South African Centre: This is a good source of ornamentals covering 600 species or about 12% of garden plants. Popular ornamental species originated from this centre are bird of paradise (*Strelitzia reginae*), cape primrose(*Streptocarpus hybrida*), belladonna lily(*Amaryllis belladonna*), Giant summer hyacinth (*Galtonia candicans*), geraniums(*Pelargonium*), gladiolus, crassula, gasteria, haworthia, gazania.

The Meso-american Centre: (Southern Mexico and Central America). There are about 500 ornamental plant species or about 10% of garden plants of the world available in this centre. Those are cacti (*Opuntia*, *Echinocereus, Mammilaria* etc,), orchids (*Odontoglossum, Oncidium*, *Vanilla*), begonia (*Begonia imperialis*), *Cosmos bipinnatus*, Dahlia, *Gomphrena haageana*, marigolds (*Tagetes erecta*, *T.patula*, *T. tenuifolia*), floss flower (*Ageratum houstonianum*), *Cemmelina tuberosa* and *Zinnia elegans.*

Tropical Asian Centre: (Indo-Malayan Centre). This centre has originated about 450 ornamental species or 8% of garden plants. Amongst them, orchids, begonias (*Begonia rex*), Indian Rubber Tree (*Ficus elastica*), Aglaonema, Codiaeum, cockscomb (*Celosia argentea*), globe amaranth (*Gomphrena globosa*), and balsam (*Impatiens balsamina*).

The European Centre: There are about 300 ornamental plant species native to Europe. Common ornamental plants derived from this centre are *Adonis vernalis*, common daisy (*Bellis perennis*), horned violet (*Viola corunata*) and sweet violet (*Viola odorata*).

The Eastern Asiatic Centre: (China, Japan). There are about 250 ornamental plant species (5%) derived from it. Important ornamentals originated are peony (*Paeonia lactiflora*), royal lily (*Lilium regale*), China wisteria (*Wisteria sinensis*), China aster (*Calliatephus chinensis*), *Sophora Tomentosa*, Day Lily (Hamerocallis) and chrysanthemum.

Tropical African Centre: There are about 160 species (3% garden plants) indigenous to this centre. Popular ornamentals are *Sansevieria trifasciata,* African violet (*Saintpaulea ionantha*), and orchids.

The Caucasian Western Asiatic Centre: This centre contributed around 150 ornamental plant species (3%) and out of them, autumn crocus (*Colchicum speciosum*), crested gentian (*Gentiana septemfida*), *Pyrethrum coccineum* and pin-cushion flower (*Scabiosa caucasia*) are popular.

The Central Asian Centre: It covers about 130 ornamental plant species (2.5% garden plants). Some commercially important species originated from this centre are water lily, tulip (*Tulipa kaufmanniana*) and other tulip species (*T. fosteriana*, *T. greigii*).

The Australian Centre: About 100 (2%) ornamental plants have been originated from this centre. *Bassaia actinophylla*, *Eucalyptus, Casuarina, Callistemon* and *Acacia longiflora* are popular amongst them.

The South American Centre: It accounts for about 600 ornamental plant species (12% garden plants). Popular ornamental plants originated from this centre are *Anthurium, Calendula, Dieffenbachia, Philodendron, Gloxinia, Caladium hybridum, Salvia splendens, Heliotropium arborescens, Verbena hybrida* and morning glory (*Ipomoea alba, I. purpurea* and *I .tricolor*).

The Macronesian Centre: It covers about 50 species; and dragon tree (*Draecena draco*), species of Aloe and beautiful shrublet campanula (*Azorina vidalii*) have been originated from this centre.

3 Mode of Reproduction (De and Bhattacharjee, 2011)

Pollination means transfer of pollen grains from anthers to stigmas. There are three types of pollination found in heterogamous plants; namely autogamy or self pollination, allogamy or cross pollination and geitonogamy.

3.1 Autogamy or self- pollination

It is defined as the transfer of pollen grains from anthers to stigmas within the same flower and always found in hermaphrodite flowers. Self pollination results in the production of homozygous populations. Self pollinated species show heterosis and do not show inbreeding depression. There are various types of mechanisms of self pollination such as cleistogamy, homogamy and chasmogamy.

Cleistogamy: In this case, the bisexual flowers do not open at all and ensure the complete self pollination. It occurs in *Salpiglossis sinuata, Viola pubescens, Impatiens glandulifera.*

Homogamy: In this case, the anthers and stigmas of a bisexual flower mature at the same time and causes self-pollination. It is found in *Lathyrus odoratus,* Lupin, Aster, Calendula.

Chasmogamy: In this case, the flowers generally open only after the pollination is over. It occurs in pansy, *Clitorea ternatea*.

3.2 Allogamy or cross pollination

It is defined as the transfer of pollen from one plant to the stigmas in flower on a different plant. Such types of pollination are brought out by air (Anemophilous), water (Hydrophilous), insects (Entomophilous) and animals (Zoophilous).

Anemophilous ornamentals: Rhododendron, Azalea, Acacia
Hydrophilous ornamentals: *Salix alba, Euphorbia grantii*

Entomophilous ornamentals: Poppy, Liatris.
Zoophilous ornamentals: Willow.

Cross pollination leads in the improvement and preservation of heterozygosity in a population. Cross pollination species are highly heterozygous and they show a certain degrees of heterosis with low to high inbreeding depression. Such type of pollination is useful in the production of hybrids or synthetics.

3.3 Various mechanisms involved in cross pollination

Monoecious plants: Male and female flowers occur in the same plant either in the same inflorescence or separate inflorescence. It occurs in *Casuarina eqisetifolia*, pine, *Begonia, Petunia.*

Dioecious plants: Male and female flowers occur on different plants. It is observed in *Juniperus* spp., *Polygonum cuspidatum*.

Protogyny: In this case, pistils mature earlier than stamens. Protogyny is found in petunia and antirrhinum.

Protoandry: In this case, stamens mature before pistils. It occurs in salvia, marigold.

Heterostyly: This condition is due to different lengths of styles and filaments leading cross pollination. It occurs in antirrhinum, primula, Limonium, Pentas.

Herkogamy: This mechanism is attributed to the physical barriers between the anthers and stigmas of a flower. It is reported in Narcissus, Peperomea, *Ruellia brevifolia*, *Viola.*

Genetic Male Sterility: This type is determined by the single recessive gene, ms carried in the nucleus. It occurs in Vinca, Pelargonium, Ageratum.

Cytoplasmic Male Sterility: This type of sterility is determined by cytoplasmic factors and progeny of male sterile plants become always sterile. It occurs in sunflower, petunia, impatiens.

Cyto-genetic Male Sterility: This type of Male sterility is determined by the interaction of genes and cytoplasm. It is found in petunia, zinnia, cosmos, marigold.

Self –incompatibility: It is incapability of viable pollen grains to fertilize the same flower. It may be due to the failure of pollen germination, pollen tube growth and degeneration of embryo after fertilization.

Gametophytic incompatibility: It is influenced by a single gene with multiple alleles located in pollen, styles and ovule which is independent in action and do not show any dominance relationship. It occurs in *Nicotiana alata*, Petunia, Rose.

Sporophytic incompatibility: It is influenced by a single gene with multiple alleles which are not independent and show dominance relationship. It is found in Cosmos, Ageratum, Chysanthemum.

Heteromorphic incompatibility: It is due to the presence of two or three types of morphologically distinct flowers which are incompatible and their style and filament length are influenced by two alleles linked with genes. In Primula, out of two flowers, Pin flowers have long style, short filament, large stigmatic cells and small pollen and 'Thrum' flowers have short style, long filament, small stigmatic cells and large pollen. Both flower types are self incompatible but cross compatible. This situation is called as 'Distyly' and governed by a single gene s, Ss for Thrum and ss for Pin flowers. In Lythrum, 'Tristyly' situation is occurred with three types flowers, long, mid long and short and each type has two positions of anthers.

Long style: mmss
Mid style: Mmss or MMss
Short Style: MmSs, mmSs, MMSS, MMSS, MmSs

Here the style length is governed by two independent loci, S and M. All these three stylar types are self incompatible but cross compatible.

Geitonogamy: When the pollen grains of a flower fall on the stigmas of another flower on the same plant, it is called as geitonogamy and it is genetically equivalent to self-pollination. e.g Periwinkle, Salvia.

Often Cross Pollination: In some crops, cross pollination exceeds 5% even upto 30% and genetically intermediate between self and cross pollinated crops.

4 Objectives of Breeding for Different Ornamentals

Development of tetraploids and triploids in marigold, verbena, amaranth etc produce bigger size and long lasting flowers. In roses, varieties with shapely buds and longer stems are required for export purpose. Varieties with longer flower duration may be developed in case of *Rosa damascena*, *Rosa bourboniana*. In gladiolus, efforts should be made to develop fragrant varieties with other desirable traits. In chrysanthemum, there is need for development of photo-insensitive varieties in different types. Hybrid cultivars in ornamentals are appreciated mostly for their uniformity, shape, size, dwarfness, colour etc. In India, breeding of F_1 and F_2 hybrids of different annual and biennial flowers which have great potential in view of superiority over open pollinated cultivars in many characteristics.

4.1 Breeding standards for seed propagated ornamentals

Breeding methods for ornamental plant breeding range from traditional selection breeding to modern biotechnology and genetic engineering. Conventional plant breeding results into development of a number of open pollinated varieties or F_1 hybrids in ornamental plants over the last decades with the objectives for improvement of yield and quality and extension of growing season. Utilization of polyploidy both auto-polyploidy from spontaneous or induced chromosome doubling and allo-polyploidy from spontaneous or artificial inter-specific hybridization is widely used among ornamentals to rapidly combine traits and to create giant type of flowers and leaves. In seed propagated ornamentals, with a considerable seed market, cultivars should normally be bred as hybrids based on inbred parental lines. In most cases seed prize can support hybrid seed production through manual emasculation and pollination among parentals (*Begonia semperflorens*, *Cyclamen* spp., *Pelargonium* spp., *Petunia* spp., *Primula* spp., *Viola* spp.).

4.2 Breeding standards for vegetatively propagated ornamentals

In vegetatively propagated ornamentals, inter-specific hybridization has been performed to an extent that traditional classification into botanical species is impossible (roses, orchids etc). Breeding schemes in such cases simply consists of hybridization followed by selection among cloned seed offspring to identify new useful clones. Systematic breeding for new improved clones in such species normally depends upon international agreements to protect breeders rights for the new cloned cultivars.

4.3 Scope of advance breeding techniques

Present floriculture scenario is dominated by for flowers with novel traits. The development of new tools for introducing foreign genes into plants in combination with growing knowledge and technology related to gene identification and isolation have enabled the specific alteration of single traits in an otherwise successful cultivars and have broadened the available gene pool of a given species. There is a large scope for improvement of floricultural crops using biotechnological tools like micropropagation, *in vitro* mutagenesis, somaclonal variation, embryo recovery, haploid culture, protoplast fusion, genetic transformation and DNA finger printing. The new strategies of *in vitro* culture have been commercially implemented for the propagation and breeding of a wide variety of ornamental crops. Nowadays, there are a number of cultivars obtained directly or indirectly by the use of induced *in vivo* mutation. Embryo recovery is effective in inter-specific or inter-generic crosses is to transfer alleles for disease resistance, environmental stress tolerance, high yield potential or other desirable characteristics of species or genus to accepted cultivars, to recover rare hybrids derived from incompatible crosses as well as to overcome seed dormancy by studying the nutritional and physiological aspects of embryo development and by testing seed viability. It is easy to detect mutations and to raise isogenies pure lines through haploid cultures. Protoplasts are excellent resources used to improve a species by introducing a gene by mutant induction or by introducing inter-specific hybrids of incompatible crosses. Nowadays, breeders can introduce genetic variation in commercial flowers by the application of recombinant DNA technology. This technology is effective for changes in phenotypic expression encoded by single genes such as corolla and foliage colour and texture, stem length, scent, temporal regulation of flowering, vase life of cut flowers and resistance to biotic and abiotic stresses.

5 Plant Introduction

Plant introduction is the process of introducing plants from their growing locality. It may be introduced either from the country of another continent (inter-continental), from another country within the same continent (intra -continental), from another state with in the same country (inter-state) or in the different states within the country or from another district within the same state (intra-state plant introduction). The main objectives of introducing plant materials from outside are for use as food, wood, medicinal or industrial purpose, to study origin and evolution of crop plants and in case of ornamentals to enrich and fulfill the aesthetic values of gardens, parks, buildings and bungalows and for genetical improvement of economic crops through direct release, selection, as donor parent and as breeding materials.

5.1 Organizations for plant introduction in India

National Bureau of Plant Genetic Resources (NBPGR), New Delhi is the central body of our country for collection, introduction, expeditions, exchange and distribution of seed and propagated materials of agri-horticultural crops. Other organizations involved in plant introduction are Forest Research Institute, Dehradun, Botanical Survey of India. The International Board of Plant Genetic Resources (IBPGR), FAO, Rome was established to introduce and conserve germplasms.

5.2 Different ways of plant introductions

Exploration expedition: It is done by a team of scientists from an organization for exploratory research to the unexplored areas within or outside the country.

Exchange: The material is generally obtained from friendly countries either direct or through FAO offices, USAID, Ford Foundation, Rockfeller Foundation.

Purchase or gift: The materials may be purchased or obtained as free gifts from individuals or institutions.

Introduction of different ornamentals in India: Among the ornamental plants, many species of orchid and rhododendron, musk rose, begonia, balsam, globe amaranth, gloriosa lily, foxtail lily, primula, blue poppy, lotus, water lily, clematis and wild tulips are native to India. The Agri-Horticultural Society of India, established in 1820 introduced hundreds of species and cultivars ornamental plants in India including *Bougainvillea, Dahlia, Mussaendra erythrophylla*, annual flowering plants from different parts of the world apart from many field crops and vegetables. The exotic flowers have mainly come from Europe, America, Africa, China, Japan and other countries. During Mughal's period, many ornamentals were introduced from Persia and Central Asia. The British and Portuguese introduced various ornamentals in India from Europe and tropical America.

Among ornamental trees, species of *Acer, Acacia, Bauhinia, Brachychylon, Cervilllia, Cryptomeria, Cotoneaster, Cupressus, Colvillea Erythrina, Eucalyptus, Lagerstroemia, Monodora, Prunus, Pyrus, Spathodera, Tabebuia* and many other were introduced from Australia, USA, Europe and African countries. Among ornamental shrubs, *Bougainvillea, Calliandra, Nerium, Rosa* etc. have been introduced. In bougainvillea, 'Allison Devy', 'Crimson Glory', 'James Walker', 'Lady Hudson', 'Orange Glory', 'Princess Elizabeth', 'Rosenka', 'Sandiago' and 'Snow White' were introduced from Kenya and USA (Singh et al, 1993).

The Persian rose, particularly the Damask rose was introduced into India during early Mughal days. Later, during the British period, the Edward rose, a hybrid Bourbon (*Rosa bourboniana*) was introduced in India in 1840. Some notable introductions of rose cultivar are 'Spotless Pink', 'Altissimo Deep Red', 'Crimson Scarlet', 'Doris Tysterman', 'Dutch Gold', 'Fragrant Delite', 'Swan Lake', 'Topekar', 'White Cocode'. About thirty three species of *Rosa* were introduced from Australia, Canada, Denmark, Germany, Holland, U. K. and USA and amongst them, *Rosa canina, Rosa laxa, Rosa hugonis, R. rubiginosa, R. multiflora, R. pomifera* are important.

A large number of exotic genotypes like *Anemone, Begonia, Chrysanthemum, Dahlia, Freesia, Gladiolus, Gloxinia, Hyacinthus, Iris, Narcissus, Lilium* and tulips have been introduced. In gladiolus, 158 cultivars have been introduced from USA, UK, Canada, Egypt, Israel and USSR; EC-197878-894, EC 197953-977 were introduced from USA; cultivars like 'Encore', 'Lorilee', 'Spartan', 'Accolade', 'Queen', 'High Light' and 'Pink Lady' from Canada; EC 216397 from Egypt; 'Trader', 'Horen', 'Novalux', 'Peter Pears' and 'Rose Prince' from Israel; 'Bid Time', WIR 790, 'Blueshire' and S'now Spirite' WIR 855 from USSR. Among species, *Gladiolus cardinalis*, *Gladiolus byzantinus* were introduced from Canada, Egypt, Israel, UK, USA and USSR*; Gladiolus communis* from Denmark. Modern hybrids of Freesia, 'Olympiad Jones' and 'Olympiad Gloe' were introduced from Denmark. British and Portugese introduced a number of carnation cultivars. NBPGR has introduced 74 collections of carnation from Australia, Canada, Cyprus, France, Germany, UK and USA. Among species *Dianthus spiculiformis, Dianthus fragrans, Dianthus pinifolius, Dianthus balbisii, Dianthus barbatus, Dianthus plumarius, Dianthus deltoides, Dianthus prateaus and Dianthus armeria* were notable. Two collections of cyclamen, *Cyclamen persicum and Cyclamen herifolium* were introduced from Denmark, Germany and U.K.

Iris laevigata was an introduction from U.K. NBPGR recently introduced *Impatiens balsamina* (EC 582735, 582736) from UK; *Impatiens glandulifera* and *Lotus corniculatus* from UK. In lily, *Lilium pirkinense* and *Lilium enzosetn* were introduced from Australia. In flowering annuals, notable exotic introductions made by NBPGR include species and cultivars of *Aster, Alcea, Antirrhinum, Calendula, Celosia, Delphinium, Eschsoltzia, Impatiens, Lathyrus, Petunia, Stock, Salpiglossis, Tagetes, Tropaelum, Viola* and *Zinnia*. *Viola tricolor* and *Viola wittrockiana* were introduced from Canada, France, UK and USA. *Zinnia angustifolia* is an introduction from Australia and France. Other annuals like *Antirrhinum majus* from Australia, France and China; *Calendula officinalis* from France; cultivars of *Tagetes erecta, T. patula and T. tenuifolia* from Australia, Holland, Slovakia and USA. A large number of exotic cultivars of orchids belonging to the genera *Cymbidium, Cattleya, Dendrobium and Paphiopedilum* were introduced.

6 Selection

It is the oldest breeding method and the basis of all crop improvements. It is choosing the best out of one's crop continued over generations for development and retention of already developed varieties. Spontaneous mutation and population improvement through natural hybridization and recombination over generations are the basis of selection. Self pollinated crops are naturally homozygous and do not show inbreeding depression. So selection is employed to isolate plants with superior genotypes and to establish separate pure lines or their seeds are bulked to produce a mixture of pure lines. Individual plants from cross pollinated crops are highly heterozygous and the progeny from such plants are heterogeneous and normally different from parent plant due to segregation and recombination. These types of crops show moderate to severe inbreeding depression and such characteristics are kept minimum for population improvements. This method is utilized in the development of cultivars of lily, dahlia, chrysanthemum, camellia etc.

Chrysanthemum cvs. 'Apsara', 'Birbal Sahni', 'Jayanthi', 'Kundan', have been developed through selection. Similarly cvs. 'Shubhra', 'Dr B.P. Pal', 'Parthasarthy' and 'Surekha' in Bougainvillea and 'Pusa Arpita' in marigold have been developed. In Bougainvillea varieties, 'Sholay' and 'Usha' are the half sib selection of cv. 'Red Glory' and 'Lady Hope' developed at IIHR, Banglore.

6.1 Selection methods for self- pollinated crops

Mass selection: This is one of the oldest method of crop improvement. The best plants from the field or bulk are selected and threshed together and the resulting bulk harvest is used to raise the crop for next generation. It is practiced in mixed population of cultivars or land variety or unimproved strains. Generally, 500 to 1000 plants are selected and bulked in the second year. Then the selected bulk is tested against the cultivar and the local check and the superior one is released as cultivars in the following year. This technique is effective in ornamental pepper.

Pureline selection: Pureline selection is the progeny of a single homozygous plant of a self pollinated species. It involves three steps:

- Selection of a large number of superior individuals from a genetically variable population.
- Raising of the self-progeny of each over several years under different environments. Unsuitable lines are eliminated in each generation.
- Replication of the trials to compare the remaining selections. This is done over several seasons, atleast three years to compare them with each other and with existing commercial cultivars.

In Aster, AST-1 and AST-2 developed through pure line selection.

6.2 Selection methods in cross pollinated crops

Mass selection: It is practiced to develop cultivars and for population improvement. In this method, a large number of superior plants are selected and harvested in bulk and seeds are used to produce the next generation. Mass selection is effective to improve qualitative characters as well as quantitative characters including yield. It is practiced in sunflower and chrysanthemum for evolution of new cultivars.

Mass – pedigree method: It is generally used for increasing seed set in introduced autotetraploids of self incompatible crops. The individuals are selected in the population on the basis of certain increasing arbitrary norms or selection indices.

Clonal selection: A clone is a group of plants produced from a single plant asexually. All the individuals belonging to a single clone are identical in genotype. The phenotypic variation within a clone is due to the environment only and phenotype is due to the effects of genotype (G), the environment (E) and the genotypic x environment interaction over the population mean. Clones are maintained easily through asexual means. In general, clones are highly heterozygous and show loss in vigour due to inbreeding. Genetical variation within a clone is due to mutation, mechanical mixture and segregation and recombination due to occasional sexual reproduction. Selecting spontaneous mutants within a clone is called clonal selection. Hundreds of popular ornamental plants grown in most part of the world originated from clonal variation and selection.

6.3 Clonal hybridization

Improvement of ornamental crops through clonal hybridization involves three steps:

- Selection of parents
- Production of F_1 hybrids and
- Selection of superior clones

Large number of cultivars of perennial ornamental plants eg. *Bougainvillea, Chrysanthemum, Dahlia, Hibiscus, Gladiolus, Rosa* etc. have been obtained by clonal hybridization.

Hybridization: It is defined as the crossing of two or more plants which are genetically different from each other to produce a new crop. Hybridization is effective to combine all the good characters in a single variety to create genetical variation and to exploit the hybrid vigour.

There are five methods of hybridization based on relationship between parental plants.

Intravarietal hybridization: In this case, crosses are made between the plants of same variety in self pollinated crops.

Intervarietal hybridization (intraspecific): In this method crosses are made between the plants belonging to two different varieties of the same species. It is useful in the improvement of self-pollinated as well as cross pollinated crops. This method is utilized for the development of cultivars of most of the flower crops like *Chrysanthemum*, *Gladiolus, Rose*, *Bougainvillea, Hibiscus* and *Camellia* (‘April Blush’, ‘April Dawn’, ‘April Rose’, ‘April Snow’).

Gladiolus varieties: Meera (G.P. 1 × Friendship), Nazrana (Black Jack × Friendship), Apsara (Black Jack × Friendship), Suverna (Hall Mark x Fidelio), Urvashi (Eurovision x Snow Princess), Neelima (Tropic Sea x Snow Princess), Roshni (Friendship Pink x Red Beauty), Jamuni (Lavender Puff x Tropic Sea).

Hibiscus varieties: Basant (IIHR × Rachaiah), Chitralekha (Debby Ann × H. S. 203), Marathi (H. S. (red) × H. S. 123), Nazneen (H. S. 203 × Rashtrapati), Phulhari (H. S. 139 × H. S. 181), Ashirbad (H.S. 21 x Hombe Gowda).

Rose varieties: Pusa Ajay (Pink Parfait x Queen Elizabeth), Pusa Komal (Pink Parfait x Suchitra), Pusa Manhar (Jantar Mantar x Lahar), Pusa Ranjana (Pink Parfait x Iceberg), Pusa Muskan (Pink Parfait x Alinka), Pusa Priya (Jantar Mantar x Queen Elizabeth), Pusa Pitamber (Jantar Mantar x Banjaran), Pusa Bahadur (Cara Mia x Century Two), Pusa Shatabdi (Jadis x Century Two), Bougainvillea varieties: Begam Sikander (‘Dr.B.P.Pal’ x ‘Jennifer Fernic), Chitra (‘Tetra Mrs. McClean and ‘Dr.B.P.Pal), Mary Palmer Special (‘Princess Margaret Rose’x ‘B.P.Pal’), Wajid Ali Shah (‘Dr.B.P.Pal and ‘Mrs.Chico’).

Interspecific hybridization (intrageneric): In this method, the plants of two different species belonging to the same genus are crossed together. This method is utilized in cultivar evolution of petunia, orchid, bougainvillea, lilium, amaryllis, verbena etc. Crosses in lilium, orchid, *Hemerocallis*, *Victoria amazonica*, *Bougainvillea spectabilis* x *Bougainvillea glabra* are common.

Intergeneric hybridization: In this case, crosses are made between the plants belonging two different genera. It is usually used for transferring the characters like diseases, insects and drought resistance from wild genera into the cultivated plants. This method is exploited for the varietal development of orchids (De et al, 2014).

Bigeneric Hybrids:
Aerdachnis = *Aerides* ×*Arachnis*;
Aeridocentrum = *Aerides* × *Ascocentrum*;
Aeridopsis = *Aerides* × *Phalaenopsis*;
Aranda= *Arachnis x Vanda*

Trigeneric Hybrids:
Brassolaeliocattleya = *Brassavola* × *Laelia* × *Cattleya*;
Colmanara = *Miltonia* × *Odontoglossum* ×*Oncidium*;
Vascostylis = *Vanda* × *Ascocentrum x Rhynchostylis*

Tetrageneric Hybrids:
Iwanagara = *Brassavola* ×*Cattleya* ×*Diacrinum* ×*Laelia*;
Kirchara = *Cattleya* × *Epidendrum* × *Laelia* ×*Sophronitis*;
Potinara = *Brassavola* × *Cattleya* × *Laelia* × *Sophronitis*

Pentageneric Hybrids:
Goodlera = *Brassia* × *Cochlioda* × *Miltonia* × *Odontoglossum* × *Oncidium*;

Hasegawara = Cattleya ×Brassavola × Broughtonia × Laelia × Sophronitis

Introgressive hybridization: In this method, one species is completely replaced by another for example through backcrossing. This is effective in orchids.

6.4 Breeding through hybridization in self-pollinated crops

Pedigree method: In the pedigree method, individual plants are selected in F_2 for raising F_3 families of each selection. Later on, in F_3 selection is made between and within the families. The variation within families tends to become narrower in the subsequent F_4 and later generations while the differences among families ensure chances of selection. The selection continues until F_6 or F_7 generations till the uniformity of all families is reached. This method is useful in varietal development of primerose, aster, pelargonium, carnation and rose.

- China aster cultivars: ‘Kamini’, ‘Poornima’, ‘Shasank’, ‘Violet’, ‘Cushion’
- Hollyhock varieties: ‘Deepika’, ‘Dulhan’, ‘Gauri’, ‘Pusa Sweta’, ‘Pusa Krishna’, ‘Pusa Lalima’, ‘Pusa Gulabi’
- Marigold varieties: Pusa Basanti Gainda' (yellow coloured flowers) and 'Pusa Narangi Gainda' (orange coloured flowers) have been developed through pedigree method.

Backcross method: Backcross is the crossing of F_1 with either of the parents and test cross is the crossing of F_1 with recessive parents. This method is effective for breeding of disease resistance and for transferring male sterility in ornamental crops. In Magnolia, ‘Yellow Bird’ has been developed by backcross method.

6.5 Breeding through hybridization in cross-pollinated crops

Single cross (A x B): This is a cross between two inbreds such as A x B or C x D. A single cross is prepared by planting two rows of female lines to one row of male line alternatively in such a way that two-third of the field will produce hybrid seed for sale. In single crosses, maximum degree of hybrid vigour is manifested and reported to produce uniform plants. Formula for number of single crosses is written as n (n-1)/2 where n=number of inbreds. This method is utilized in gladiolus, chrysanthemum, dotted paeony.

Three way cross (A x B) x C: In this case, a cross is made between a single cross used as female and an inbred used as male. In this method, vigorous hybrid of first generation is used as female in order to get maximum yield of hybrid seed. This method is used in chrysanthemum and orchids.

For example variety of rose (*R. Wichuriana* × Floradora) × Debbie, Buccaneer a hybrid seedling of Golden Rapture × (Max Krause × Capt. Thomas). In case of orchids, trigeneric hybrid *Brassolaeliocattleya (Brassavola × Laelia × Cattleya) and Mokara (Ascocentrum ×Vanda × Arachnis*).

Double cross (A x B) x (C x D): It is the cross between two single crosses involving four different inbreds. A double cross is made by alternate planting of two single cross plants in an isolated area and detasselling of the single cross used as female parent. Double crosses are used for production of commercial hybrids. It is used commercially in orchids, *Viola tricolor* and ornamental trees.

For example variety of rose 'Christian Dior' a cross between (Independence × Happiness) × (Peace × Happiness). In case of orchids tetrageneric hybrid Potinara (*Brassavola × Sophronitis × Laelia × Cattleya), and Robinara (Aerides × Ascocentrum × Renanthera × Vanda*) are some of the examples.

Top cross or inbred x variety cross (A x Variety)**:** It is a cross between an open pollinated variety and inbred line. It is employed in *Ageratum houstonianum, Bellis perennis, Gerbera jamesonii.*

Composite cross: Composites are advanced generation seed mixture of inter- varietal or inter-racial cross.

Synthetic cross: A synthetic variety is produced based on the exploitation of additive genetic variance. In this case, inbred lines, clones, mass selected varieties and lines developed by recurrent selection or reciprocal recurrent selection are generally synthesized following hybridization and testing of their general combining ability to develop a synthetic cultivars.

Heterosis breeding: Cross pollinated and asexually propagated species show moderate to severe inbreeding depression. Inbreeding is the mating between closely related individuals. Inbreeding depression is defined as the loss or reduction in vigour and fertility as a result of inbreeding. Inbreeding causes the appearance of lethal and sub-lethal alleles reduction in vigour, reproductive ability, yield and increases homozygosity.

Heterosis is defined as the superiority of a F_1 hybrid over both its parents in terms of yield or some other characters.

Manifestation of heterosis: Cross pollinated species show heterosis when inbred lines are used as parents. In such species, genetic additive variance is one of the essential source for improvement of hybrid vigour. In some self-pollinated species, heterosis is applied for the production of hybrid seeds. The superiority of hybrids (heterosis) over its parents is manifested on increased yield, increased reproductive ability, increase in size and general vigour, improve quality, early flowering and maturity, greater resistance to insect pests and diseases, greater adaptability.

Heterosis in ornamental plants: In marigold, highest heterosis was observed in the crosses 'Alaska' x 'Hawaii', 'Alaska' x 'Cupid Orange Mum' and 'Katrain Local' x 'Cupid Orange Mum' for flower size, flower weight and flower number, respectively . In another study on diallel crosses involving six parents one hybrid raised from the cross of 'Giant Double African Orange' x 'Cracker Jack' was reported promising for commercial purposes. A hybrid, 'MS-8' x 'Pusa Narangi Gainda' developed by using apetalous male sterile lines was found promising in terms of higher flower yield.

In antirrhinum, F_1 dwarf hybrids are developed using parents *Antirrhinum majus* and *A. glutinosum*. Over dominance was observed in the inheritance of all characters.

In balsam, heterosis was reported involving five parents in a diallele set of crosses for various characters. Maximum heterosis was found for numbers of flowers per plant followed by branches per plant.

In China Aster, considerable heterosis was recorded involving 12 parents in a diallele set of crosses for all the characters. Three crosses 'Shell Pink' x Azure Blue', 'AST-20' x 'Azure Blue' and 'AST-20' x 'AST-16' were developed for manifestation of heterosis in terms of flower size, numbers of flowers per plant and stalk length.

In hollyhock, five F_1 hybrids namely 'Pusa Pink Beauty', 'Pusa Yellow Beauty', 'Pusa Pastel Pink', 'Pusa Apricot Supreme' and 'Pusa Pastel Pink Supreme' were developed.

In single multiflora and grandiflora types of petunia, heterosis involving diallele crosses using eight parental lines were studied for all characters.

Mutation breeding: Mutation is the sudden heritable changes occurred in an organism exception to Mendelian segregation and recombination and the mutated individual is called mutant. The term mutation was first mentioned by De Vries (1900). Mutation may be caused by spontaneous and induced and the result of a change in the gene or chromosomes or change in the cytoplasmic genes.

There are various types of mutation found in ornamental plants.

Gene or point mutations: Mutation due to changes in the base sequences of genes are called gene or point mutations. It is used directly as improved variety, to increase variability in allogamous species, for cross breeding, to induce mutation in inbred lines, to induce male sterility and sport development.

Chromosomal mutations: Mutation due to changes in chromosomal structure are called as chromosomal mutations. It is used for transferring characters from other species and genera and diploidization of polyploids.

Somatic mutations: Mutations due to changes in buds and somatic tissues used in propagation are called as somatic mutations.

Cytoplasmic mutations: Mutation due to changes in cytoplasmic characters are called as cytoplasmic mutation.

Genome mutations: Mutations due to alteration of chromosome number (polyploidy, haploidy, aneuploidy) are called genome mutations.

Spontaneous mutations: Mutations occurring in natural population at a low rate automatically are called spontaneous mutations. The frequency of spontaneous mutation is very low.. Spontaneous mutations are caused by atomic rays and particles, electric currents, hybridity, polyploidy, aging factors, nutritional deficiencies, high temperature, natural mutagens, injuries, disease and insect attacks etc. Spontaneous mutations have been reported in *Oenothera, Godetia, Paeonia, Bougainvillea, Dahlia,* Rose etc.

Induced mutations: Artificial mutations caused by a treatment with certain physical or chemical agents are called as induced mutations.

Mutagens: The physical or chemical agents causing mutations artificially are called mutagens. Mutation is caused by physical and chemical mutagens. Physical mutagens are alpha rays, beta rays, X-rays, gamma rays, neutrons and UV rays. Chemical mutagens are 5-bromouracil, 5-chlorouracil, mustard gas, sulphur mustard, nitrogen mustard,ethyl methane sulphonate (ems), methyl methane sulphonate (mms), ethylene oxide, ethylene imine, azasorine, mitomycin c and streptonigrin etc. are used.

Mutagenesis: It is the treatment of a biological material with a mutagen to induce mutations.

Mutation breeding: It involves the mutation inductions and isolation of mutants for crop improvement.

Mutation in cross pollinated crops: Cross pollinated crops are heterozygous and open pollinated and thus detection of mutant is difficult. The method of handling the M_2 and M_3 generations is same as self-pollinated crops except selfing is done to check out crossing.

Mutation in asexual propagated crops: These plants are heterozygous and so mutation from dominant to recessive are easily detected and chromosomal mutation is common. The mutated plant becomes a chimera ecto-, meso- and endo-chimera depending upon variation in epidermal tissues. The chimeric structure is the most important factor in mutation breeding and so, less differentiated primordial are treated. Chimeric formation is avoided by irradiating the youngest possible stage of bud. Suitable propagation methods like budding, stooling are selected and the shoots of mericlinal chimera are also pruned.

Mutagenic treatments: Physical mutagens like X-rays and gamma rays are preferred over chimeric mutagens for better penetration and more chromosomal rearrangements.

Applications of mutation breeding includes elimination of defective characters, higher yield through production of superior cultivars, increase in variability, exploitation of mutated genes in heterosis, induction of male sterility for use in hybrid seed production, production of sports or chimeras, induction of polyploids, diploidization of polyploids, breaking of undesirable linkage, production of haploids.

Mutation breeding in plants: Ornamental plants are ideal for application of mutations induction techniques because many economically important traits like flower characteristics or growth habit are easily monitored after mutagenic treatment. Most of ornamental species are heterozygous and propagated vegetatively which allows the detection, selection and conservation of mutants in the M_1 generation; for example the origin of moss rose was a mutant of *Rosa centifolia* and about 5819 rose cultivars were developed as bud mutations. Almost 50% cultivars of *Rhodhodendron* and *Chrysanthemum* have been developed from natural sports or induced mutations. First mutation in flower was reported in tulip cv. 'Faraday'.

At present, mutation breeding is applied to alter flower character (colour, size, morphology, fragrance, period, petal number, self sterility, compatibility, sexuality), leaf characters (form, size, flowering, pigmentation), growth habit (compact, climbing, branching), physiological traits (photoperiodic response, early flowering, free flowering, flower keeping quality and tolerance to abiotic and biotic stress) and shoot (nodal density, thorniness, waxy cover).

6.6 Mutant cultivars of important ornamental crops

Rose: *Induced mutations***:** 'Abhisarika', 'Pusa Christina', 'Striped Christion Dior', 'Madhosh', 'Angara', 'Sharada', 'Sukumari', 'Yellow Contempo', 'Pink Contempo', 'Curio', 'Twinkle', 'Light Pink Prize'.

*Bud sports***:** 'Salmon Beauty', 'Clg. Cri Cri', 'Winter Holiday', 'Mme Butterfly', 'Lady Sylvia', 'Rapture', 'Better Times', 'Coral Cluster', 'Juliana Rose', 'Cameo', 'Careless Love', 'Candy Stripe', 'Banhar', 'Anand Rao', 'Balwant', 'Chandralekha', 'City of Lucknow', 'Durgapur Delight', 'Janaki', 'Kanchani', 'Nava Sadabahar', 'Pusa Mansij', 'Pusa Urmil', 'Pusa Abhisek', 'Chitra'.

Carnation: *Induced mutation:* "Arka Flame'.

Gladiolus: *Induced mutations:* 'Shobha', 'Triplex', 'Shakti', 'Shubhangini'.

*Spontaneous mutations***:** 'Salmons Sensation', 'Ratna's Butterfly'.

Chrysanthemum: *Induced mutations***:** 'Alankar', 'Anamika', 'Basanthi', 'Hemanti', 'Kapish', 'Lohit', 'Man Bhawan', 'Sheela', 'Asha', 'Ashankit', 'Aruna', 'Basant', 'Gairik', 'Kansaya', 'Jhalar', 'Nirbhaya', 'Nirbhik', 'Pingal', 'Pitaka', 'Pitamer', 'Purnima', 'Rohit', 'Shafali', 'Shukla', 'Shveta', 'Svarnim', 'Tamra', 'Taruni', 'Talike', 'Yellow Gold', 'Pusa Kesari', 'Pusa Arunodaya'.

Spontaneous mutation: "Kasturba gandhi', 'Sonar Bangla', 'White Cloud', 'Sharad Shobha'

Bougainvillea: *Induced mutations***:** 'Arjuna', 'Jaya', 'Lady Hudson of Ceylon Variegata', 'Silver Top', 'B. Pallavi', 'Los Banos Variegata', 'Mahara Variegata', 'Tetra Mrs.McClean', 'Los Banos Variegata 'Jayanthi', 'Dr.B.P. Pal'

*Bud sports***:** 'Scarlet Queen Variegata', 'Thimma', 'Partha Variegata', 'Mary Palmer', 'Thimma', 'Dr. B. P. Pal', 'Archana', 'Shweta', 'Parthasarthy', 'Surekha', 'Nirmal', 'Jawaharlal Nehru', 'Surekha', 'Mrs. McClean Nirmal'

Dahlia: *Natural mutations***:** 'Manali', 'Juanita'.

*Sports***: '**Candy Keene', 'Salmon Keene', 'Pink Frank Hornsey', 'Yellow Hornsey', 'Lemon Hornsey', 'Pearl Hornsey', 'Rose Hornsey', 'White Kerkrade', 'Majestic Kerkrade', 'White Alvas', 'White Rustig', 'Pink Jupiter', 'Pink Shirley Alliance', 'Rosemary Clare', 'Pink Symbol', 'Lavender Symbol', 'Lemon Chester', 'Yellow Chester', 'Kenya White', 'Kenya Blue', 'Kenya Yellow', 'Manjushri'.

*Induced mutations***:** 'Rotonde', 'Ornamental Rays', 'Pride of Sindri', 'Bichitra', 'Jyoti', 'Jubilees', 'Netaji', 'Pearl', 'Black Beauty', 'Vivekananda', 'Happiness', 'Jayaprakash'.

Tuberose: 'Rajat Rekha', 'Swarna Rekha'.

Perennial Portulaca: **'**Jhumka', 'Karana Pali', 'Lalita', 'Mukta', 'Ratnam'.

Coreopsis: 'Pusa Tara'

Hibiscus: 'Anjali'

African Violet: 'Double Flowers', 'Pink Flowers', 'Girl Foliage', 'Fantasy Flowers', 'Star Shaped Flowers', 'Fringed Flowers', 'Bustled Foliages', 'Coral Pigments', 'Yellow Flowers'.

Hosta: **'**Frances Williams', 'Northern Lights', 'Platinum Tiara', 'Golden Sunburst', 'Color Glory'.

6.7 Ploidy breeding in ornamental crops

A crop species with a genetic chromosome number 'n' is known as haploid and somatic chromosome is diploid (2n). A crop species whose somatic chromosome number is the exact multiple of the basic number is called euploid and the crop species whose somatic number is not an exact multiple of the basic number is called aneuploids. Depending upon the multiplicity of the basic number, euploids may be monoploid (x), diploid (2x), triploid (3x), tetraploid (4x), hexaploid (6x), octaploid (8x) and so on. Species above diploids are called polyploids. Polyploids with same genome number are termed as autopolyploids and those with different genomes are termed as allopolyploids.

In general, haploids are weak and sterile but other polyploids have larger plant parts, large cell, stomata with slower growth rate than diploids. Monosomics do not survive in diploid species and nullisomics donot survive in polyploidy species.

Amphidiploid is an allopolyploid having two copies of each genome present in it. Tetraploids are vigorous with robust vegetative growth, thicker leaves and bigger flowers. Triploids show the characteristics of both hybrid vigour and polyploidy vigour.

6.8 Advantages of polyploidy

- Ornamental haploids have more decorative value due to small flowers and prolonged blooming.
- Triploids have sterile flowers with longer flower life as reported in azaleas, lilies and hyacinths. Triploid chrysanthemum is used to produce pyrethrum.
- Tetraploids have luxuriant vegetative growth. Due to increased flower size, tetraploid cultivars are available in zinnia, antirrhinum and petunia.
- Somatically induced polyploids or allopolyploids contribute heterosis and hybrid vigour.
- Interspecific hybridization followed by polyploidization have helped in the evolution and domestication of many ornamental plants such as rose, chrysanthemum, gladiolus, alstroemeria, lilium, orchids etc.
- Meiotic polyploidization through homeologous recombination in the interspecific hybrids is reported in *Alstroemeria* and *Lilium*.
- Polyploids are more tolerant to drought, cold, mutagens, herbicides and poor soils.

6.9 Production of polyploids

- Tetraploid and higher level of polyploidy are induced using regeneration methods, heat and cold treatment on germinating seeds and by using chemicals like colchicine, nitrous oxide, oryzaline, trifluralin and phosphoric amide.
- Polyploidy due to somatic mutation may be caused by disruption in mitosis resulting in chromosome doubling, e.g. *Primula kewensis.*
- Polyploidy may be produced from the union of unreduced gametes-eggs and sperms that have not undergone normal meiosis and still have a 2n constitution.
- Polyploidy is more frequent at high altitudes, high latitudes, in wet soils and meadows.
- Recently, *in vitro* polyploidization is followed to speed up the heterosis breeding in ornamentals, to reduce the number of aberrant plants and to reduce the time span required for polyploidy production.

Achievements of polyploidy in ornamentals: Polyploidy has been very much exploited in the evolution of species and cultivars of various ornamental crops like tulip, dahlia, anthurium, bougainvillea, lily, cacti, primula, dahlia, narcissus, rose etc. Induced tetraploids are reported in marigolds, petunia, snapdragon, portulaca, chrysanthemum, calendula and lily.

6.10 Polyploid species

Tulip

Triploid: *Tulipa lanata*, *Tulipa stellata*
Tetraploid: *Tulipa clusiana, Tulipa stellata*
Pentaploid: *Tulipa clusiana*

Narcissus

Triploid *: Narcissus pseudonarcissus hispanicus*
Hexaploid*: Narcissus bulbocodium*
Diploid: *Narcissus pseudonarcissus, Narcissus poeticus*

Rose

Diploids **:** *Rosa gigantea, Rosa multiflora, Rosa wichuriana, Rosa chinensis, Rosa moschata*
Tetraploids: *Rosa gallica, Rosa damascena, Rosa foetida*
Triploid: *Rosa bourboniana*

Lily

Triploid: *Lilium tigrinum*

Marigold

Diploid: *Tagetes erecta, Tagetes tenuifolia*
Tetraploid: *Tagetes patula, Tagetes minuta, Tagetes biflora, Tagetes remotiflora*

Dahlia

Tetraploid: *Dahlia imperialis*
Octaploid: *Dahlia variabilis, Dahlia coccinea, Dahlia rosea*

Carnation

Tetraploid: *Dianthus chinensis*

Anthurium

Diploids: *Anthurium andreanum, Anthurium hookerii, Anthurium magnificum*
Triploid: *Anthurium scandens*
Tetraploids: *Anthurium digitatum, Anthurium wallisii*

Jasmine

Triploid: *Jasminum primulinum, Jasminum sambac, Jasminum grandiflorum*
Tetraploid: *Jasminum flexile, Jasminum angustifolium*

Primula

Diploid: *Primula frondosa*
Tetraploid: *Primula farinosa*
Hexaploid: *Primula scotica*
Octaploid: *Primula scandinavica*

Amaryllis

Hexaploid: *Amaryllis belladonna*
Heptaploid: *Amaryllis blumenvia*

Gladiolus
Pentaploid: *Gladiolus psittacinus*

6.11 Polyploid cultivars
Antirrhinum
Tetraploid: 'Tetra Giant', 'Tetra Guilt', 'Velvet Beauty', 'Red Shades'

Bougainvillea
Triploid : 'Cypheri', 'Temple Fire', 'Lateritia', 'Perfection', 'Poultoni Special'
Tetraploid: 'Crimson King', 'Princess', 'Mahara', 'Magnifica', 'Shubhra', 'Mrs. McClean', 'President Roosevolt', 'Lady Mary Baring', 'Thimma', 'Zakariana'
Aneuploid: 'Begum Sikander', 'Wajid Ali Shah', 'Chitra'

***Day lily* (*Hemerocallis* sp.)**
Diploid: 'Barbara Mitchell Ruffled', 'Master Piece', 'Ruffled Perfection'
Tetraploids: 'Tetra Apricot', 'Tetra Peach', 'Crestwood Series', 'Wedding Band', 'Winter in Eden', 'Bill Norris'

Petunia
Doubled Haploid: 'Mitchel'
Autotetraploid: 'State Fair', 'Old Mexico'

Gladiolus
Triploids: 'Manmohan', 'Monohar', 'Manhar', 'Mukta', 'Manisha', 'Mohini', 'Triloki', 'Sanyukta'
Aneuploids: 'Archana', Arun'
Tetraploids: Major cultivars

Amaryllis
Triploid: 'Kiran'
Tetraploid: 'Samrat', 'Tetra Apricot', 'Tetra Starzynski'

Amaranthus
Tetraploid: 'Amar Tetra'

Rose
Tetraploid: Major garden cultivars
Triploid: 'Prema, 'Surekha', 'Surya'
Trisomic: 'Mohini'

Orchids
Amphidiploids (*Dendrobium*): 'Jacquelin Thomas Y 166'
Tetraploid (*Phalaenopsis*): 'Riverbend'
Tetraploid (*Oncidium*): 'Popcorn'
Tetraploid (*Spathoglottis*): 'Lion'
Tetraploid (Vanda): 'Atherton', 'Juliet', 'Hula Girl', 'Wood Lawn' and 'Douglas'

Stock
Aneuploid: 'Snow Flake'

Marigold
Triploids: 'Seven Star', 'Showboat', 'Nugget'

7 Production of Hybrids
Hybrids are the progenies of the cross between two or more genetically unlike parents.

Hybrids are manifested in various ways:

- Increase in flower size and doubleness
- Increase in number of flowers
- Uniformity in size and maturity
- Dwarf and compact
- Free flowering and basal branching
- Better resistance to drought, insect-pests and diseases
- Better and wider adaptability to environmental conditions

7.1 Speciality of F_1 hybrids

- Dwarf and compact growth with basal branching: *Petunia, Dianthus, Impatiens, Begonia, Geranium*
- Faster growth with longer growing season: *Petunia, Geranium*
- Doubleness : Petunia, Stocks, marigold, geranium
- Tolerant to heat and humidity: *Begonia, Gerbera*
- Sterility: Marigold, Zinnia
- Pot culture: Bougainvillea, Petunia, Pelargonium, Begonia
- Free Flowering: Verbena, Marigold
- Giant Flowers: Antirrhinum
- Bedding plants with long blooming period: *Begonia semperflorens, Ageratum houstonianum*
- Cut flowers : Gerbera, Antirrhinum
- Early appearance of first flower: *Pelargonium zonale, Anthurium scherzerianum*
- More number of flowers per season: *Bellis perennis*

Hybrid varieties exploit both General Combining Ability (GCA) and Specific Combining Ability (SCA) through utilization of heterosis. Single cross hybrids are more uniform than that of open pollinated, synthetic or composite varieties. Production of hybrids is possible both in cross and self-pollinated crop species. Hybrid varieties are maintained in the form of their parental inbreds.

There are various techniques used in production of hybrids.

- *Hand emasculation and hand pollination*: This technique is useful in hermaphrodite flowers and practiced by skilled workers. e.g. *Pelargonium, Antirrhinum majus, Cyclamen persicum, Impatiens walleriana, Dianthus caryophyllus, Salvia splendens*
- *Hand emasculation and natural pollination:*
- *Removal of male plants and pollination:* In dioecious species, male and female flowers are grown on separate plants and the male plants are removed and only females are left. Desired male plants of the desired variety are grown side by side to effect natural pollination. Seeds produced on female plants are harvested as hybrid seeds.
- *Exploitation of male sterility*: It includes the use of cytoplasmic-genetic male sterility, genetic male sterility, gametocidal sprays, and through the chemical suppression of male flower. It is used in zinnia, verbena, marigold, rose etc. for F_1 hybrid seed production.
- *Use of self-incompatibility*: Self-incompatibility is applied for production of F_1 seeds in *Primula chinensis, Petunia hybrida, Bellis perennis, Ageratum maxicum, Heliotrope ampervianum*, pansy etc.
- *Use of gametocide for chemical emasculation.* e.g. Sunflower
- *Use of marker genes to identify selfs to eliminate at seedling stage.*

The first hybrid of double petunia was developed in Japan and later F1-hybrids were developed in ornamental flowers in the Netherlands, Denmark, Germany, the USA and the UK. The few important hybrids were first released in Petunia (in 1940-50); geranium single (1960); antirrhinum, pansy, marigold and zinnia (1965); ageratum (1966); geranium double (1970); dianthus, impatiens and portulaca (1976-77); gerbera (1980) and carnation (1981). There is continuous research for developing new F1-hybrid flowers. Therefore, every year new and more attractive hybrids are being released by different seed companies in the world. Now, F1-hybrids are available in many flowers from A (antirrhinum) to Z (zinnia).

There are constant efforts by flower breeders to produce new and more attractive hybrids. Hybrid technology has been set up to meet the requirements of new bedding plant technology using automated system, smaller containers, shorter crop time, energy stress, singulated seeding, etc. It is evident that India is far behind the latest technology of F1-hybrids in flowers. Obviously, there has been no appreciation in India of the potentialities of hybrids in flowers. Further, hybrid seed production in ornamental plants is labour intensive and has a good potential for the employment of youth in rural and suburban areas. It may also generate gainful income by setting up ancillary industries dealing with equipment and other facilities also.

With the favourable climatic conditions of Jammu and Kashmir, Himachal Pradesh and Punjab, commercial production of F1-hybrid seeds for export can be attempted by seed companies and government agencies so that the country earns a good amount of foreign exchange. Already in Punjab, some private growers have initiated the seed production programme of open pollinated varieties of ornamental flowers for export and are thinking of expanding this venture to hybrid seeds as well. Such export-oriented programmes are required to be promoted and encouraged in view of the “focus thrust area” assigned to floriculture by the Agricultural and Processed Food Products Export Development Authority (APEDA) and the Government of India. One of the pioneer companies which has undertaken this venture is Plantsman’s Seeds, Patiala, having 250 acres under production of flower seeds for export.

Among ornamentals F_1 hybrids are available in Antirrhinum, Ageratum, Begonia, Calceolaria, Cyclamen, carnation, Dianthus, Geranium, Gerbera, Hollyhock, Impatiens, marigold, Nicotiana, Petunia, Portulaca, Stocks, Verbena etc. (Table 1).

7.2 Distant hybridization

Distant hybridization is defined as the crosses between individuals from different species belonging to same genera or to different genera. The former is called as interspecific and the latter one is called as intergeneric hybridization. The first distant hybridization was reported in the production of hybrid between carnation (*Dianthus caryophyllus*) and sweet William (*Dianthus barbatus*) by Thomas Fairchild in 1717. Distant hybrids are difficult to produce due to the failure of fertilization where zygote is not formed. In many cases, zygote is produced after fertilization but development of zygote is hindered at various stages because of the presence of lethal genes, genotypic disharmony between the genomes of the two parental species, chromosome elimination, cytoplasmic incompatibility and endosperm abortion. Some distant hybrids show mortality during seedling development or even after initiation of flowering and this is attributed to the presence of lethal genes, genetic imbalance and cytoplasmic incompatibility.

8 Achievements of Distant Hybridization in Ornamental Plants

Generally polyploids respond better to transfer genes from wild species than diploids due to the presence of additional homologous or homeologous genomes. Due to high heterozygosity, cross pollinated species get benefited from interspecific gene transfer from wild species. Closely related species accept gene transfer more easily because of high homology between their chromosomes.

8.1 Rose

Popular Tea roses: *Rosa odorata* and *Rosa gigantea*
Bourbon rose: *Rosa chinensis* (China rose) × *R. damascena* (Autumn Damask rose)
Polyantha roses: Crosses of *R. multiflora*, *R. wichuriana*, *R. indica major*
Damask roses: *R. phoenicia* × *R. gallica*
Noisette rose: *R. chinensis*×*R. moschata*

Park rose: *R. pendulina* × *R. rugosa*
White rose: *R. corymbifera* x *R. gallica*

Table 1 Some F_1 hybrids of ornamentals

Name	F_1 hybrids
Marigold	Pusa Sankar-1, Inca, Solar Red, Discovery Yellow, Durango Bolero, Durango Red, Gold Coin, Climax, Nugget, Red & Gold, Space Age, Showboat, Red Heaven
Hollyhock	Pusa Pink Beauty, Pusa Yellow Beauty, Pusa Pastel Pink Supreme, Pusa Apricot Supreme
Begonia	Primma Donna, Gin Cocktail, Lotto Mixed, Illumination Orange, Illumination Apricot, Illumination Rose, Non-stop Mixed, Non-stop Ornament Mixed, Pin Up, Pin Up Flame.
Portulaca	Sundial Peach, Calypso Mix, Tutti Frutti Mix, Margaritta
Cineraria	Venezia, Jester Mix Blue, Jester Crimson, Jester Pink, Jester Pink Bicolour
Delphinium	Guardian, Steinchen Strain, Magic Fountains
Impatiens	Super Elfin, Tutu Red Bicolour, Belizzy Colour Balls Double Mixed, Envoy Peach Butterfly, Extreme Mixed, Java Series, Borneo, Tango, Show Topper
Ageratum	Blue Blazer, Blue Horizon, Blue Hawaii, Blue Pearl, Blue Puffs, North Sea, Summer Snow, Blue Heaven
Petunia	Flambe Salmon, Cascade Pink Orchid Mist, Double Cascade Blue, Colour Parade Mixed, Daddy Mixed, Super Cascade Improved Mixed, Balleriana, Pink Morn, Silver Medal, Orange Bells, Coral Bells, Summer Sun, Polo, Apricot Tart
Verbena	Adonis Mango, Blue Spires, Pink Spires
Aster	Serene, Duchness Mixed, Colour Carpet
Cockscomb	Century, Sparkler, Toreador
Iris	Blue Diamond, Ideal, Telstar, White Wedgewood
Larkspur	Blue Cloud, Giant Imperial, QIS
Lavendula	Silver Streak
Phlox	Patriot, Chanal
California Poppy	Mission, Bells
Antirrhinum	Rocket, Sonnet Mix, Butterfly Series, Kim Mixed, Magic Carpet, Carioca, Coronette, Floral Carpet
Pincushion Flower	Blue Moon
Statice	Misty, Excellent, Fortress Mix, Pastel Shades, Arrow, New Era, New Wonder
Zinnia	Sunrise , Gold Sun, Red Sun, Peter Pan, Golden Dawn, Dasher Orange, Dasher Scarlet, Exquisite, Bonanza
Pansy	Flamenco, Black Moon, Cats White
Sunflower	Double Shine, Sunrich Orange, Jerusalem Gold, Little Dorrit, Harlequin, Elite Sun, Solar Eclipse, Orit
Geranium	Ringo 2000, Black Velvet Series, Maverick Coral, Pinto, Printer Series, Show Girl, Jackpot
Amaranthus	Amar Shola, Sparkler Series
Viola	Valentine, Pandoras Box, Sorbet, Sweeties, Penny Sunrise, Ultima Morpho
Primula	Peso Series, Lira Series, Corona Series, Twilight, Sterling Series, Earnst, Benary, Joker, Finesse, Lucento, Finale, Twilly Series, Juno
Alstroemeria	Jazz
Calendula	Coronets, Gypsy Festival Mix, Pacific Beauty Mix, Mandarin

8.2 Bougainvillea

Bougainvillea buttiana (cv. Mrs Butt) = *B. peruviana* × *B. glabra*
B. spectoglabra = *B. Spectabilis* × *B. glabra*
B. specto-peruviana = *B. spectabilis* ×*B. peruviana*

Inter –specific hybrids: Begum Sikander, Wajid Ali Shah, Chitra, Dr. R.R. Pal, Summer Time, Spring Festival, Pink Beauty Pixie, Rose Queen.

Intra-specific hybrids: Dr. H.B.Singh, Purple Wonder, Chitravati, Mary Palmer Special

8.3 Gladiolus

(1) To produce scented hybrids:
Gladiolus victorialis = *G. byzantinus* × *G. cardinalis*
G. gandavensis = *G. cardinalis* × *G. psittacinus*
Fragrant Glad = *G. Tritis* × *G. recurvus*

(2) To produce crimson flower with markings: *G. oppositiflorus* × *G. psittacinus*
Red light flowers: *G. brenchleyensis* = *G. cardinalis* × *G. psittacinus*
Crimson flowers with white markings: *G. turicensis* =*G. gandavensis* × *G. saundersii*
Homoglad hybrids: *Homoglossum watsonianum* × *G. tristis*

(3) To evolve triploid varieties: Gladiolus cv. Friendship (2n=60) × *G. tristis* (2n=30)

(4) To evolve aneuploid varieties:
Archana = G. *psittacinus* 'Sylvia' (2n=75) × Gladiolus cv.Friendship (2n= 60)
Arun = G. *psittacinus* 'Sylvia' (2n=75) × Gladiolus cv.Fancy (2n= 60)

(5) To evolve Gladanthera hybrids: Gladiolus cv. Filigree × *Acidanthera bicolor*

8.4 Carnation

(i) Perpetual carnation: *Dianthus caryophyllus* × *D. chinensis*
(ii) Annual Marguerite Carnation: *D. chinensis* × *Dianthus caryophyllus*
(iii) Allwoodii Carnation = (*D. plumarius x D. gratianopolitanus)* × (*D. caryophyllus* × *D. chinensis*

8.5 Jasmine

Success in fruitset:
(i) *Jasminum auriculatum* × *J. flexile*
Jasminum auriculatum × *J. grandiflorum*

(ii) *Jasminum grandiflorum* × *J. auriculatum*
Jasminum grandiflorum ×*J. callophyllum*
Jasminum grandiflorum × *J. flexile*

(iii) *Jasminum sambac* × *J. grandiflorum*

(iv) Induced tetraploid × Diploid of J*asminum auriculatum*

8.6 Tuberose

(i) Hybrid Production:
Polianthes geminiflora × *P. bulliana*
Polianthes blissii= *P. geminiflora* × *P.tuberosa*
P. bundrantii = *P. tuberosa* × *P. howardii*

(ii) Rainbow tuberose = *P. blissii* × *P. bundrantii*

8.7 Dahlia

(i) Hybrid Production: *Dahlia imperialis* × *D. coccinea, D. coccinea* × *D. pinnata*
(ii) Octaploid Dahlia : *D. imperialis* × *D. coccinea*

8.8 Amaryllis

(i) Reginac hybrids: *Amaryllis pardina* × *A. leopoldii*
(ii) Long Trumpet hybrids: *A. elegans* × *A. stylosa*
Long Trumpet hybrids: *A. elegans* × *A. striata*

Long Trumpet hybrids: *A. elegans* × *A. vittata*
(iii) Cv. 'Surya Kiran' = *A. styllosum* (Red) × *A. styllosum* (white)

8.9 Gerbera
Gerbera cantabrigensis = G. jamesonii × *G. viridifolia*

8.10 Anthurium
Hybrid with grey orange spathe: *A. scherzerianum* × *A. wendlingerii*

8.11 Antirrhinum
Production of hybrids:
Antirrhinum majus × *A. molle* (Magic Carpet)
A. majus × *A. linkianum*

8.12 Marigold
(i) Production of hybrids: *Tagetes erecta* × *T. patula*: Red & Gold, Nugget, Show Boat, Red Seven Star
(ii) Polyploidy Production: *Tagetes patula* (Allotetraploid): *T. erecta* × *T. tenuifolia*

8.13 Verbena
Hybrid : *Verbena tenuisecta* × *V. hybrida*

8.14 Amaranthus
Amaranthus caudatus
↓
Segregating generation
↓
Amar Shola

8.15 Hibiscus
Intergeneric hybrid: Thilagum = *Hibiscus rosa sinensis* × *Malvaviscus arboreus*

8.16 Orchid
Inter-specific orchid: IIHR-38 (*Dendrobium* Pompadour × *D. superbiens*)

Inter –generic hybrids:
(i) Bigeneric:
Aranda = Arachnis × Vanda
Ascocendra = Ascocentrum × Vanda
Brassocattleya = Brassovola × Cattleya
Laeliocattleya = Cattleya × Laelia

(ii) Trigeneric:
Tanakara = Aerides x Phalaenopsis × Vanda
Limara = Arachnis × Renanthera × Vandopsis
Ridleyara = Arachnis × Trichoglottis × Vanda

(iii) Tetrageneric:
Potinara = Cattleya x Brassovola x Laelia × Sophronitis
Yamadara = Cattleya × Brassovola × Epidendrum × Laelia

(iv) Pentageneric: Hasegawaara = Cattleya × Brassovola × Broughtonia × Laelia × Sophronitis

9 Breeding Approaches for Disease Resistance

(1) Hybridization combined with pure line breeding
(2) Mutational approach
(3) Back cross breeding

9.1 Development of disease resistance in ornamental crops

Rose: Black spot is a serious disease of roses that causes severe losses to commercial and home gardens. The breeding lines 'Spotless Gold' (Floribunda, F_3 selection: Goldlocks × *Rosa rugosa*), 'Spotless Yellow' (Floribunda, F_3 selection: Goldlocks × *Rosa rugosa*) have been used as resistant parents in breeding programmes. Some resistant varieties have been developed through complex hybridization like 'A Makenzie', 'Charles Albert', 'Champlan', 'William Buffin' etc. resistant to black spot and mildew. Researchers at North Carolina State University in USA observed that roses combat Botrytis or petal blight if injected with a celery gene, called Mannitol dehydrogenase. Varieties developed at IARI, New Delhi which were found to be moderately tolerant to powdery mildew and black spot is 'Pusa Ajay' (Pink Parfait x Queen Elizabeth), 'Pusa Mohit' (Suchitra × Christian Dior) is found tolerant to black spot and 'Pusa Gaurav' (Pink Parfait x Arjun) is tolerant to dieback and black spot.

Gladiolus: The major problem in commercial cultivation of gladiolus is a wilt disease by *Fusarium oxysporium f. Sp. Gladioli*. The varieties Debonair, Golden Goddess, Jo Wagenaar, Katrian Local and Ratna's Butterfly are resistant to *Fusarium* wilt disease. Certain hybrids like SGH-13C (Pfitzer's Sensation x Golden Goddess), SGH-6 (Jo Wagenaar x Pfitzer's Sensation) and SGH-20 (Dedonair x Pfitzer's Sensation) are tolerant to wilt disease. The resistant hybrid 82-11-90 (Beauty Spot x Psittacinus hybrid) and two tolerant hybrids 82-7-59 (Watermelon Pink x Lady John) and 82-18-16 (Watermelon x Mansock) have good vegetative characterstics. Variety 'Dhiraj' developed at IIHR, Bangalore is resistant to *Fusarium* wilt.

Carnation: *Fusarium* wilt, bacterial wilt, stems rot and *Alternaria* leaf spot are major setbacks of carnation. A line 91BO4-2 (cross between spray type cultivar Super Gold x *Dianthus capitatus*) is highly resistant to bacterial wilt. Cultivars Arbel and Scarlette had novel resistance against *Fusarium* wilt. Guba evolved four cultivars Watham Pink, Regal Pink, Spicy rose and Mrs EF Guba which were resistant to *Fusarium* wilt, rust and blight.

Chrysanthemum: Chrysanthemum is damaged by *Phoma chrysanthemella* and *Septoria chrysanthemella*. Varieties developed at PAU, Ludhiana which possess multiple resistance against these microorganisms are Baggi and Ratlam Selection.

10 Biotechnological Advances for Improvement of Ornamental Plants

Apart from the various methods used in the improvement of ornamental plants discussed earlier, there is an enormous large scope for improvement of floricultural crops using biotechnological tools like micropropagation, *in vitro* mutagenesis, somaclonal variation, embryo recovery, haploid culture, protoplast fusion, genetic transformation and DNA finger printing.

Micropropagation: It is the major aspect of biotechnology for large scale propagation of floriculture crops via *in vitro* cloning. *In vitro* generated plants are uniform, true to type with increased vigour. An *in vitro* system is generally started from a bud, an apex or meristem and is multiplied by stimulation of axillary branching or by nodal culture. Axillary shoot proliferation is widely used in ornamentals. Besides, explants such as bulbs scales, base plate of corms, bulbs and inflorescence are generally used in Liliaceae, Iridiaceae and Amaryllidaceae families. Leaf and root segments, flower buds, flower stalks, petioles are also used as explants.

Some of the important flower crops propagated through ***in vitro*** techniques are given below along with explant source:

Anthurium: Leaf segments, petiole, flower stalk segments, spathe, spadix.
Chrysanthemum: Leaf segments, internodes, petals, petioles.
Carnation: Leaf segments, internodes, petals.
Gerbera: Leaf, petiole, flower stalk segment.
Gladiolus: Inflorescence stalk, leaf sections.
Orchids: Epidermal peelings, leaf segments, root tips, shoot apices.
Rose: Internodal segments, petals, leaf segments, immature embryos, root segments.
Tuberose: Leaf segments, inflorescence, stalk segments, shoot apices.
Lily and Amaryllis: Segments of bulb scales.

***In vitro* mutagenesis:** Mutation induction with cell and tissue culture techniques have become popular since a large population of haploid and diploid cells can be handled in a small space, developing new individuals in a short period of time. *In vitro* treatments with chemical mutagens occur more uniformly than *in vivo* treatments in which a controlled environment and culture medium are used.The main attributes of mutant ornamental plant cultivars obtained through direct propagation of induced mutants are listed below:

Annual ornamental plants: flower color, more flowers, flower shape, leaf shape, number of flower petals, large leaf, large plant, small plant, large flower, plant type, growth rate, number of branches, ornamental novelty, regeneration skill and flower longevity.

Ornamental plants with roots and tubers: flower color, flower shape, plant type, long stem, leaf color, neutrality to photoperiod, early blooming, large flower and stem color.

Perennial ornamental plants: flower color, short stem, small flower petals, striped leaf, vigorous growth, early blooming, more branches, greater branch density and more flowers.

Somaclonal variation: Somaclonal variation is to designate all types of variation which occur in plants regenerated from plant tissue culture. Mechanisms involved in the somaclonal variation induction include gross karyotypic changes that accompany *in vitro* culture via callus formation, cryptic chromosome rearrangements, somatic permutation with changes of parts among sister chromatides, transposition of elements, genetic amplification or decrease, and several combinations of these processes. Somaclonal variations is reported in Begonia, Chrysanthemum, Kalanchoe etc.

Embryo recovery: Embryo recovery is effective in interspecific or intergeneric crosses resulting seeds with abortive embryos. The objective of such crosses is to transfer alleles for disease resistance, environmental stress tolerance, high yield potential or other desirable characteristics of species or genus to accepted cultivars. One of the objectives of this technique is to recover rare hybrids derived from incompatible crosses as well as to overcome seed dormancy by studying the nutritional and physiological aspects of embryo development and by testing seed viability. These rare hybrids can serve a source of explants with high totipotency tissues.

Haploid culture: The haploid parts of the plants consist of pollen and embryo sac. There are two major methods used for haploid production. When pollens are used, called androgenetic methods and if ovules are used called parthenogenetic method. In haploids, it is easy to detect mutations and to raise isogenies pure lines.

Protoplast fusion: Protoplasts have been widely applied to biotechnology including plant development, gene expression and regulation, biochemical studies, studies on cell wall synthesis and the pathogen host interaction mechanisms in the cells. Protoplasts are isolated in a range of plant tissues and organs, including leaves, fruits, petioles, cotyledons, stems, floral pedicels, somatic embryos and cell suspensions. Cell suspensions are the most used to manipulate and have high isolation efficiency.

Protoplasts of *Iris germanica* and *Iris ensata* could be fused by electrofusion.

Synthetic seed: It is the encapsulated somatic embryos which functions as mimic seeds and develops into seedlings under suitable environmental conditions. It may be encapsulated bulb, bud or any form of meristems. In addition to somatic embryos, axillary buds, adventitious buds, shoot tips and protocorms are also used to produce synthetic seeds. Synthetic seeds are reported in orchid, *Dianthus, Lilium, Pelargonium*.

Genetic transformation in ornamental plants: Genetic transformation is the transfer or introduction of a DNA sequence or, more specifically, of a gene to an organism without fertilization or crossing. The genetically transformed plants are called transgenic plants. Genetic introduction is the controlled introduction of nucleic acids in a receiver genome without fertilization.

Different genetic transformation techniques have been established with the development of tissue culture techniques and genetic engineering which include the use of *Agrobacterium tumefaciens*, particle acceleration (biolistics), polyethylenoglicol, electroporation, sinication, silica carbonate microparticles, microlaser, micro and macro-injection and direct DNA application.

During 90's, first transgenic petunia was developed. Among major cut flower crops, rose, chrysanthemum and carnation all have been genetically transformed. *Rosa hybrida* cv. 'Royalty' has been transformed by co-cultivation of *Agrobacterium* and friable embryogenic callus followed by embryogenesis to recover transformed plants.

Chrysanthemum indicum and *Chrysanthemum grandiflora* both have been transformed by *Agrobacterium* infection of either leaves which regenerated transformed plants by organogenesis or peduncle which formed transformed callus capable of regenerating transformed plants.Transformed *Dianthus caryophyllus* (carnation) cultivars have been produced by co-cultivation of leaves, petals, or stems with *Agrobacterium* followed by direct or indirect organogenesis. Besides, *Agrobacterium* mediated transformation has also been reported in *Narcissus, Gladiolus, Lilium longiflorum, L. leichlnii var. maximowiczii* and *Tulipa*. In addition to these floral crops, the following flower crops have been tried for transformation. These are *Gerbera, Dendrobium, Antirrhinum, Anthurium, Eustoma and Pelargonium.*

Molecular breeding of ornamental crops for various approaches: The first successful application of genetic engineering for flower colour modification was petunia to produce crimson coloured pelargonidin pigments by transferring Al gene from *Zea mays* which codes for a specific protein dihydroquercetin-4-reductase (DQR). The first antisense technology has been used genetically engineered petunia to incorporate antisense Chs gene (Chalcone Synthase gene) to alter flower colour. Blue carnation is developed through characterization of anthocyanin and use of anti-sense suppression to block the expression of a gene encoding Flavonone -3-hydrogenase. In antirrhinum, novel yellow colour has been tried with genetic modification of chalcone and aurone flavanoid biosynthesis. Florigene was one of the first companies to obtain an alteration of colour by genetic engineering. Working together with chrysanthemum breeder *Fides*, *Florigene* has transformed the pink chrysanthemum variety 'Moneymaker' into a white flower, by blocking the *chalcone synthase* gene responsible for pigment synthesis.

Genetic engineering is also applied to increase the vase life of flowers, by blocking the ethylene production of flowers. Ethylene triggers flower deterioration.

DNA---Finger Printing: DNA---Finger Printing is a technique used to distinguish between individuals of the same species using only samples of their DNA. DNA profiling exploits highly variable repeat sequences called Variable Number Tandem Repeats. These loci are variable enough that two unrelated humans are unlikely to have the same alleles.

RFLP (Restriction Fragment Length Polymorphism) analysis is found to be useful for estimating genetic diversity, to assist in the conservation of endangered species and plant genetic resources. It is also used for plant genome mapping. Polymerase Chain Reaction (PCR) based Finger Printing amplifies the amounts of a specific region of DNA using oligo nucleotide primers and a thermostable DNA polymerase. This method is useful for estimating genetic diversity, identification of species or cultivars, genome mapping, population genetics etc. RAPD (*Randomly Amplifies Polymorhic DNA*) is the efficient method for genome mapping and characterization of genetic resources.

References

Basilevskaya N.A., 1960, Tsentry proiskhozhdenia dekorativnikh rasteniy, V: Evolutsia, Biogeografia, Genetika i Selektsia, Nauka, Moskva, [Basilevskaya, N. A., The centers of origin for ornamental plants]

Coats A.M., 1968, Flowers and their histories, Adam & Charles Black, London

De L.C., Bhattacharjee S.K., 2011, 'Ornamental Crop Breeding', Pp. 438, Published by Aavishkar Publishers & Distributors, Jaipur , Rajasthan (ISBN: 978-81-7910-348-7)

De L.C., Rao A.N., Rajeevan P.K., Pathak Promila, 2014, Orchid improvement-an overview, J. Orchid Soc. India, 28: 35-45

Hui-Lin Li, 1974, The origin and cultivation shade and ornamental trees, University of Pennsylvania Publ., Philadelphia

Raghava S.P.S., 1999, Genetic improvement of ornamental plants in India, Journal of Ornamental Horticulture, 2: 1-6

Singh B.P., Gupta P.N., Rana R.S., 1993, New introductions in ornamentals, Journal of Ornamental Horticulture, 1: 68-72