B. Sc. (Hons.) Horticulture
Semester : VI
Course No : H-FL-364
Credits : 2+1 = 3
Course title- Breeding and seed production of ornamental crops.
Course Teacher: Dr. Arun B. Bhosale

Course No.- H/FL-364 Title:- Breeding and seed production of ornamental crops

Credit hours: 3(2+1) Semester- VI

Theory-History of improvements of ornamental plants, scope and importance of breeding of ornamental crops.Centre of origin of flower crops and ornamental crops, objectives and techniques in ornamental plant breeding. Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental and flower crops *viz*., rose, jasmine, chrysanthemum, tuberose, gerbera, gladiolus, dahlia heliconia, lilium, gaillardia, petunia, hibiscus, bouganvillea, zinnia, cosmos, dianthus, snapdragon, pansy, crossandra, marigold, geranium, antirrhinium, china aster, orchids, anthurium, carnation, etc. Breeding for disease resistance.Development of promising cultivars of important ornamentals and flower crops.Role of heterosis and its exploitation, production of F1 hybrids and utilization of male sterility, production of open pollinated seed.Harvesting, processing and storage of seeds, seed certification.

Practical: Study of floral biology and pollination in important species and cultivars. Techniques of inducing polyploidy and mutation. Production of pure and hybrid seeds. Harvesting, conditioning and testing of seeds. Practice in seed production methods.

Lesson/Course Plan- Theory

Lecture No.	Topics	Weightage (%)
1-2	History of improvements of ornamental plants Scope and importance of breeding of ornamental crops.	8
3-4	Objectives and techniques in ornamental plant breeding	8
	Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental and flower crops *viz*.	
5-7	Rose	8
8-10	Jasmine, Hibiscus, Bouganvillea	8
11-16	Chrysanthemum, Gerbera, China Aster, Gaillardia, Dehlia, Zinnia, Carnation, Marigold, Cosmos	10
17-19	Tuberose, Gladiolus, Lilium,	8
20-21	Orchid, Anthurium, Heliconia, Antirrhinium,	8
22-23	Petunia, Dianthus, Snapdragon, Pansy, Crossandra, Geranium	4
24	Breeding for disease resistance.	4
25-26	Development of promising cultivars of important ornamentals and flower crops.	4
27	Role of heterosis and its exploitation	8
28	Production of F1 hybrids and utilization of male sterility	8
29	Production of open pollinated seed.	8

30	Harvesting processing and storage of seeds	
31	Seed certification.	3
32	Recommendations of Joint Agresco	3
	Total	**100**

Practical programme

Practical No.	Topics
1	Acquaintance with breeding tools for floricultural crops
2	Methods of emasculation and pollination, selfing
3	Study of floral biology and pollination of rose, jasmine, chrysanthemum, tuberose
4	Study of floral biology and pollination of gerbera, gladiolus, dahlia heliconia, lilium, gaillardia
5	Study of floral biology and pollination of petunia, hibiscus, bouganvillea, zinnia, cosmos
6	Study of floral biology and pollination of dianthus, snapdragon, pansy, crossandra, marigold, geranium
7	Study of floral biology and pollination of china aster, orchids, anthurium, carnation
8	Techniques of inducing polyploidy and mutation.
9	Production of pure and hybrid seeds rose, jasmine, chrysanthemum, tuberose
10	Production of pure and hybrid seeds gerbera, gladiolus, dahlia heliconia, lilium, gaillardia
11	Production of pure and hybrid seeds petunia, hibiscus, bouganvillea, zinnia, cosmos
12	Production of pure and hybrid seeds china aster, orchids, anthurium, carnation
13	Harvesting, conditioning and testing of seeds
14	Harvesting, conditioning and testing of seeds
15	Practice in seed production methods.
16	Practice in seed production methods.

Suggested Reading:

Reference Books:

- Agarwal, P. K 1994. Principles of Seed Technology. ICAR Publication, NewDelhi.
- Agarwal, R. L. 1996. Seed Technology. Oxford&IBHPublishers, New Delhi.

- Bhattacharjee, S.K. and L.C. De. 2003. *Advanced Commercial Floriculture*. Aavishkar Publishers, Distributors, Jaipur (Rajasthan) India.
- Bose, T. K., L.P. Yadav, P. Patil, P. Das and V.A. Partha Sarthy. 2003. *Commercial flowers.* Partha Sankar Basu, Nayaudyog, 206, Bidhan Sarani, Kolkata-700006.
- Callaway D.J. and M.B. Callaway. 2000. Breeding Ornamental Plants. Timber Press.

- Harding, J., F.Singh and J.N. Mol. 1991. Genetics and Breeding of Ornamental Species. Springer Publishers.
- Pal, B. P. 1966.*The Rose in India*.Directorate of Knowledge management in Agriculture, Indian council of Agriculture Research-New Delhi.
- Singh, B. D. 1983. Breeding Principles and Methods. KalyaniPublishers,New Delhi.
- Vainstein, A. 2002. Breeding for Ornamental: Classical and Molecular Approaches. Springer Publishers.

e-reading: http://ecourses.iasri.res.in/

Lecture 1 & 2

History of Improvements of Ornamental Plants,

Scope and Importance of Breeding of Ornamental Crops.

History of Breeding

Objective:

To acquaint the students about the historical landmarks that contributed to the development of modern day cultivars of commercial ornamental crops like rose, gladiolus, carnation and chrysanthemum etc. It will also give information about different techniques and procedures adopted by various workers over a period of time for the improvement of ornamentals.

History:

- The history of breeding dates back to as early as 700 B.C., when Babylonians and Assyrians hand – pollinated date palms. Sex in plants was discovered by Camararious in the year In 1694.
- The first artificial hybrid was, however, produced in an annual flower crop. The hybrid 'Fairchild Mule' was prepared by crossing sweet william with carnation (*Dianthus barbatus* x *Dianthus caryophyllus*) by Thomos Fairchild in 1717.
- Thereafter, several workers carried out the work on crop improvement. Sir John Gregor Mendel proposed for the first time the laws of inheritance. With the advent of time many new hybrids were developed in different floricultural crops including petunia, pansy, aster, gerbera, statice, cyclamen, marigold etc in different parts of the world.
- Sir Joseph Bank introduced 7000 new ornamental plants species were introduced to England from China and India in the year 1789 which included Rose (Chinese) and Chrysanthemum.
- Initially private nurserymen or amateur breeders took the work of crop improvement and developed several varieties in ornamentals. Later on crop specific research was taken over by several ICAR institutes and SAU's throughout the country.
- In India, seed production was started on limited scale in Srinagar and plains of North India. Initial work on hybrid seed production in ornamentals was started by M/S Indo American Hybrid Seeds (India) Pvt. Ltd., Bangalore. The company started producing F_1 hybrid seeds of Petunia for 100% export during mid sixties.

- Production of seeds of open pollinated flower crops was started by M/S Beauscape Farms, Sangrur, Punjab who started flower seed production involving farmers on large scale. Now many companies have started producing seed on large scale for export to Holland, UK, USA, France, Germany, and Japan etc.
- The main areas of flower seed production in India are Punjab (Sangrur, Patiala, and Ludhiana), Haryana (Panipat, Sirsa), Karnataka (Bangalore, Rani Banur), West Bengal (Kalimpong), Himachal Pradesh (Kullu valley) and J&K. (Srinagar valley).

Rose:

- Rose breeding has been receiving a lot of importance on the hands of professional nurserymen, amateurs and government research institutes. The main objectives of rose improvement have been to evolve varieties with attractive flower colour, form and fragrance, floriferousness, disease and pest resistance and their suitability for growing under sub-tropical conditions.
- B.K. Roychaudhary, a nurseryman in Santh Pargana was possibly the first Indian rose breeder who raised the variety 'Dr. S.D. Mukherji' in 1935.
- During 1956-67, B.S. Bhattacharjee and his sons developed several hundred rose varieties of which 125 are listed in Dr. B.P. Pal's book ‘The Rose in India’. He also recognized that a separate line is required for breeding in the warm tropical climate.
- Some important roses raised by Bhattacharjee are 'Heart Throb'. 'Raja Ram Mohan Roy', 'Sugandha', 'Kalima' among Hybrid Teas and 'Pandit Nehru' among Floribundas.
- Shri G. Kasturi Rangan has contributed to all the rose types by a prolific output of varieties numbering almost a hundred.
- Dr. B.P. Pal (IARI) has taken up rose breeding at institute level and developed some hybrid seedlings and released his first rose variety 'Rose Sherbet' in 1962.
- Other hybrids released by him are; 'Delhi Princess' (Floribunda) 'Dr. Homi Bhaba' (Hybrid Teas) 'Kanakangi', 'Poornima', 'Hasina', 'Lalima', 'Nayika', 'Rat Ki Rani', 'Raja of Nalagarh', 'Ranjana', and 'Surkhab'.
- Among the Floribundas, apart from 'Delhi Princess', several varieties like 'Banjaran', 'Chitchor', 'Madhura', and 'Suryakiran' are well known. Other important varieties are 'Divaswapna', 'Apsara', 'Arawalli Princess', 'Indian Princess', 'Akash Sundari', 'Golden

Afternoon', 'Eastern Princess', 'Nishada', 'Sandeepini', 'Dr. R.R. Pal', 'Lal Makhmal', 'Dilruba', and 'Ashirvad'.

- Late Raja Surendra Singh of Nalagarh, M.N. Hardikar and M.S. Viraraghavan developed varieties like 'First Offering', 'Mahadevi', 'Vanamali', 'Amrapali', 'Kanchi', 'Picasso', 'Priyatama', and 'Bhagmati'.
- Some of the popular varieties raised at IARI include 'Mrinalini', 'Bhim', 'Dr. B.P. Pal', 'Jawahar', 'Raktagandha' and 'Priyadarshini' (H.T.) and 'Prema', 'Chandrama', Neelambari', 'Sadabahar' and 'Mohini' (floribundas).
- 'Mohini', is having unusual chocolate colour. During 1991, the Institute has released six more varieties 3 in H.T. Group, 2 floribundas and 1 climber.
- Several varieties have also been evolved through natural mutations or as bud sports of existing varieties. At IARI, 3 rose varieties were developed through induced mutations are 'Abhisarika', 'Pusa Christina' from 'Christian Dior', and 'Madhosh'.
- National Botanical Research Institute (NBRI), Lucknow has been the other centre where significant work has been done in this field. It has developed and released nine gamma ray mutants. These are 'Angara' (from 'Montezuma'): 'Sharada' (from 'Queen Elizabeth') 'Sukumari' (from 'Americas Junior Miss') 'Tangerine Contempo', 'Yellow Contempo', 'Pink Contempo' (all from 'Contempo'); 'Curio', 'Twinkle' (from 'Imperator') and 'Light Pink Prize' (from 'First Prize').
- At present rose improvement work is being carried out in different ICAR institutes and SAU's.

Gladiolus:

- Breeding work in gladiolus has been carried out at IARI, New Delhi; IIHR, Hessaraghatta; NBRI Lucknow and Horticulture Experiment & Training Centre, Chaubattia, Uttrakhand and IHBT Palampur.
- NBRI released 11 cultivars of Gladiolus. Notable among these are 'Jwala', 'Priya Darshini' and 'Gazal'. These are open pollinated seedling selections.
- Another variety 'Kohra' is a cross between G. psittacinus hybrid and 'King Lear'.
- Systematic hybridization involving gladiolus 'Frendship' (2n = 60) with G. tristis (2n = 30), eight new triploids (2n = 45) cvs. namely, 'Manmohan', 'Monohar,' 'Manhar', 'Mukta',

'Manisha', 'Mohini', 'Triloki' and 'Sanyukta' were evolved. Two aneuploid cvs. 'Archana' and 'Arun' were also evolved.

- Gladiolus breeding at IARI started in seventies and three improved varieties namely 'Agni Rekha', 'Mayur' and 'Suchitra'. were released in 1980. Another promising variety 'Pusa Suhagin' has also been released by the institute.
- At IIHR, 4 gladiolus cvs. were released in 1979 and 2 in 1980. These are 'Meera', 'Nazrana', 'Poonam', 'Sapna', 'Aarti' and 'Apsara'. Further irradiation of corms of 3 cvs. of gladiolus with gamma rays resulted in the isolation of a desirable and stable mutant from cv. 'Wild Rose'. This mutant was named and released as 'Shobha' in 1980.
- Four very promising hybrids Chaubattia 6/4, Chaubattia 14/23, Chaubattia 19/1 and Chaubattia 21/10 were selected by Horticultural Experiment & Training Centre, Chaubattia, Uttrakhand.

Chrysanthemum:

- Work on chrysanthemum improvement was taken up at NBRI, Lucknow; IIHR, Hessaraghatta; PAU Ludhiana and BCKV Kalyani.
- At NBRI, selection from seedlings raised from pollinated seeds resulted in evolution and release of several outstanding cvs. Some of the popular varieties released are, 'Birbal Sahni', 'Hemant Singar', 'Suhag Singar', 'Jyoti', 'Kundan', 'Rim Jhim', 'Sharada', 'Sharad Bahar', 'Sharad Mala', 'Sharad Shoba', 'Sharad Singar', 'Varsha' and 'Vasantika'.
- 'No pinch, no stake' type cvs. 'Sharad Singar', 'Hemant Singar', and 'Guldasta' were also released.
- IIHR, Hessaraghatta has also developed some varieties namely, 'Indira', 'Rakhee' and 'Red Gold'.
- At PAU, Ludhiana cvs. 'Santi', 'Vasanti', and 'Baggi' were released.

Carnation:

- IIHR, Bangalore has released the first variety in India as Arka Flame as a result of in vitro mutation breeding. Recently another variety Arka Tejas has been released.

- At I.A.R.I., New Delhi, experiments on mutation breeding were carried out. Seeds of different lines of carnation have been irradiated with 6 to 20 kr. dosage of gamma rays and some interesting mutants with variegated leaf were obtained (Kaicker, 1988).
- Development of new hybrids through in vitro mutation breeding is also in progress at Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan and the mutants are under evaluation.

Bougainvillea:

- Bougainvillea is grown widely throughout the country. In all, more than 150 cultivars have been developed in bougainvillea. Of these, a large number of cultivars have been developed at IARI New Delhi, IIHR Bangalore and NBRI, Lucknow.
- The Bougainvillea improvement work in India started with the introduction of a few varieties by the Agri Horticultural Societies at Calcutta and Madras. 'Scarlet Queen' named by Sir Percy Lancaster in 1920 is probably the first Bougainvillea raised in India.
- At IARI New Delhi, 5 highly floriferous cultivars were released in 1959 named 'Dr. R. R. Pal', 'Sonnet' 'Spring Festival', Summer Time' and 'Stanza'. Of these, 'Dr. R.R. Pal' is very vigorous and also makes a good rootstock for budding bougainvillea varieties otherwise difficult to propagate.
- At NBRI Lucknow, some important cvs. developed are viz. 'Wajid Ali Shah', 'Begum Sikander' and 'Mary Palmer Special'. Other varieties developed at Lucknow include 'Dr. B.P. Pal' and 'Tetra Mrs. Mc Clean', this work has also led to the development of varieties with blotched bracts as in 'Chitra'.
- Bougainvillea breeding work at IIHR Hessaraghatta has also resulted in release of six cultivars namely 'Chitravati' 'Dr. H.B. Singh', 'Jawahar Lal Nehru', 'Purple Wonder', 'Sholay' and 'Usha'.
- The Division of Floriculture & Landscaping IARI has been designated as the 'International Registration Authority for Bougainvillea Cultivars' and the first check list describing more than 300 cultivars of bougainvillea was published during 1981.

Crop improvement work has also been taken up in a number of annual flowers.

Significant achievements are listed below:

- Systematic hybridization and selection programme in Amaranthus has resulted in the development of eight cvs. namely 'Amar Kiran , 'Amar Poet , 'Amar Prithu , Amar Parvati', 'Amar Suikaran', 'Amar Tirang', Amar Raktab', and 'Amar Mosaic'. These represent various combinations of leaf shape and colour, and are entirely new to floriculture trade.
- A tetraploid cultivar 'Amar Tetra' was evolved through colchiploidy, 'Amar Shola', a hybrid amaranth is a selection from a cross within Amaranthus caudatus complex involving a grain type and an ornamental type.
- Evaluation of available germplasm of China Aster at IIHR Hessaraghatta has led to selection of 25 purelines developed by single plant selection. Of these AST-1 and AST-2 were found to be promising.
- In marigold, an outstanding F1 triploid developed at NBRI, Lucknow by using male sterile African diploid marigold (Tegetes erecta) and male fertile French tetraploid (T. patula) has performed well in all climates. F1 hybrid developed is dwarf, highly floriferous and free flowering. A few promising selections have also been made at UAS, Bangalore and PAU, Ludhiana.
- At NBRI, Lucknow, four free flowering hybrid verbena have been evolved by hybridizing V. tenuisecta and V. hybrida. The hybrid types obtained after repeated back crossing are summer hardy with genes that confer heat resistance. These verbenas are excellent both as for rockeries and for growing in beds. The hybrids can be propagated vegetatively (Khoshboo, 1979).
- In Zinnia, by recurrent selection from the irradiated seeds of Zinnia elegans a mixed coloured variety resistant to leaf curl virus has been evolved at IARI, New Delhi (Swarup and Raghava, 1974).

Scope and importance of breeding of ornamental crops

SCOPE

Scope for improvement

In India, floriculture is only a developing subject which offers much scope for improvement. This problem can be tackled from several angles such as conservation, domestication and introduction. India is rich in its plant resources, many of which are of

ornamental value and some are potentially ornamental. Much of this wealth is wasted as a result of rapid urbanization, industrialization, and unscrupulous collection.

For example, some unscrupulous nurserymen are selling one beautiful *Paphiopedilum insigne orchid* plant for the price of a single flower in foreign markets. To conserve such rare orchids, the ICAR has now started some orchid sanctuaries, which is a correct step in this direction.

Domestication of wild plants

Domestication of wild plants with potential ornamental value is another way of improving garden wealth. In the process of domestication, possibly in an altogether different climate, the wild plants generally pass through many changes, which itself may cause some chance improvement.

We have some very good plants in the wild with potential ornamental value, especially ferns, which can be acclimatized and domesticated under quite different climates. In this regard, the National Botanical Research Institute (formerly the National Botanic Gardens), Lucknow, has done some good work in acclimatizing the Himalayan ferns in the sub-tropical climate of Lucknow.

Scope for enriching ornamental plants

Introduction of plants either from the wild with potential ornamental value or from abroad offers a good scope for enriching ornamental plants. Initially, we should introduce wild plants with potential ornamental value, which can be improved upon by systematic breeding.

Simultaneously, plants of proven quality can be introduced from abroad and acclimatized in our country. The process of introduction has improved our ornamental horticulture to a great extent. The introduction of *Mussaenda philippica*, the double-bracted mussaenda with white, pink, and red colours, from Thailand have acclimatized very well in the humid and mild climates of Kolkata, Bangalore, and Kerala. The introduction of many beautiful bougainvilleas from abroad, e.g. ‘Lady Mary Baring’, ‘Golden Glow’, and the multi- bracted cultivars such as ‘Mahara’, ‘Cherry Blossom’, etc. has enriched our ornamental horticulture to a great extent. A great variety of the so-called Hawaian Hibiscus introduced by Lal bagh, Bangalore, has completely changed the complexion of many gardens in and around Bangalore.

Biotechnological tools

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.

Propagation

Easy and rapid propagation of ornamentals will go a long way in spreading floriculture in India. The use of mist propagation units along with the application of root-promoting hormones has enabled many difficult-to root trees and shrubs to root from cuttings. This method has improved the scope of supplying rare plants to garden lovers at comparatively cheap rates. Another field where not much work has been done is the production of disease-free plants. The tissue culture method offers the production of virus-free plant material. This method should be employed increasingly in ornamental plants not only for getting disease free stocks but also to have rapid multiplication.

Dwarfing of plants

Dwarfing of ornamentals by growth-retardant sprays is being exploited commercially in advanced countries.

In India, growth regulators have also been used to dwarf ornamentals. With the help of growth retardants it is possible to dwarf large plants to manageable sizes, so that the flat dwellers in cities can grow them in their limited spaces.

Plants sprayed with growth retardants become tolerant to adverse growing conditions, the leaves become darker in shade and shining and on many occasions early flowering is induced.

In chrysanthemum the growth-retardant spray can obviate the process of pinching. The commonly used growth retardants are B-Nine, Phosphone, and Cycocel. Maleic hydrazide (MH) also acts as an effective retardant. This method should be increasingly employed by the nurseries to encourage flat dwellers to take to gardening.

Extending Blooming Period

Some of the commercial flowers bloom only for a short period of the year irrespective of the planting date.

For example, in North India, chrysanthemum starts blooming by November 15 and completes flowering by the first week of January. This causes a glut in the flower market. Therefore, staggering of the blooming period of such crops will go a long way in solving the

marketing problem for the growers. The blooming of chrysanthemum can be altered by manipulating the photoperiod. This crop needs longer photoperiods for vegetative growth but shorter photoperiods for flowering. It is possible to extend the blooming period of chrysanthemum from the usual 45 days to five months under Lucknow conditions.

Scope and importance of breeding of ornamental crops

1. Crop improvement - Genetic resource enhancement, evaluation and conservation.
2. Breeding of novel colour, short duration, temperature and drought tolerant ornamental cultivars.
3. Breeding of dwarf cultivars of high value flowers/foliage plants.
4. Strengthening/standardization/popularization of F_1 hybrid seed production in important annual flowers.
5. Exportable 'made in India' varieties using molecular breeding and advanced techniques.
6. Production technology.
7. Development of agro-technologies for open field and protective cultivation – region specific ,energy efficient, low cost and ecofriendly production systems.
8. Commercialization of 'Specialty Flowers' as new flowers to attract buyers and market demand.
9. Digitalized spray and fertigation schedules.
10. Production of quality planting materials through tissue culture.
11. Improved media, new cladding materials and alternate energy and light sources.
12. New generation molecules for enhancing blooming span, shelf life, etc.
13. Mechanization of planting to packaging and storage.
14. Post-harvest technology a. Standardization of operation procedures for isolation of pigments, essential oils and natural colours/dyes.
15. New flower crops suitable for making dry flowers and technologies for efficient drying.
16. Natural dyes for pot- pourries and other flower arrangements.
17. Post-harvest engineering for improved packaging and low cost storage to reduce perishability.
18. Research on anti-senescence technology to delay senescence.
19. Landscaping - Improved grass species for turfs.

20. Urban greening technologies and vertical gardening.
21. New plants suitable for landscaping.
22. Plant health management.
23. Healthy landscape and beautiful flowers.
24. An inventory of pests and pathogens of flower crops.
25. Digitalized pest and disease forecasting expert system.
26. Prevention/management/eradication of the emerging pests and pathogens under changing climatic scenario.
27. Crop protection strategies with reduced pesticide inputs.
28. Multiple pest and disease resistant flowering plants.
29. Assured plant Biosecurity by generating database on potential pest and diseases of flower crops, diagnostics and containment techniques and information sharing.
30. Quality floriculture products meeting international sanitary and phytosanitary standards.

Lecture No. 3 & 4

Objectives and Techniques In Ornamental Plant Breeding

Origin and Objectives

The origin of plant breeding is as old as human civilization when the man started selecting superior plants and regenerating them for his use. Initially breeding started as an art, as the superior plants were selected based upon the human skill and preference. The scientific selection and development of superior plants was taken up only after the discovery of sex in plants. This process was further refined when Mendel proposed the laws of inheritance. Objectives of breeding in floricultural crops:

- The prime objective of any plant breeding programme is to develop superior plants over the existing ones in relation to their economic use. Like other crops, the breeding objectives of flower crops also differ from crop to crop and depend upon the nature of the plant and the part used for commercial exploitation.
- Flowers have many beneficial components for the consumer that can be created, enhanced, or improved by flower breeding programmes using classical or molecular techniques.
- Although the breeding objectives are specific yet to generalize, major objectives of floriculture breeding are:

1. Improved quality:

- Quality is the most important attribute of the floricultural crops as a single blemish on the petal can is not be tolerable to the consumer.
- The quality parameters again varies from crop to crop. For example in gladiolus the quality parameters would include novel colour, longer spike length, more number of florets /spike, orientation of florets on the spike etc while in case of rose, the breeding objectives will include flower colour, stem length and strength, bud length, bud shape, freeness from blemishes etc. Therefore improvement in quality although differs from crop to crop but is the major objective of a breeding programme.

2. Induction of Variation:

- The major aim of any improvement programme is to induce variation.

- Variation in colour is the most important breeding objective in different floricultural crops as the trends for colour preferences continuously change in the market.
- Variation in flower shape, size and form and foliage charcters etc. are other important considerations in flower crop improvement programme.

3. High flower yield:

- The ultimate aim of plant breeder is to improve the yield of economic produce. In floricultural crops, increasing yield signifies increased number of flowers per plant per unit area. A newly evolved variety with suitable quality characteristics could only be commercialized if it is giving optimum flower yield and could give economic returns to the growers.

4. Biotic Resistance:

- Considerable yield losses are caused by disease and insect pest infestation to various floricultural crops. Therefore, the newly developed commercial varieties could only be accepted if it would be able to resist the biotic influences e.g. reaction to insect pest and disease attacks etc.
- Resistant varieties could be developed which have genetic resistance to insect pest and disease infestation. For example breeding objectives may include development of resistant varieties in carnation against *Helicoverpa armigera* and red spider mite, in rose, against aphids and red spider mite, in gerbera, against white fly etc.

5. Resistance against abiotic stresses:

- In flower crops and ornamentals plants cultivars are required to be developed against abiotic stresses like temperature (high and low), light (high and poor intensity), varied photoperiod, drought, salinity, alkanity and acidity conditions of soil.

Techniques/Methods of crop Improvement

Crop improvement in ornamental crops various techniques (like introduction, selection, hybridization, mutation, polyploidy and genetic engineering) used.

Existing variation in nature is not sufficient enough to meet out the modern trends in global floriculture market, therefore different techniques were used for inducing required variability in the existing germplasm. Like other agricultural crops, in floricultural crops also

work on varietal improvement has been carried out and significant achievements have been made in developing new ornamental varieties with superior traits.

Systematic genetic improvement of flower crops began in India during sixties at the Indian Agricultural Research Institute (IARI), New Delhi; National Botanical Research institute (NBRI), Lucknow; Indian institute of Horticultural Research (IIHR) Bangalore and in some agricultural and traditional universities. Several amateurs and professional flower growers have also contributed substantially to evolve new cultivars in some ornamentals.

Different Methods

Different methods used for introduction of variation in the existing gene pool are:-

1. Introduction /Domestication
2. Selection
3. Hybridization
4. Mutation breeding
5. Polyploidy
6. Genetic Engineering

1. Introduction

- Plant introduction refers to transportation of crop plants/genotypes from the place of their origin/cultivation to such areas where they have not been grown earlier.
- Plant introduction is one of the ancient methods of crop improvement. Introduction is of two types, primary introduction and secondary introduction.

A. Primary introduction

- In this type, the introduced crop/variety is well suited for new environments and released as a commercial variety without any alteration in original genotype. In most of commercial cutflower crops, primary introduction is widely adopted technique for increasing gene pool.

B. Secondary Introduction

- In this, the introduced variety may be subjected to selection, to isolate a superior variety or may be hybridized with a local variety to transfer one or more characters from the local varieties.

Some plants introduction agencies of India

1. NBPGR (National Bureau of Plant Genetic Resources, New Delhi)
2. FRI (Forest Research Institute ,Dehradun)
3. The Botanical Survey of India
4. Central Research Institutes for different crops.
5. NRC Orchids, Gangtok, Sikkim

2. Selection

- Selection is one of the oldest method of crop improvement.
- It refers to the process that favours survival and further propagation of some plants having more desirable characters than others.
- Selection is more efficient when genetic variation is present in the base population and it utilizes the variation already present in the population.
- Several outstanding cultivars have been released by selection. Chrysanthemum cvs. ‘Apsara’, ‘Birbal Sahni’, ‘Jayanthi’, ‘Kundan’, have been developed through selection. Similarly cvs. ‘Shubhra’, ‘Dr B.P. Pal’, ‘Partha sarthy’ and ‘Surekha’ in Bougainvillea have been developed. Similarly many new varieties have been released in different floricultural crops.
- In Bougainvillea varieties, 'Sholay' and 'Usha' are the half sib selection of cv. 'Red Glory' and 'Lady Hope' developed at IIHR, Banglore
- 'Kamini', 'Poornima', 'Shashank' an 'Violet Cushion' varieties of China Aster are developed from Pedigree selection method

3. Hybridization

- It is the mating or crossing of two plants or lines of dissimilar genotype.
- In plants, crossing is done by placing pollen grains from male parent on the stigma of the flowers of other genotypes is female parent.
- The seeds and the progeny resulting from the hybridization are called F_1 hybrids. The main objective of hybridization is to create genetic variation. When two genetically different plants are crossed the genes from both the parents are brought together in F_1.

Types of Hybridization:

Based upon the taxonomic relationship of the two parents involved the hybridization it, may be classified as

(1) Inter varietal hybridization and

(2) Distant-hybridization.

Inter varietal Hybridization

• The parents involved belongs to the same species, they may be strains, varieties or races of the same species.

• These crosses may be simple or complex, depending upon the number of parents involved.

• Gladiolus varieties: Meera (G.P. 1 × Friendship), Nazrana (Black Jack × Friendship), Apsara (Black Jack × Friendship) are some of the examples

• Intervarietal hybrids of Hibiscus

1. Basant: IIHR × Rachaiah
2. Chitralekha: Debby Ann × H. S. 203
3. Marathi: H. S. (red) × H. S. 123
4. Nazneen: H. S. 203 × Rashtrapati
5. Phulhari: H. S. 139 × H. S. 181

Distant Hybridization

• Distant hybridization includes cross between different species of the same genus or of different genera.

• When two species of the same genus are crossed, it is known as inter specific hybridization.

• Arka Tejas, a carnation cultivar is a interspecific hybrid between *Dianthus carophyllus* × *Dianthus chinensis*

4. Mutations Breeding

- Mutation is a sudden heritable change in a characteristic of an organism.
- Mutation may be the result of a change in a gene, a change in chromosomes that involves several genes or a change in a plasma gene.
- The term mutation was introduced by Hugo de Vries in 1900. Mutation breeding attracted considerable attention during 1950s and 1960s, and several countries took up research projects in mutation breeding.
- Mutation is the most useful technique of inducing variation among the vegetatively propagated crops, and therefore, holds promise for the development of new varieties in ornamentals which are generally vegetatively propagated.

- Mutations are of two types:

1. Spontaneous Mutations

• The mutations that occur in natural population (without any treatment by man) at a low rate; these are known as spontaneous mutations.

• The frequency of spontaneous mutations is generally one in 10 lacs, i.e., 10^{-6}.

• In chrysanthemum varieties like 'Kasturba Gandhi' from 'Mahatama Gandhi', 'Sonar Bangla' from 'Snow Ball', 'White Cloud' from 'Pink Cloud', 'Sharad Shobha' from 'Sharada' were delopped through spontaneous mutations.

• In Bougainvillea, 'Jawahar Lal Nehru' is a bud sport mutant of cv. 'Lalbaugh' developed at IIHR, Banglore

2. Induced Mutations:

• Mutations may be artificially induced by a treatment with certain physical or chemical agents; such mutations are known as induced mutations, and the agents used for producing them are termed as mutagens.

• The utilization of induced mutation for crop improvement is known as mutation breeding. This type of mutation is generally utilized for the development of new varieties in ornamentals.

• Mutations can be induced by using chemical (colchicine, EMS, MMS etc.) and physical mutagenic (X-rays and gamma rays etc.) agents.

• In gladiolus cv. 'Shobha' (mutant of 'Wild Rose') developed by 1 kR treatment with gamma rays.

Mutation Breeding in Rose

- 'Pusa Christiana': Mutant of 'Christian Dior', gamma rays induced
- 'Abhisarika': Mutant of 'Kiss of Fire'
- 'Madhosh': Mutant of 'Gulzar', EMS (i.e. 0.025% for 8 hours)
- 'Angara': Mutant of 'Montezumma'
- 'Sharda': Mutant of 'Queen Elizabeth'

5. Polyploidy

- Generally the chromosome number of most of the species is highly stable and referred to as diploid i.e. having 2n number of chromosome.

- Sometimes a low frequency of irregularities may occur which gives rise to individuals with chromosome numbers different from the normal somatic chromosome number of the species.
- These changes in basic chromosome number contribute to the evolution of variation in the species.
- When an individual possess multiple of its own basic chromosome number it is called a polyploidy.
- Polyploidy has been exploited in ornamentals for induction of vigorous hybrids, double type of flowers, increased yield and for induction of fertility.
- Aneuploid Hybrid of Bougainvillea: 'Begum Sikander', 'Wajid Ali Shah', 'Chitra' (NBRI, Lucknow).
- 'Dr. B. P. Pal' (Tetraploid of Shubra), 'Tetra Mrs McClean' (Tetraploid of Mrs McClean).
- 'Begum Sikander': An aneuploid hybrid of Dr B. P. Pal × Jennifer
- 'Mary Palmer Special': Triploid seedling of Dr. B. P. Pal × Princess magaret Rose
- 'Chitra': Tetraploid of Tetra Mrs McClean × Dr. B. P. Pal
- 'Mohini', a trisomic variety of rose is a cross between Sea Pearl (4n) × Shola (2n)

6. Genetic engineering:

- Genetic engineering in ornamentals assumes greater utility, as conventional breeding success is limited due to high ploidy level, large nuclear genome and long generation time.
- The first genetically engineered crops were petunia and chrysanthemum, both with altered flower colour. Plant genetic engineering relies on two processes

1. The insertion of genetic material into plant cells
2. The regeneration of plants from these cells.

Gene transfer techniques:

a. *Agrobacterium* mediated gene transfer.

b. Electrophoresis

c. Electroporation

d. Laser cell perforation

e. Microinjection

f. Liposome mediated gene transfer

g. Silicon carbide technique

h. Ultra sonication

DNA fingerprinting:

- DNA finger printing has been standardized in rose, chrysanthemum and rhododendron. It can be used for the correct identification of the cultivar.

Lecture No. 5 - 7

Introduction, Selection, Hybridization, Mutation and Biotechnological Technique for Improvement Of Ornamental and Flower Crops *viz*.

Rose

Breeding objectives in Rose

- To develop varieties suitable for cut flower with long stem for cultivation in open field as well as under protected conditions.
- To develop varieties with enhanced vase life.
- To develop varieties resistant to diseases like black spot, dieback etc.
- To develop varieties resistant to various insect pests like trips, red spider mite, bud borer.
- To develop varieties which are demanded in domestic and international market for varied colour and fragrance
- To develop varieties for the production for rose oil.
- To develop varieties suitable for various uses like cut flower, pot plant, border plant as well as to develop varieties suitable for landscaping purpose.
- To develop varieties for reliving or using as shock absorber.
- To develop varieties for improved yield and quality for open field as well as for protected condition
- Develop varieties with new and rare colors.
- To develop thornless varieties.
- B.K. Roychoudhary, a nurseryman of Mihijam in Santhal Parganas, W. B. was possibly the first Indian rose breeder who raised the variety 'Dr. S.D. Mukherjee' in 1935.
- Another nurseryman, B.S. Bhattacharjee of Deoghar evolved a variety named 'Makrishna Dev'.
- The late Dr. B.P. Pal, who was Director of IARI, has been one of the well known rose breeders who took up rose breeding towards the end of fifties and has developed 105 varieties of rose. His first rose variety was 'Rose Sherbet' which is highly fragrant, with the oil content of 0.003 per cent and was released in 1962.

- Besides Dr. B.P. Pal other amateur rose breeders are late Raja Surendra Singh of Nalagarh, M. N. Hardikar, M. S. Viraraghavan, Dr. S. Banerjee, Braham Datt, Dr. Y. K. Hande and S.C. Dey.

Important species of Rose:

Several important species of Asian origin are diploid having chromosome number 14. These are:

- ***Rosa chinensis:*** large climbing evergreen shrub armed with brown, scattered and hook prickles. Flowers single, blush pink or crimson or pink, non-fragrant.
- ***Rosa gigantea:*** very vigorous climber with thick, hooked prickles. Flowers large, single, white or pale yellow, fragrant and borne singly.
- ***Rosa moschata:*** vigorous climber with reddish, sparsely prickly stems. Flowers with, usually semi double but sometimes single with musk fragrance in terminal clusters.
- ***Rosa multiflora:*** deciduous shrub with vigorous climbing branches. Flowers single, white with golden centre of stamens, borne in clusters and scented.
- ***Rosa wichuriana:*** a vigorous rambler producing single flowers, white with yellow centre, scented in large clusters. Valuable as a parent of garden ramblers.

A number of Western species with which these Asian hybrids crossed to yield several modern groups of roses are tetraploids with 28 chromosomes. These include *Rosa gallica*, *R. foetida* and their derivatives such as *Rosa damascena* and *R. centifolia*.

1. ***Rosa gallica:*** shrub rose with stiff erect stems. Distinguished by comparatively thornlesssness but an abundance of small prickles. Flowers single, purplish crimson in small clusters.
2. ***Rosa foetida:*** erect shrub with prickly stems, flowers single, bright golden yellow with unpleasant aroma, solitary or occasionally in clusters of 2-3. It has given rise to many modern yellow roses.
3. ***Rosa centifolia:*** loose growing shrub with large flowers, fully double with overlapping petals, strongly fragrant, deep pink with a slight purplish hue towards centre.
4. ***Rosa damascena:*** Hybrid origin. Old vigorous shrub with exquisite fragrance. Flowers borne in large clusters, semi double, sweet scented, bluish white to deep pink flowers.

Floral Biology of Rose

Inflorescence:

Solitary (Potentilla, Rosa servica) or grouped in racemose (Agrimonia). terminal corymbose (Rosa moschata), terminal cyme (Geum) or corymbose cyme (*Potentilla sibbaldi*).

Flower:

Actinomorphic very rarely zygomorphic (Chrysobalanoideae), bisexual or rarely unisexual (Spiraea aruncus), pentamerous or tetramerous, hypogynous or epigynous (Pyrus) or perigynous (Rosa); stipules may be represented by epicalyx (Fragaria, Potentilla).

Calyx:

Sepals 5, gamosepalous, adriate to the receptacle; sometimes epicalyx present; calyx tube remains free or adnate to the ovary, green, imbricate or valvate aestivation.

Corolla:

Petals 5, or multiples of 5, polypetalous, rosaceous, inserted on the receptacle cup variously coloured; petals entirely absent (Poterium, Alchemilla, Pygeum gardneria), or petals may be indefinite (Rosa spp.); sometimes stamens may be transformed into petal like structures; imbricate aestivation in bud.

Androecium:

Stamens 2, 3 or 4 times the number of petals, may be indefinite, free, commonly borne on the rim of the torus; anthers small, dithecous, splitting longitudinally, introrse in bud; rarely stamens 1 to 4 (Alchemilla).

Gynoecium:

Carpel 1 (Prunus, Prinsepia) or (Agrimonia atorium) or 5 (Pyrus) or indefinite (Fragaria and Rosa), apocarpous rarely syncarpous, ovary superior sometimes inferior (Pyrus), axile placentation, nectar secreting disc present between stamens and carpels; when syncarpous the placentation is axile, if apocarpous then basal.

Fruit:

Variable; drupe (Prunus), etario of achenes (Potentilla) berry (Eriobotrya japonica), pome (Pyrus).

Seed:

Non-endospermic.

Pollination:

Entomophilous-insects are attracted by nectar, colour, aroma or protandrous nature.

Floral formula:

⊕ rarely ♂♀ ☿ K (5) C5 or α A α $G_{1-\alpha}$ or (2 – 5)

Range of floral structure:

The Rosaceae, has a wide range of floral structure.

In the sub-family Spiraeoideae the thalamus is flat or slightly concave but never a deep cup or a convex receptacle. Flowers are pentamerous with 10 – á stamens, 5 carpels which may be free as in Spiraea or fused as in Lindleya.

In the sub-family Pomoideae the thalamus is a deep cup. Flowers pentamerous with 20 or more stamens; carpels 4 or 5 syncarpous and also fused with the inner wall of the cup like thalamus e.g. Pyrus, Crataegus, Cotoneastor etc.

In the Rosoideae the thalamus is cup shaped as in Rosa or convex as in Fragaria and Rubus. Epicalyx is found in Alchemilla and Potentilla. Calyx and corolla five each, stamens á. In Alchemilla unisexual and apetalous flowers may be found. In Agrimonia the stamens á to 1. Carpels á e.g. Rosa, Potentialla Fragaria, Rubus; in Ulmaria only 10 carpels on a flat or concave thalamus.

In sub-family Neuradoideae the thalamus is cup shaped and 5-10 carpels arise from the base of the cup and fused with each other.

In the Prunoideae a deep cup shaped thalamus is found; on the margin of the thalamus 5 sepals and petals each, 10-20 or more stamens arise but only one carpel arises from the base of the cup. The ovary contains only a pair of pendulous ovules.

In the Chrysobalanoideae the thalamus is again a deep cup and there is only one carpel at the base of the cup. But here the style is basal and not terminal and ovule ascending and not pendulous, in several genera the flowers may be zygomorphic. This sub-family has been considered as a connecting link between Prunoideae on the one hand and Papilionaceae on the other.

Techniques of Breeding

1. Natural Crossing and Selection:

- Roses in nature are cross pollinated by insects, especially the bees.
- During the course of development, a huge amount of heterozygosity and different ploidy levels have been accumulated in roses.
- Seeds from naturally formed rose fruits may give a variable progeny, especially in the modern varieties, possessing a complex pedigree.
- Even without artificial crossing of hybridization, many new forms may be obtained from the segregating populations.
- A large number of modern rose varieties have been developed through selection.

2. Hybridization

- Hybridization of different species has been primarily responsible for the evolution of new groups of roses.
- Interspecific hybridization has played an important role in rose improvement.

Steps of hybridization

1. Emasculation should be done during the bud stage, just before they open out. This should be done carefully with a pair of finely pointed scissors or sharp knife, without damaging the stigma and to avoid self fertilization
2. The petals of the flowers selected as a male parent are removed and anthers are gently rubbed on stigma of the female parent with the help of soft camel brush.
3. Pollen may also be applied with the help of fingers of soft brush.
4. After crossing, a small polythene or butter paper bag is put over the crossed flower to protect it from any further natural cross pollination by insects.
5. The pollinated flowers are labeled indicating the parents of the cross as well as the date of crossing.
6. Rose fruits (hips) containing seeds, which takes 3-6 months to mature are harvested when they turn brownish red.

3. Mutation breeding:

- Recently many cultivars with novel flower colours have been evolved which are generally the results of artificial induction of mutations.
- These were produced as a result of treating the buds with X-rays, radio isotopes or various chemical mutagens.
- Several cultivars have been evolved through natural mutations or as bud sport of the existing cultivars.

Important mutants of rose developed in India

Sr. No.	Mutants	Parents	Mutagen	Centre whrere released
1.	'Pusa Christina'	Christian Dior	Gamma rays	IARI
2.	'Abhisarika'	Kiss of Fire	Gamma rays	IARI
3.	'Madhosh'	Gulzar	EMS (0.25% for 8 hours)	IARI
4.	'Su Kumare'	Queen Elizabeth	Gamma rays (3 Kr)	NBRI, Lucknow
5.	'Saroda'	Queen Elizabeth	Gamma rays	NBRI, Lucknow
6.	'Shavda'	Queen Elizabeth	Gamma rays	NBRI, Lucknow
7.	'Mrinalini striped'	Mrinalini H.T.	Gamma rays	-----
8.	'Mrinalini light pink mutant'	Mrinalini cv.	Gamma rays	-----

Genetic Engineering in Rose

- In the past, roses were simply red, yellow or white. Blue roses could not exist as rose plants are unable to produce blue pigments naturally
- By means of gene technology, this goal has been achieved. Designer cut flowers are being created with exceptional colours with prolonged shelf life, with added fragrances or with built in frost protection.
- After 13 years of joint research by Australian company Florigene and Japanese company Suntory, a blue rose was created in 2004 using genetic engineering.
- Years of research resulted in the ability to insert a gene for the plant pigment delphinidin cloned from petunia and into an old garden *Cardinal de Richelieu* rose.

Rose breeding in India and abroad

- The work on rose breeding is being carried out at the Indian Agricultural Research Institute (IARI), New Delhi, National Botanical Research institute (NBRI), Lucknow and IHBT, Palampur.
- NBRI has developed and released nine gamma ray mutants, and also detected three spontaneous mutants.

IARI, New Delhi:

- **H.T. Rose:** Abhisarika, Anurag, Arjun, Bhim, Charugandha, Chitwan, Dr. B.P. Pal, Ganga, Jawahar, Mother Teresa, Mridula, Mrinalini, Nurjehan, Priyadarshini, Pusa Sonia, Raj Kumari, Raktagandha, Rangasala, Surabhi, Vasant
- **Floribunda:** Arunima, Chandrama, Deepshikha, Himangini, Mohini, Nav Sadabahar, Neelambari, Prema, Sadabahar, Saratoga, Shabanam, Sindoor, Suchitra, Suryodaya
- **Miniature:** Delhi Scarlet
- **Poliantha:** Swati

NBRI, Lucknow:

Hybrid Tea: Light Pink Prize, Mrinalini Stripe, Pink Montezuma, Summer Holiday Mutant,

Winter Holiday Mutant

- **Floribunda:** Ankara, Curio, Pink Contempo, Salmon Beauty Lighter, Sharada, Sukumari, Twinkle, Yellow Contempo, Pink Imperator
- **Miniature:** Windy City Mutant
- **Climber:** Climbing Cri Cri

<u>Different Varieties evolved in India</u>

Rose varieties evolved by amateur growers:

DR. B. P. PAL (Evolved 105 Varieties)

- **H.T. Rose**: Akash Sundari, Apsara, Aravali Princess, Ashirwad, Dilruba, Diva Swapna, Dr. Homi Bhabha, Dr. M.S. Randhawa, Dr. R. R. Pal, Golden Afternoon, Hasina, Homage, Indian Princess, Kamla Devi Chattopadhyay Kanakangi, Lalima, Lal Makhamal, Mechak, Mrs. K.B. Sharma, Maharani, Nayika, Nishada, Pahadi Dhun, Poornima, Raat ki Rani, Raja Surendra Singh of Nalagarh, Rajhans, Ranjana, Sandeepani, Sharmili, Shanti Pal, Sir C.V. Raman, Surkhab, Uma Rao
- **Floribunda**: Akash Nartaki, Banjaran, Chitchor, Delhi Brightness, Delhi Princess, Deepak, Jantar Mantar, KumKum, Madhura, Manmatha, Paharan, Parwana, Rangini, Rupali, Suryakiran, Tarang
- **Climber**: Climbing Dr. Homi Bhabha, Delhi White Pearl, Delhi Pink Pearl

M.N. Hardikar: Cynosure, First Rose Convention, Flying Tata, Swami

Y.K. Hande: lndian Pearl, Perfumer, Ajanta Caves, Gauri, Good Morning, Pink Wave

Muniswami : Poliantha- Pink Shower

M.S. Viraraghavan

- **H.T. Rose**: Kanchi, Nefertiti, Priyatama, Rajni, Tamrabarani, Vamsadhara
- **Floribunda**: Amarapali, Bhagmati, First Offering, Mahadev, Vanamali
- **Climber**: Kanyakumari

S.C. Dey: Martin Luther King, Sun God

Raja Surendra Singh of Nalagarh

- H. T. Rose: Ghajal, Nazr-e-Nazar, Yamini Krishnamurthy
- Floribunda: Gopika

Braham Datt

H.T. Rose: Don NieIson, Gond Beauty, Indian festival, K.K. Thakur, Pride of Nagpur, Soft Touch

Rose varieties evolved by nurserymen in India

Ajanta, Dr. P. Banerjee, Dr. S.D. Mukherjee, Heart Throb, Kalima, President Radhakrishnan, Raja Ram Mohan Roy, Ramakrishna Devgandha, Jai Hind, Menaka, Muktadhara, Pandit Nehru, Peetmanjari, Sir Jagdish Bose, Urvashi, Agnihotri, Anupama, Blue Delight, Chitrangini, Lemon Time, Pestel Delight inivasa, Tungbhadra, Vaishnavi, Vasavi, Arkavathi, Devadasi, Hemavathi, Kamini, Kumari, Natravathi, Priya etc.

Breeding work done in Abroad

Hybrids teas

Sr.No.	Cultivars	Parents	Remarks
1	Allegro(Geranium Red)	(Happiness x Independence) x (Soraya)	Meilland,1962
2	Americana (Bright Red)	(Poinsettia Seedling x New Yorker)	Boerner,1961
3	Apollo(Yellow)	(High Time x Imperial gold)	Armstrong,1972
4	Avon(Bright Red)	(Nocturne X Chrysler Imperial)	Morey,1961
5	Buccaner (Yellow colour)	(Golden Rapture Max Krause x Capt.Thomas)	Swim,1952
6	Champagne (Apricot Flowers)	(Charlotte Armstrong x Duquesa De Penaranda)	Lindquist,1961
7	Christian Dior(Velvety Red)	(Independence x Hapiness) x (Peace x Happiness)	Meilland,1958)
8	Confidence (Light Pink)	(Peace x Michele Meilland)	Meilland 1951
9	Duet (Light Red)	(Fandango x Roundelay)	Swim,1960

10	Eiffel tower(pink)	First love x named seedling)	Armstrong and Swim,1963
11	First Lady Nancy(Yellow)	(American Heritage x First Prize)	Armstrong 1981
12	Happiness (Red)	(Rome Gloryx Tassin) x (Charles P.Kilham x(Charles p.Kilham x Capucine Chambari)	Meilland,1949
13	Montezuma (Velvety Red)	(Fandango x Floradora)	Swim 1955
14	Oklahoma (Dark Red)	(Chrysler Imperial x Charles Mallerin0	Swim and Weeks 1964
15	Peace (Yellow)	(George Dickson x Souvenir De Claudius Pernet0 x (Goanna Hil x Charles p Kilham) x (Margaret Macgredy)	Meilland,1942

Floribundas

Sr.No.	**Cultivars**	**Parent**	**Remarks**
1	Allgold (yellow)	(Goldilocks x Ellinor Legrice)	Le Grice,1956
2	Arabian Nights (Salmon-Orange)	(Spartn x Beaute)	Mc Gredy, 1963
3	Charleston (Yellow)	Masquerade x (Radra x Caprice)	Meilland,1963
4	Daily Sketch (Pink)	(MA Perkins x Grand Gala)	Mcgredy,1960
5	Fashion (coral Peach)	(Pinocchio x Crimin Glory)	Boerner,1949
6	Flamenco (Salmon)	(Cinnabar x Spartan)	Mcgredy,1960
7	Gala (pink, yellow base)	(Unnamed Seedlings x Seventeen)	Jeelly,1973
8	Independence (Scarlet)	(Baby chateau x crimson Glory)	Kordes,1950
9	Mercedes (Scarlet)	(Anabell x Unnamed Seedlings)	Kordes,1974
10	Queen Elizabeth (Carmine, pink)	(Charlotte Armstrong x Floradora)	Lammerts,1954

Polyanthas

Sr. No	Cultivars	Description	Remarks
1	Baby Faurax	Purple Flowers, produced in clusters, with bluish tinge	Lille,1924
2	Cameo	Salmon-pink with orange shade very attractive	De Rviter,1932
3	Echo	Dwarf form of Tausendschon pink and white flowers I cluster	Lamberi,1914
4	Emmleloord	Olala x Finale, Orange Red borne in cluster	Buisman and Son,1973
5	George Elger	Yellow baby Rambler Dwarf Growing	Turbat,1912
6	Ideal	Dark velvety Crimson flowers Best Polyantha in this.	Spek,1921
7	Renoncule	Blooms small, Soft, Rose Pink	Barbier,1913

Miniatures

Sr. No	Cultivars	Parent	Remarks
1	Army's Delight	Little Darling x Little Chief	Williams,1980
2	Antique Rose	Baccara x Little chief	Moore,1980
3	Brightside	Persian Princess x Persian Princess	Moore,1974
4	Cream puff	Little Darling x Elfinesque	Bennett,1980
5	Dusty Rose	Little Vanderbilt x Cecile Brunner	Morey,1974

Climbers and Ramblers:

- **Auriel Dombasle:** Climbers with medium sized flowers of vermillion and yellow shade on reverse.
- **Dublin Bay:** Climbers with medium sized blood red flowers in clusters.
- **Gold Bunning:** Large golden yellow blooms in abundance over a long season.
- **Dynamite:** Flowers bright red with a fiery colour, long pointed buds, free bloomers.
- **Landora:** Climbing form of H.T. Landora, flowers yellow, well shaped
- **John F. Kennedy:** Climbing form of John F. Kennedy with large white flowers
- **Snow Garden:** Climber with rich glowing deep pink flowers
- **Golden Showers:** Daffodil yellow, fragrant flowers, produced singly or in clusters on strong stems.
- **Mermaid:** Hybrid of *Rosa bracteata* X Yellow Tea Rose. Pale yellow buds with a mass of amber stamens, single and fragrant flowers
- **Pinata:** Yellow blooms with orange red on edge of petals, always covered with blooms.

Lecture No. 8 - 10

Introduction, Selection, Hybridization, Mutation and Biotechnological Technique for Improvement Of Ornamental and Flower Crops *viz*.

Jasmine, Hibiscus, Bouganvillea

Jasmine Breeding

Jasmines are a group of perennial highly domesticated ornamental plants grown for their fragrant flowers. Of 200 species growing wild in tropical and sub tropical world 42 are known to grow in India. However, only 4 of these species are grown commercially in the country. Jasmines have enormous scope as commercial ornamental flower as well as essential oil industry. Efforts for genetic improvement in jasmines have been taken up recently.

IMPORTANT SPECIES

1. *Jasminum sambac*

Buds and flowers of this species (Arabian jasmine, Tuscan jasmine, bela, mogra) are used for garlands, adorning of hairs, worship and decorations.

2. *Jasminum auriculatum*

Buds and flowers of this jasmine (Juhi, jui, mullai) are commonly used for garlands, adorning hairs, worship and decoration.

3. *Jasminum grandiflorum*

This jasmine (French jasmine, chameli, pitchi) is the chief source of jasmine essential oil

4. *Jasminum pubescence (Syn J. multiflorum)*

This jasmine (kundphul, kundamu, and kundum) is practically non-scented but very attractive. It is one of the hardiest jasmines and least affected by pests and diseases.

Floral Biology

- Flowers of jasmine are hermaphrodite having 2 bilobed anthers. The gynoecium, has one ovule, simple style and bilobed stigma. Ovary is superior, bilocular having axial placentation.
- In jasmine 4 patterns of anthesis have been reported viz. 5 to 6 PM (early), 6 to 7 PM (medium), 7 to 8 Pm (late) and 8 to 10 PM (very late). Similarly three patterns of

dehiscence were recorded 3 to 11 PM, 4 to 5 PM and 5 to 6 PM. Period of blooming in jasmine vary from 3 to 4.5 months. Maximum number of flower buds opens from 6 to 7 Pm.

- Floral dimorphism expressing long and short carpel have been reported in *Jasminum grandiflorum*. Distinct differences in flowering behavior of these two types were observed. The long carpel (pin) type had prolific flowering, whereas short carpel (Thrum) type expressed shy flowering. In *Jasminum auriculatum* pin and thrum type flowers have been reported. Thrum type plants were reported to be superior to pin type in floral bud length, corolla tube length, and diameter of open flower.

SEED SET AND GERMINATION

- Seed set depends on genotype and environment on the basis of seed setting percentage. In one study at IIHR, Bangalore, jasmines were grouped into 5 groups viz., profuse seed setting type i. e 70 to 80 per cent (*J. auriculatum*); moderate seed setting type i.e. 5 to 10 per cent (*J. calophyllum, J. flexile*); poor seed setting type (*J. angustifolium, J. grandiflorum, J. savissinum*) ; very poor seed setting type i.e. below 1 per cent (*J. arborescens, J, rigidum*) and nill seed set type (*J. humile, J. nitidum, J, officinale and J. pubescens*).

OPEN POLLINATED SEEDLING SELECTION

- A high yielding variety of *Jasminum auriculatum* , 'Parimullai' was evolved by TNAU, Coimbatore. It yields 4300 kg flowers compared to 2500 kg obtained in ordinary types. It is resistant to gall mite infestation also.
- In *J auriculatum* several seedling selections were evaluated at TNAU, Coimbatore. A seedling selection yielded over 8.8 tonnes of flowers/ha and 0.34% concrete, the floral buds possessed short corolla tube and bold bud size. The selection was released as 'CO1 Mullai'. Based on their distinctive morphological and economic character six clones of *J. grandiflorum* were identified. Among these, the clone Jg3 Scions of the strain, Lucknow), was promising in flower production (10,144 kg/ha) and concrete recovery (29.42 kg/ha). It was released as 'CO1 Pitchi' by TNAU. At IIHR, Bangalore, by clonal selection a high yielding strain (Pink Pin) of *Jasminum grandiflorum* has been developed. Its potential

flower yield is 10 tonnes per hac and potential recovery of concrete is 35 kg/ha. At IIHR, Bangalore Anon has recently named it as 'Surabhi'. Another strain developed by IIHR, is 'Pink Thrum.' It produces more concrete (0.41 per cent) but is poor in flower yield.

- Narayanaswamy et al. evaluated 18 Jasminum types (4 Cvs. of *J. auriculatum* and 14 cvs. of *J. sambac*) to occurrence of rust (*Uromyces hobsoni*). Leat spot (*Cercospora jasminicola*) and anthracnose (*Colletotrichum sp*). *Jasminum sambac* cv. 'Eruvatchi', J. calophyllum and J. paniculatum were completely free from the 3 diseases. Jagadish Chandra et al. screened 18 species and 11 varieties of *Jasminum* against yellow ring mosaic virus. Seven species (*J. angustifolium, J. arborescens , J. calophyllum, J. nitidum, J. rigidum, J.* sambac and *J. suavissimum*) expressed 10 to 100 per cent infection. Whereas 5 species (*J. auriculatum, J. beesianum* and *J. grandiflorum L.* (Pin and Thrum types) *J. officinalis* and *J. auriculatum* did not exhibit the symptom indicating they possess factor for resistance, hence can be used in breeding programme for disease resistance. In this connection it is to mention that jasmine species like *J. calophyllum, J. flexile, J. angustifolium* and *J. rigidum* when grown in Coimbatore were found to be tolerant to yellow ring Mosaic but on growing in Bangalore, those were observed to be susceptible. In *Jasminum amingay* has revealed appreciable tolerance to white fly and red spidermite.

Hybridization

- Genetic improvement in jasmines through hybridization appears to be complicated. The most important barrier is non-fruitfulness is most species and cross combinations. Under natural conditions seed set varies with variety in species. Peak and active flowering occurs during night. Breeder normally face difficulty in emasculation and pollination as styles in some cases are long and fiery delicate, so risk of damaging the stigmatic region is very high The problems are further aggravated by the greater impact of insect interference due to fragrance. It has been observed that very minute insects move up and down the corolla tube thus possibly making the stigma dusted with pollen. Normally jasmine fruit contain only one seed. Growth of seedling is slow. Keeping all the points in view jasmine breeder has to devise suitable breeding technique and method to control the minute insect before emasculation and after pollination, so as to get wide

range of variability for different plant characters. There should be bud pollination to avoid insect interference.

- A large number of crosses were attempted at IIHR, Banglore, involving *Jasminum arborescence, J. calophylum, J. flexile, J. grandiflorum, J. humile var. wallihianum, J. nitidum* and *J. rigidum*. Most cross combination failed to set seed. Certain combination produced very shriveled seeds. Except from one combination involving the parent *J. flexile* and *J. suavissimum* in others there was no germination. Some workers evaluated 18 hybrid progenies of two parental combinations viz., 'Mutant' x 'Parimullai' (A1 to A10) and 'Mutant' X Long point (B1 to B7) for their variability. Higher variability was observed for plant volume and flower yield per plant. B7 and A 1 expressed consistently highest flower yields. Several intervarietal crosses of *J grandiflorum* were attempted at IIHR Bangalore. Only one combination viz. Seed set selection × Pink Pin yielded 6.8 %, seed set 0 to 3.2 per cent. Hybridization of *Jasminum pubescens*, with several allied species failed to yield any seedset.

Mutation Breeding

Jasminum species should be subjected to a range of physical and chemical mutagens for creation of large spectrum of variability for the characters of economic importance. Induced variability when followed by cycles of recombination and selection can result in improvement of desirable attributes which otherwise may not respond to selection. Once a desirable mutant is achieved it is easy to multiply it by vegetative propagations. Rao and Krishnan reported a spontaneous mutant with larger flowers in *Jasminum auriculatum*. On comparison with the source plant, it excelled in length and width of floral bud, length of corolla tube, diameter of open flower, number of petals, length and width of petal and 100 floral buds weight.

- At TNAU, Coimbatore, Chezhiyan *et al*. reported a variegated mutant *Jasminum auriculatum*. It was obtained on seed irradiation with 7.5 Krad, 12.5 Krad, 30 Krad and 10 Krad + Ethyl methane sulphonate 2%. The plant flower normally in 12 months. Because of short stature and variegated foliage this mutant has added ornamental value.
- In case of *Jasminum grandiflorum*, Nambisan *et al*. reported two induced mutant viz. resistant to *Cercospora jasminicola* and dwarf. However, both yielded lower concrete percentage. Sensitiveness of *J. grandiflorum*, cuttings to gamma radiation has been reported by Kumar et al. Softwood cuttings of the variety 'CO1 Pitchi' were subjected to

0.5 to 3 Krad. Rooting declines from 55% in 0.5% in 3 Krad. Similar trends was observed with regard to sprouting of axillary buds. Rooting in-non-treated cuttings was 85%. Devaiah and Srivastava reported that LD50 was close to 2.5 Krad for *Jasminum grandiflorum* var. Pink Pin' and close to 0.5 Krad for var. 'Pink Thrum', close to 2.5 Krad, for *J. flexile*, close to 1 Krad for *J. calophyllum* and 2 Krad for *J. sambac*. "Gundumalli'. Percentage of rooting, number of roots per cutting, length and thickness of roots decreased with increase in intensity of gamma radiation.

Polyploidy

- Spontaneous triploid in (2n = 39) *Jasminum sambac* has been reported by Sharma & Sharma , in *J. grandiflorum* by Murthy & Khanna , in *J. ilicifolium* by Taylor in *J. nitidum* by Taylor , in *J. primulinum* by Krishnaswamy shaman , and in *J. autumnale* by Sharma and Sharma.
- Spontaneous tetraploidy (2n = 52) have been reported by Dutta in J. *calophyllum*, by Raman in *Jasminum flexile*. Triploidy in *J. grandiflorum* has been found to increase concrete content and there by hold promise by as useful avenue for improvement of this crop. Efforts to induce tetraploidy has been attempted in jasmine. Suppression of polyploidy by diploid growth despite pinching has been a bottleneck in polyploidy programme. Induced tetraploidy in *J. grandiflorum* did not reveal superiority.

Hibiscus Breeding

The genus *Hibiscus* L. belongs to the family Malvaceae. There are 300 species widely distributed in tropical and sub-tropical parts of the world. Out of these only four ornamental species of Hibiscus, namely, *H. rosa-sinensis* L., *H. schizopetalus* Hook., *H. mutabilis* L. and *H. syriacus* L. are grown almost all over the tropics and sub-tropics. Among these ornamental species, *H. rosa-sinensis* L. (Shoe Flower) is the most important and beautiful of them all. A large number of types are found freely growing in India and majority of these types are hardy- and tolerant to drought conditions compared to the Hawaiian varieties.

Most of the improvement work through breeding in *Hibiscus rosa-sinensis* L. has been taken up in sub-tropical areas such as Mauritius, Hawaii, Fiji, India, California and Florida. In India, work on improvement of ornamental Hibiscus was mainly taken up at the Indian institute of Horticultural Research, Hessaraghatta; Lalbagh Botanic Garden, Bangalore; Tamil Nadu Agricultural University, Coimbatore and Kerala Agricultural University, Trichur, besides some leading nurserymen. An attempt has been made here to review the breeding work done in India in this crop.

Species and Cultivars

Species

Some of the important ornamental Hibiscus species grown in India and other parts of the world have been described by various workers.

A brief description of each species is as follows:

***H. rosa-sinensis* L.:** A native of Asia, probably China, but now conspicuous in all warm countries. A large evergreen shrub called the Shoe flower or Chinese rose. Corolla 10-15 cm across, column conspicuously exserted. The leaves are brightly green ovals, pointed at the apex and coarsely toothed except round the base. There are many new colours including white, yellow, pink, orange, terracotta, cerise etc.

***H. schizopetalus* Hook.:** This is also called Coral hibiscus and was imported from Africa. A large, glabrous distinct shrub with many slender drooping branches. 11 bears red or orange-red flowers drooping and with deeply fringed and recurved petals. The staminal tube is quite long measuring up to 15 cm. Leaves ovate-elliptic, 5-7 cm long, acute or acuminate, dentate, calyx tubular, staminal column long and exerted.

***H. mutabilis* L.:** This is native of China. It is known as the Changeable Rose or Persian Rose. Leaves large, heart-shaped, almost as broad as they are long and hairy. The edge is serrate. The flowers are single or double, 7-10 cm across, pure white in the morning and gradually turn pale pink to deep pink.

***H. syriacus* L.:** It is a native of East Asia and is known as Rose of Sharon It is also known as Tree Hollyhock or Althea shrub. A glabrous erect growing shrub. Leaves rather small, traingular-ovate, 5-7 cm long. Thriving best in hills and Produces lovely white, blue or mauve flowers either single or double.

Cultivars

There are several hybrids of the *Hibiscus rosa-sinensis* type with single and double flowers in varying shades. Their brief characteristic features are as follows:

Single flower cultivars

'Agnes' : Large flowers with cyclamen-pink and deep pink centre.

'Australian Single' : Very large flowers and deep rose with maroon centre.

'Glowing Sunset' : Deep glowing salmon orange

'Lipstick' : Bright red with dark centre.

'My Beauty' : Very large pink with a prominent maroon centre.

'Netaji' : White flowers with crimson centre.

'Viceroy' : Small deep rose-red flowers.

'Waimeae' : Snow white with slightly fragrant flowers.

Double flower cultivars

'Alipore Beauty' : Grows like a tree, bearing deep rosy cerise medium-size flowers. Highly floriferous.

'Aurora' : Very large flowers with flesh pink colour.

'Chitra' : Marigold Orange flower.

'Daffodil' : Large size with true Daffodil yellow.

'Dream' : Large mauve flowers.

'Golden Gleam' : Very huge attractive shade of buttercup yellow.

'Juno' : Large flowers with cerise colour.

'Mahatma' : Big double flowers, cadmium orange with red centre.

Breeding

Many of the *Hibiscus rosa-sinensis* cultivars were proved to be completely sterile. Only a limited number combined desirable characters with a reasonable degree of fertility, could be used as parents for the breeding programme. The improvement of ornamental Hibiscus through breeding in India is mainly done in tropical areas of southern states like Karnataka, Tamil Nadu and Kerala where the environmental conditions like temperature and humidity are congenial for seed setting in some of the species and cultivars. The major objectives included were plant with good growth habit, floriferous nature, desirable flower colour, size, shape and good keeping quality.

Hybridization

Hybridization is one of the most important methods of breeding in Hibiscus. Before taking up hybridization, basic information on pollen morphology, production, fertility, germination, pollination techniques are prerequisites. These have been discussed below:

Pollen Morphology

Individual pollen grains of H. rosa-sinensis L. and two other species like *H. mutabilis* and *H. schizopetalus* are pantoporate, spheroidal and spinose. Pollen diameter varied and ranged from 25.91µ in Acc. 29 to 198.58µ in Acc. 25. It was also noticed that though there was variation in colour and size, the pollen grains of different types and species had similar shape.

Pollen Production

In Hibiscus, the varieties were found to differ significantly in pollen production. The number of pollen grains per anther was found to vary from 159 to 359. Variation in the pollen output per anther among different types and species of Hibiscus are varied from 87 in Acc. 16 to 500 in *H. mutabilis*. The pollen production per flower depended on the number of anthers per flower.

Pollen Fertility

Pollen fertility of Hibiscus was estimated by acetocarmine staining technique. Pollen grains which stained well, looked plumpy and well-shaped were considered as fertile and those unstained, small or shrivelled as sterile. Different types and species showed-significant variation in pollen- fertility and it ranged from 4.6 Per cent in Acc. 7 to 97.4 per cent in *H. mutabilis*.

Pollen Germination

Pollen germination studies in vivo showed that the pollen grains of only six ('Rose', 'Sunset', 'Juno', 'Australian Single', 'Splendens' and *H. schizopetalus*) out of ten varieties germinated on the stigma. Among the above six varieties pollen tubes elongated only in four 'Rose', 'Sunset',

'Jluno' and *H. schizopetalus*.

Pollination and Fruit Set

The pollination technique followed during hybridization' is quite simple. After selecting the desired female parents, flower buds are emasculated with a fine forceps one day prior to the opening and these buds can be tied in the middle with a thread so as to make it convenient for bagging. On the following day, pollen from- desired male parent which have been bagged properly are brought along with the staminal column and slowly smeared on the sticky stigmatic surface of the female parent. After crossing, the crossed flowers are bagged with a butter paper bag to protect from further cross-pollination by insects. The pollinated flowers are labelled indicating the parents involved and the date of crossing. After a week of crossing, the bags can be removed and the young capsules may be allowed to develop under natural conditions. Generally, the successful crosses will show swelling of the capsule and do not fall easily. Generally, the capsules take for seed maturity after hybridization 40 to 71 days under Bangalore conditions.

Promising Hybrids and Seedlings

The intraspecific hybridization of *H. rosa-sinensis* was undertaken mainly at the Indian institute of Horticultural Research, Hessaraghatta, Lalbagh, Bangalore and Tamil Nadu Agnoultural University, Coimbatore resulted in raising of large number of F_1 progeny. The promising seedlings from the segregating population were tested thoroughly for various attributes before release.

Varieties developed at IIHR, Hessaraghatta: Out of the nearly 1200 intravarietal hybrids and opan-pollinated seedlings of *H. rosa-sinensis*, 25 new varieties with attractive flowers were released between 1972 to 1979. These are mentioned below along with their flower colour. 'Aikta' (Post Office Red), 'Anuradha' (Golden Buff), 'Arunodaya' (Nasturtium Orange), 'Ashirwad' (Yellow), 'Basant' (SulphurYellow), 'Benazeer' (Bright Yellow), 'Bharat Sundari' (Deep Neyron Rose), 'Chitralekha' (China Rose with white variegated petal), 'Dilruba' (Mark Golden Buff), 'Geetanjali' (Turkey Red), 'Jogan' (Azalea Pink), 'Nartaki' (Marigold Orange), 'Nazneen' (Tangerine Orange), 'Neelofer' (Magenta Rose), 'Pakeezah' (Carmine Red), 'Phulkari' (Delft Rose with yellow border), 'Priya' (Rose Bengali), 'Queen of Hessaraghatta' (Orange), 'Ratna' (light yellow with orange stripe), 'Red Gold' (Dutch Vermilion), 'Red Saturn' (Signal

Red), 'Shanti' (Primrose Yellow), 'Smt. Indira Gandhi' (Indian Yellow), 'Smt. Kamala Nehru' (Rose Bengal) and 'Tribal Queen' Cardinal Reds.

Some of the very popular ones are briefly described below:

'Arunodaya': This seedling was produced from the cross 'IIHR-H 2' and 'Rachaiah'. A vigorous shrub with many lateral branches, highly floriferous. Flowers are single, 16-18 cm across. Petals are incurved along the margin. Corolla Nasturtium Orange (25 B) and the basal part of the corolla is Rose Bengal (57 B) which spreads upto 3 cm.

'Ashirwad': This is a cross between 'H.S. 21' and 'Hombe Gowda'. A vigorous plant with prominent lenticells all over the surface of branches, floriferous. Flowers are single, 18-21 cm across. Corolla Cadmium Orange (23 B) and slightly Mandarin Red (40 C) towards one side of the border. Petals with slightly- ruffled margin. The basal part of the corolla Currant Red (46 A) with Neyron Rose (55 A) border which spreads upto 3.5 cm.

'Basant': This hybrid seedling is across between 'IIHR-1' and 'Rachaiah'. A moderately vigorous shrub with erect lateral branches. Leaves are slightly pubescent. Flowers are single, 17-20 cm across. Petals are slightly incurved along the margin. Corolla Sulphur Yellow (6 A) without any conspicuous centre. This is one of the best yellow coloured varieties in hibiscus.

'Nazneen': This seedling was produced from the cross 'H.S. 203' and 'Rashtrapati'. A moderately vigorous shrub with slightly pubescent leaves, floriferous. Flowers are single, Nightly cup-shaped, 18-22 cm across. Corolla is Tangeririe Orange (24 B). Petals are recurved along the margin and with silky texture. Basal part of the corolla is red -with light mauve border which spreads up to 3 cm.

'Dr. B.P. Pal': This is also a seedling of 'Lahiana'. Flowers single, measures 22 cm across. The base of the corolla is whitish pink and turns to rose pink later on. The petals are Mandarin Red with prominent veins. The general colour effect of the flower is rich deep gold washed with vermilion.

'Mother': This is a hybrid seedling between 'Honi Honi' and 'Cornet'. Leaves cordate, ovate, acute and undulate. Flower 15-17 cm across. The base Clothe corolla is Capsicum Red and the margin of the petal is Saffron Red.

Mutation Breeding

Three somatic mutants have been isolated, one in cv. 'Cruenthus' and two others in 'Alipore Beauty'. Both the varieties were exposed in pots, under semi-acute exposures. In cv. 'Cruenthus',

a mutation with change of flower form from double to single type has been established. In cv. 'Alipore Beauty' two somatic mutants one with deep red flower colour as against light red carmine colour and the other with deep red flower colour coupled with semi-double form with an average of 2-15 petals have been isolated. Single flower mutant of cv. 'Alipore Beauty' through induction of gamma rays and it has been named as 'Anjali'.

Boganvellia Breeding

INTRODUCTION

Bougainvillea is a popular ornamental plant mainly grown for its attractive colourful bracts that splash colour to the surrounding. It is popular among parks, home and institutional gardens grown mainly as bush, climber, hedge, topiary, standard, pot plant, bonsai, on pergolas and trees (Roy, 1987; Sharma and Roy, 2001). Wide adaptability to different agro-climatic conditions and easy multiplication has made it a popular ornamental plant of the world. Moreover, as it is a drought and pollution resistant plant, it is well suited for industrial places and on road dividers (Kumar and Prasad, 2002). Bougainvillea is originated in South America and was first collected by Commerson, a French Botanist, at Rio-de-Janeiro, Brazil. The genus 'Bougainvillea' belongs to family Nyctaginaceae and was discovered by French Botanist Commerson in 1766-69. The generic name Bougainvillea Commers. was first published by A. L. De Jussieu in his work Genera Plantarum in 1789 (Jussieu, 1789). It is not clear whether the cultivars outside South America were derived from plants already cultivated in Brazil or from truly wild plants (Holttum, 1938). Much of the evolution in Bougainvillea took place outside its native home, primary factor being natural hybridisation and showy bracts accompanied by self incompatibility (Zadoo et al., 1975). The B. glabra and B. spectabilis are widely used species and most of the present Bougainvillea cultivars are thought to have originated from them. Third species, B. peruviana is also of horticultural importance. According to Khoshoo (1998), Bougainvillea also has three hybrid groups namely, B. × buttiana (glabra × peruviana), B. × specto-peruviana and B. × spectoglabra. Among these, B. spectabilis and B. glabra were reported to be more tolerant to cooler climate. Bougainvillea grows well throughout the plains of India, but only B. glabra thrives well at higher altitudes (Pal and Swarup, 1974). Considering its ornamental and commercial importance in nursery trade, R and D were taken up by different national research institutes (IARI, IIHR, NBRI, BARC), state agricultural universities, AgriHorticultural Societies (Kolkata and Chennai) and even by progressive nursery men. As a result, a large number of new cultivars have been developed in India. Considering the contribution made by India, the international registration authority for new cultivars lies in the Indian Agricultural Research Institute (IARI), New Delhi, which is an international recognition conferred upon by International Society for Horticultural Science. In India, crop improvement work was started in early 20th century with the introduction of B. spectabilis in 1860 from

Europe. However, the popularity really started with the introduction of cv. 'Mrs. Butt' from Royal Botanic Garden, Kew to The Royal Horticultural Society, Kolkata in 1923 (Swarup and Singh, 1995). Percy Lancaster, the renowned British horticulturist, has been credited for the development of first cultivar of Bougainvillea - 'Scarlet Queen' in 1920 and subsequently another excellent bi-coloured cultivar 'Mary Palmer' developed by him paved the way for Bougainvillea cultivation in India.

Flower morphology:

To understand the morphology of a flower is very important for the crop improvement programme of any crop. The flowers of Bougainvillea are hermaphrodite, tubular in shape with a constriction in the middle and borne in clusters of three, each flower subtended by a brightly coloured bract, which helps to attract insects for cross pollination. Bract colour in bougainvillea is contributed by betacyanins and betaxanthins i.e. betalains (Mabry and Dreiding, 1968).The tip of the flower is conspicuous with a star. There is a solitary carpel at the base surrounded by a ring shaped nectar. During morning hours (around 10 am) anthesis takes place followed by anther dehiscence and stigma receptivity. Butterflies visit the flowers attracted by the brightly coloured bracts and the nectar glands aids in cross pollination. The opened flowers remain so for a day, after which the upper part of the flower tube gets twisted in a spiral. Most of the Bougainvillea cultivars are diploid with a chromosome constitution 2n =34, irrespective of the species / hybrid group to which they belong (Zadoo et al., 1975). Xu et al., 2009 reported the occurrence of sixteen stages during bud and flower development in one inflorescence of Bougainvillea.

Major facts in the evolution of cultivated Bougainvillea:

The year 1910 was marked by a major discovery in cultivated Bougainvillea when Mrs. R.V. Butt brought crimson coloured Bougainvillea cuttings from Cratagena (Columbia) to Trinidad. Over the years the cultivar turned out to be evermutating, being the source of various colour mutants that have added materially to the richness of the colour in the genus. The plant was named after Mrs. Butt. This plant reached Kew in 1915 and from there it got distributed to India, Africa, Australia, Malaya and Singapore in 1923 (Holttum, 1955). The cv. 'Scarlet Queen' was introduced to India directly from West Indies by Mr. Tomlinson in 1920. Percy Lancaster gave the name Scarlet Queen to this variety. According to him, the coloured bracts of this plant are slightly darker than Mrs. Butt but the actual flower is malformed, so instead of there being

three white or cream coloured flowers in the bracts, there are merely little bunch of anthers (Holttum, 1955; Zadoo et al., 1976). In 1931, Mrs. McClean of Trinidad produced apricot orange bracts instead of the normal crimson bracts of Mrs. Butt plant. This variant was propagated by R.O. Williams and named as cv. 'Mrs. McClean' (Holttum, 1955). The cv. 'Scarlet Queen' produced orange coloured variety in 1932 at Madras in the garden of Mrs. Louis Wathen. It was named as 'Louis Wathen' by Mr. B.S. Nirody. Subsequently majolica yellow sports appeared from Louis Wathen and Mrs. McClean by spontaneous bud variation and were named as Enid Lancaster and Mary Baring (Pal and Swarup, 1974). S. Percy Lancaster had separated a purple coloured sport from Scarlet Queen in 1942 and named it as Alick Lancaster. The variegated leaved bud sports from Scarlet Queen has been released as cvs. 'Scarlet Queen Variegata' and 'Rao' (Pal and Swarup, 1974). An important floriferous and recurrent blooming seedling was raised by P.S. Swaminathan at Madras from Princess Margaret rose and named it Mrs. H.C. Buck (Lancaster,1951; Holttum, 1955). The famous bicoloured variety Mary Palmer was isolated from Mrs. H.C. Buck in 1949 by S. Percy Lancaster (Holttum, 1957). 'Thimma' with variegated foliage and 'Shubra' with pure white bracts were evolved as a sport of Mary Palmer (Pal and Swarup, 1974).

Milestones in the bougainvillea cultivation:

The first milestone in the history of Bougainvillea cultivation that created a sensation among the Bougainvillea lovers was the evolution of a bicolored cultivar 'Mary Palmer' bearing white and magenta coloured bracts on the same plant in 1949. It appeared as a bud sport of 'Mrs. H.C. Buck following its drastic pruning, resulting in a complex chimera. It was named after Mrs. Palmer, in whose garden at Alipore, Calcutta, it appeared first. This is one of the most outstanding and popular cultivars of Bougainvillea even today. The second milestone was the evolution of Bougainvillea cultivars having variegated foliage which remains attractive even when plants are not in bloom. These cultivars are very much preferred for pot culture. Some of the outstanding varieties which have variegated foliage are Archana, Arjuna, Louis Wathan Variegata, Marietta, Parthasarthy, Scarlet Queen Variegata, Surekha and Thimma. The third milestone was the evolution of multibracted cultivars commonly known as 'Million Dollar' group as a budsport of B. X buttiana in Phillipines namely Cherry Blossom, Los Banos Beauty, Mahara and Roseville's Delight having 18-21 bracts as against to common occurrence of three per flower. This group has further brightened the usefulness of this plant for ground as well as

pot culture. The fourth milestone was the evolution of Bougainvillea cultivar Shubhra. It has fulfilled the long felt desire of having parchment white bracts, with perpetual blooming habit. It is also hardy and easy to multiply. Progress in Bougainvillea breeding was hampered all over the world largely because of the extensive pollen and/ or seed sterility. Thus the choice of female and male parents is limited only to a few relatively fertile types which, more often were not attractive cultivars. After detailed studies of the reasons for sterility, fertility was restored by colchiploidy. This has been the fifth milestone, which has enabled immediate broad basing of germplasm by inclusion of such cultivars in the breeding programme that were out for reach of Bougainvillea breeders all over the world (Sharma, 1986).

Breeding approaches in Bougainvillea: India is one of the major repositories of a wide range of bougainvilleas, and approximately 50 % of the present-day cultivars have been evolved in India (Janakiram et al., 2013). The work on development of Bougainvillea has largely been done by the Agri-Horticultural Societies at Calcutta and Madras. The Lal Bagh Garden at Bangalore also contributed a great deal by introducing a large number of exotic cultivars, particularly the multibracted varieties from the Philippines. Different breeding approaches followed in bougainvillea are hybridization, polyploidy, mutation and bud sports. A large number of varieties have been developed at the NBRI (Lucknow), BARC (Mumbai) and IIHR (Bengaluru).

Hybridization:

Hybridization enable the origin of totally new colour forms of Bougainvillea. It also increased the possibilities and limits of selection. The natural hybridization with polyploidy has been the single factor contributing to evolution in nature and under domestication by plant breeding (Khoshoo and Mukherjee, 1970).

The cultivars developed from interspecific crosses are:

Crosses	**Varieties**
B. peruviana x B. glabra	: Begum Sikander, Mrs. Butt
B. peruviana x B. spectabilis	: Wajid Ali Shah
B. buttiana x B. peruviana	: Chitra
B. spectabilis x B. buttiana	:Dr. R.R. Pal, Summer Time, Spring Festival
B. glabra x B. spectabilis	: Maharaja of Mysore, Pink Beauty, Pixie, Rose Queen

The cultivars which were developed from intraspecific crosses are:

Crosses	Varieties
B. glabra (Trinidad x Formosa)	: Dr. H.B. Singh
B. glabra (Formosa x Trinidad)	: Purple Wonder
B. spectabilis (Lalbagh x Red Glory)	: Chitravati
B. peruviana (Dr. B.P. Pal x Princess Margaret Rose)	: Mary Palmer Special

(Swarup and Singh, 1995)

The varieties which were evolved through **hybridization** at IIHR (Indian Institute of Horticulture), Bangalore are Dr H.B. Singh, Chitravati and Purple Wonder. Among these varieties, Dr H.B. Singh was patented as Krishna in Australia (Anonymous, 1996)

Mutation: The hybridization is not possible in multibracted bougainvillea due to absence of flower tubes/ flowers and all varieties are not able to set seeds at all places. Hence, a alternative method, i.e. induced mutation breeding resulted in evolution of different new Bougainvillea cultivars (Swaroop et al., 2015).. Mutation leads to the origin of many new forms of Bougainvillea. In recent years, mutation breeding has been used as a valuable supplement to traditional methods of plant breeding which helps in the development of better cultivars (Arora and Pahuja, 2008). Most of the cultivars of Bougainvillea were developed through selection of 'budsports' or by mutation breeding. Mutation breeding is one of the important methods to create variability in flower crops and it also reduces the time required to develop a new variety (Kannan et al., 2002). Mutation breeding is the only method that can be used to improve double bracted Bougainvillea, since conventional cross-breeding is not possible because of the absence of flowers (Datta, 1990). Different bract colours ranging from white to yellow, orange, magenta, red, purple and violet have arisen as a result of mutation among various forms of three basic species (Mabry and Dreiding, 1968). The relative proportion of these pigments determines the variation in bract colour (Kochhar and Ohri, 1977). Bract colour variations were due to qualitative and quantitative differences in pigment composition (Anand et al., 1997). The mutation studies of bougainvillea has been carried out at National Botanical Research Institute, Lucknow and Bhabha Atomic Research Center, Bombay (Banerjee, 2010).

The mutants developed at National Botanical Research Institute, Lucknow were as follows:

Mutant	Parents	Characteristics	Developed/ Reported by
Arjuna	Gamma ray mutant of 'Partha'	Single bract cultivar with pinkish purple colour and variegated leaves	Gupta and Shukla, 1974
Los Banos Variegata	Los Banos Beauty	Variegated leaves with excellent pattern, attractive leaves and bract colour is mallow purple	Banerjee and Datta, 1987
Pallavi	Roseville's Delight	Variegated leaves having pale and light green combination	Banerjee et al., 1987
Mahara Variegata	Mahara	Variegated leaves with creamish yellow and green Bract rhodamine purple	Datta and Banerjee, 1994
Mahara Variegata abnormal leaves	Mahara	Variegated leaves Bract colour unaltered but shape and size reduced	Banerjee, 2002
Los Banos Variegata silver margin	Los Banos Beauty	Attractive variegated leaves with green and silver margin	Banerjee, 2002
Los Banos Variegata 'Jayanthi'	Chemical mutagen (EMS 0.02 %) induced mutant of cv. Los Banos Beauty	Differs from the original variety in foliage colour	Jayanthi et al., 2000
Pixie Variegata	Chemical mutagen (EMS 0.02 %) induced chlorophyll variegated mutant of cv. 'Pixie'.	Margin of the leaves creamish colour	Banerjee, 2009
Los Banos Variegata Silver Margin	Gamma ray mutant of Los Banos	Beauty Leaf lamina is green and its margin is silver (1-2 mm width), varigated leaves are extreamly curved	Banerjee, 2012

Bhabha Atomic Research Centre, Bombay developed mutants of Bougainvillea such as Lady Hudson of Ceylon Variegata (Induced mutant of Lady Hudson), Jaya (Induced mutant of Jayalaxmi), Jayalaxmi Variegata (Induced mutant of Jayalaxmi) (Broertjes and Van Harten, 1998), Suvarna (Induced mutant of Lady Hudson), Poultoni Variegata (Gamma ray induced mutant of 'Poultoni') and Silver Top (Induced mutant of 'Versicolour') (Raghava, 1999).

Bud sports:

Some excellent cultivars of bougainvillea were originated as a result of spontaneous bud variation namely Alick Lancaster, Bhabha, Cherry Blossom, Fantasy, Jawaharlal Nehru, Lady Mary Baring, L.N. Birla, Louis Wathen, Mary Palmer, Mrs. McClean, Parthasarthy, Roseville's Delight, Shubhra etc. Spontaneous bud variation resulted in three change in the cultivated Bougainvillea i.e. Change in bract colour, imperfect flower tube development and leaf variegation (Holttum 1955,1957). The cv. 'Sholay' and 'Usha' are important seedling selections at IIHR from Red Glory and Lady Hope respectively (Anonymous, 1996). From cv. 'Arjuna' a chlorophyll variegated bud sport originated which were named as 'Abhimanyu'. It was detected by Dr. Banerjee at NBRI, Lucknow (Banerjee, 2012). In the year 1963-1967, Dr. J.V. Pancho first reported the multibracted cultivars of bougainvillea in Laguna, Phillipines. The cultivar such as Carmentica, Cherry Blossom, Mahara, Godrej Cherry Blossom, Los Banos Beauty, Mahara Variegated, Pallavi, Rosevilles Delight, Archana and Marietta are multibracted. They are called multibracted cultivars as they have 20-40 bracts as compared to the normally occurring three bracted cultivars of bougainvillea. Also the flower tube is absent or rudimentary in such varieties. The multibracted varieties originated from the cultivars of B.x Buttiana (Pal and Swarup, 1974; Banerjee, 2012).

Polyploidy:

Due to seed sterility in bougainvillea further breeding was hindered as a result of which it limits the selection of male and female parents for developing new cultivars. After detailed studies, fertility in bougainvillea was restored by colchiploidy. Thereafter, numerous colourful and floriferous bicoloured cultivars at triploid, tetraploid and aneuploid has been raised. Some of the cultivars with induced polyploidy areWajid Ali Shah, Mary Palmer Special, Dr. B.P. Pal, Tetra Mrs. McClean, Chitra and Begum Sikander.

Characterization:

Many varieties have recognized the basis of morphological and agronomical features in previous days. Even though verities carry some morphological and agronomical features through their genetic background but these features can be influenced by the environment (Fu et al., 2008). With consideration of Bougainvillea cultivars, are widely diverse among themselves mainly due to the color of bracts leaf and bract size, foliage variegation, floral tube, star, a presence of pubescence etc. Collectively, all these factors generate a lot of confusion in the identification of the particular cultivar (Mac Daniels, 1981). Therefore, researchers are willing fully seeking the easier and effective way to identify these cultivars. Classification of Bougainvillea cultivars based on the different characters studied by Kumar et al. (2015) which will lead to the characterization of a particular genotype. This quantification of existing genetic variation and identification of cultivar based on economic traits and grouping the cultivars based on genetic divergence helps in selecting appropriate cultivar and utilizes them for future bougainvillea improvement through systematic and scientific breeding approaches.

Molecular characterization of Bougainvillea:

In recent years, several molecular approaches have become available, for characterization of a genotype at the genomic level. Among them, RAPD is most commonly used for the identification of cultivar due to its simplicity, rapidity and requirement of only a small quantity of DNA to generate numerous polymorphisms (Wight et al., 1993; Cheng et al., 1997). For quantifying genetic variation in plant species, morphological traits are commonly used since they provide a simple technique while simultaneously assessing genotype performance under relevant growing environments (Fufa et al., 2005). In Bougainvillea, till date, only a few studies were conducted to assess the genetic variation including, growth behavior studies (Gupta et al., 2006, Kumar et al., 2002), correlation studies (Singh et al., 2010, Singh et al., 2006). Although the characterization work in Bougainvillea is more dealt with RAPD markers they were not much preferred as suitable marker systems for diversity and evolutionary studies due to their less reliability and lower reproducibility (Chatterjee et al., 2007, Hammad 2009, Srivastava et al., 2009). Reduction of duplications in Bougainvillea through the development of molecular markers profile which also serves as a potential tool in cultivar identification. Therefore, use of more reliable and reproducible molecular markers like SSRs becomes indispensable in

Bougainvillea, like in any other plant species. Simple Sequence Repeats (SSRs or microsatellites) have become genetic markers of choice in many plant species due to their multi-allelic nature, a high abundance, co-dominant inheritance, reproducibility, high degree of polymorphism, and extensive genome coverage (Varshney et al., 2005). To make out the relationship between the different cultivars of bougainvillea, SSR markers were used in a study by Kumar et al., (2014) to characterize the cultivars. The investigation further revealed the fact that, the SSR markers are robust in detecting a high level of molecular polymorphism to characterize and in grouping the Bougainvillea cultivars besides establishing the genetic relationship and diversity which further used in crop improvement programmes.

Bougainvillea promotion:

BSI (Bougainvillea Society of India) was founded by Dr. B.P. Pal during 1962-63 with the main objective to organize bougainvillea festival every year to create awareness among the people. BSI, New Delhi has more than 350 life members. Division of Floriculture and Landscaping, Indian Agricultural Research Institute, New Delhi, is the International Bougainvillea Registration Authority, appointed by the International Society for Horticultural Science, Belgium, for registration of bougainvillea germplasm since 1966 and it has compiled a checklist of more than 300 varieties developed all over the world. This check-list is a very useful document for reference purposes, giving authentic descriptions of the varieties. At present, the repository maintains more than 95 varieties of Bougainvillea (Janakiram et al., 2013).

Conclusion

Bougainvillea is a very important landscape plant which plays a devoid role in the gardens. The availability of different forms in flower and plant habit made bougainvillea popular among the garden lovers. Most of the bougainvillea cultivars are evolved through natural mutations (Bud sports), whereas, induced mutation and hybridization also bring down significant contribution to the development of various forms. In ornamentals, consumers always seek for the new variant and hence, there is still to develop new variants with different flower colours and plant architecture. In this regard, the above information may be beneficial for development of new cultivars with novel colour and forms.

Lecture No. 11 - 16

Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental and flower crops *viz*.

Chrysanthemum, Gerbera, China Aster, Gaillardia, Dehlia, Zinnia, Carnation, Marigold, Cosmos

Chrysanthemum

Chrysanthemum (Chrysanthemum morifolium Ramat.) is one among the most versatile and internationally recognized floriculture crop. Maximum diversity of chrysanthemum is scattered in eastern parts of the world hence also recognized as Queen of East', Glory of East' or Autumn Queen'. Fukai et al., (1995) suggested that Florists' Chrysanthemums (2n=54) originated by crossing and doubling between Chrysanthemum zawadskii var. latilobum (Maxim.) Kitamura (2n=18) and Chrysanthemum indicum var. Procumbense (Lour.) Kitamura (2n=36). The cluster analysis of ISSR-PCR for 86 plants of chrysanthemum revealed that Chrysanthemum vestitum is closest to medicinal and largeflowered chrysanthemum in genetic distance and the evolution of chrysanthemum may be mainly in one way that is from wild chrysanthemum to medicinal chrysanthemum to ornamental chrysanthemum (Zhou, 2009). The genus chrysanthemum comprises of 100 to 200 species which varies in their morphological attributes like growing habit, form and colour.

Hybridization

Availability of sufficient germplasm is prime need for further improvement in any crop. Improvement work and investigation, collection, evaluation, preservation and utilization of resources are important for the sustainable use of significant germplasm. In present, conventional breeding techniques are still being used for improving various horticulture traits in chrysanthemum. All the cultivated chrysanthemums are allohexaploid (2n=6x=54) with somatic chromosomes number ranging from 2n= 47-60 (Dowrick, 1953) with sporophytic type of self-incompatibility (Drewlow et al., 1973) involving more than one locus (Petty et al., 2003). Type of SI and its mechanism facilitates the development and production of F1 hybrid chrysanthemum cultivars seeds for use in cut flower, bedding and pot plant industries (Zagorski et al., 1983). Interspecific hybridization clearly provides an effective means of cultivar improvement in chrysanthemum. The SI mechanism in chrysanthemum was demonstrated as change in sexual organs during pollination in cv. Lineker Salmon' and Lineker White'

Mutation breeding

Induced mutagenesis is very effective in chrysanthemum breeding method, as confirmed in the past by many researchers. In India, the success of mutation breeding in ornamentals is quite impressive. Chrysanthemum when exposed to the effect of mutagen, most often the colour of the inflorescence changes which determines the decorative value of cultivars.

Advances in genetic engineering

Genetic transformation so far is the most potent tool for breeding ornamental plants. The ability to regenerate whole plants from tissue culture is a prerequisite for most transformation systems and has been achieved in D. grandiflora by a number of groups using various species and cultivars, basal media, different plant growth regulator (PGR) and media additive combinations and concentrations, derived organogenesis from a number of explant sources including: stems (nodes and internodes), axillary buds, leaves, shoot tips or apical meristems, protoplasts, roots, pedicels and florets.

Yellow *Chrysanthemum* × *morifolium*	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Asterales
Family:	Asteraceae
Subfamily:	Asteroideae
Supertribe:	Asterodae
Tribe:	Anthemideae
Genus:	*Chrysanthemum* L.
Type species	
Chrysanthemum indicum L.	
Synonyms	
• *Chrysanthemum* subsect. *Dendranthema* (DC.) DC. ex Kitam. • *Neuractis* Cass. • *Pyrethrum* sect. *Dendranthema* DC. • *Leucanthemum* (Tourn.) L. • *Dendranthema* (DC.) Des Moul. • *Pyrethrum* sect. *Dendranthema* DC.	

List of chrysanthemum cultivars released by different institutes in India

Institutes	Hybridization	Selection	Mutation
NBRI, Lucknow	Ajay, Appu, Apsara, Apurva, Apurva Singar, Arun Kumar, Arun Singar, Bindiya, Birbal Sahani, Dhawal, Diana, Gauri, Gulal, Guldasta, Haldighati, Hemant Singar, Himanshu, Jaya, Jayanti, Jubilee, Jwala, Jyoti, Jyotsna, Kargil 99, Kaumudi, Kiran, Kirti, Kundan, Lal Kila, Lalima, Lalpari, Lilith, Maghi, May-Day, Mayur, Meghdoot, Mini-Queen, Mohini, Mother-Teresa, NBRI Pushpangadan, NBRI Khoshoo, NBRI Kaul, NBRI Himanshu, NBRI Little Orange, NBRI Little Hemant, NBRI Little Kusum, NBRI Little Pink, NBRI Yellow Bud Sport, Neelima, Niharika, Nirmal, Pancho, Peet Singar, Phuhar, Priya, Prof. Harris, Puja, Ragini, Rangoli, Sadbhavna, Shanti, Ratna, Sharda, Sharad Kanti,' Sharad Kumar, Sharad Mala		Sharad Mukta, Sharad Sandhya, Sharad Shobha, Sharad Singar, Shizuka, Shyamal, Suhag Singar, Sujata, Suneel, Sunayana, Suparna, Surekha Yellow, Surya, Swarn Singar, Sweta Singar, Tushar, Vandana, Vasantika, Vijay, Vijay Kiran, Vinaya, White Charm, White Profile, Y2K, Yellow Charm, Yellow Prolific, NBRI Yellow Bud Sport.
IARI, New Delhi		Pusa Aditya, Pusa Sona, Pusa Anmol, Pusa Chitraksha, Pusa Guldasta, Pusa Shwet	Pusa Arunodya, Pusa Kesari
IIHR, Bengalore	Arka Ganga, Arka Pink Star, Arka Ravi Arka Swarna, Chandrakant, Chandrika, Indira, Kirti, Nilima, Pankaj, Rakhee, Ravikiran, Red Gold, Yellow Star, Yellow Gold, Usha Kiran		
PAU, Ludhiana	Anmol, Baggi, Gul-E-Sahir, Royal Purple, Yellow Delight, Autumn Joy, Garden Beauty, Winter Queen, Punjab Gold, Punjab Shyamli		
YSP, Nauni		Solan Shringar	
TNAU, Coimbatore	CO 1, CO2, MDU		

Table.2 List of mutant variety released by different countries (Mutant Variety Database, 2017)

Countries	Varieties released	
Belgium	7	Marconi, Copper Marconi, Red Marconi, Dark Red Marconi, Torino, Dark Torino, Yellow Torino
Brazil	3	Repin Rosa, Ingrid, Cristiane
China	19	Xishihanxiao, Chuntao, Yingsidai, Mantianxin, Zixia
India	49	Agnisikha, Navneet, Subama, Sonali, Surekha Yellow, Sharad Har, Navneet Yellow, Jugnu, Batik, Raktima, Kesar, Lalima Tubular
Japan	56	Amazon, Araddin, Baiogiku Rainbow orange, Baiogiku Rainbow Peach, Baiogiku Rainbow Pink, Baiogiku Rainbow Red, Baiogiku Rainbow White, Baiogiku Rainbow Yellow, Yellow Prism etc
The Netherlands	80	Amber Boston, Apricot Impala, Blue Star, Blue Winner, Bronze Star, Dark Milos, Yellow Winner, Yellow Westland, Yellow Clingo etc
Germany	34	Izetka Filmstar Bronze, Izetka Herbstgold, Ilzetka Kopenicker Barbarossa Rotstern, Izetka Marienhain Cremeweiss etc
Poland	6	Lady Amber, Lady Bronze, Lady Salmon etc
Russian	17	Radii, Saputnik, Selena, Sointse, Saturn etc
Vietnam	3	VCM 1, VCM 2, VCM 3
Korean Republic	2	ARTI Purple, ARTI Queen
Thailand	1	Golden Cremon

Table.3 Some of the genetic transformation studies in chrysanthemum

Species/Cultivars	Foreign genes	References
Dendranthema grandiflora	NPT II, GUS	(Van Wordragen *et al.*, 1991)
***Dendranthema grandiflora* cv. 'Yellow Spider'**	GUS, NPT II	(Pavingerova *et al.*, 1994)
***Dendranthema grandiflora* cv. 'Kitamura'**	NPT II, GUS	(Seiichi *et al.*, 1995)
***Dendranthema grandiflora* cvs. 'Polaris', 'Hekla', 'Iridon'**	GUS, NPT II	(Sherman *et al.*, 1998)
***Dendranthema grandiflora* cv. 'Peach Margaret'**	NPT II	(Boase *et al.*, 1998)
Dendranthema grandiflora	GUS	(Seo *et al.*, 2003)

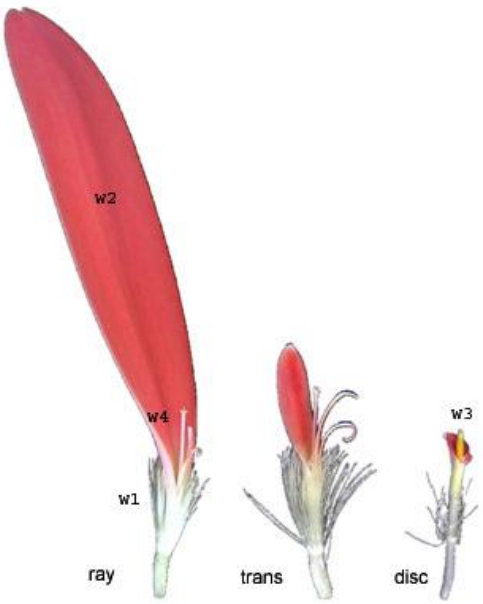
Gerbera

Genetics and Breeding of Gerbera:

There are about 40 species which are half hardy and perennial in nature. Important species are G. jamesonii, G. uirdifolia, G. asplenifolia, G. aurantiaca, G. kunzeana; G. aberdaria, G. abyssinica, G. ambigua, G. anadria, G. bojeri, G. bracteata, G. chiliensis, G. eineraria, G. elliptica, G. krausii, G. tuberosa, G. tomentosa, etc. Diploid and tetraploids forms exist. The basic no. of chromosome is 25. Increase in number of chromosomes has shown useful effects on plant and flower size.

Floral Biology

The sunflower family (Asteraceae) is characterized by head-like inflorescences (capitula) that resemble single solitary flowers but are typically composed of tens to hundreds of flowers that are often specialized in structure and function. In gerbera, three different flower types are distinguished: the marginal ray flowers, the central disk flowers and the intermediate trans flowers. The presence of different flower types within a single genotype makes gerbera a unique target for developmental and evolutional studies since the traditional model plants for flower development (e.g. *Arabidopsis*, *Petunia* and *Antirrhinum*) bear only single flower forms in their inflorescences.



In each three flower types, four whorls of flower organs can be found:

- *Whorl 1* - Flowers of Asteraceae lack conventional sepals, but in most genera, including gerbera, the base of the corolla is surrounded by hairy pappus bristles, specialized organs that are involved in seed dispersal.
- *Whorl 2* - Gerbera flowers usually have five petals. Dorsal petals are thin and threadlike in ray and trans florets while lateral and ventral petals are fused together to form a ligule-like structure. This creates the typical bilaterally symmetrical shape of these flowers (zygomorphy). In central disc flowers, petals are shorter and less fused and ultimately, the centermost flower is radially symmetrical (actinomorphic) with separate petals.
- *Whorl 3* - Although stamen development starts similarly in all types of flowers, the mature ray and trans flowers have only female sex organs. That is because anthers arrest at early stages of development resulting in the formation of nonfunctional staminodes. In disc flowers, anthers develop fully and form a postgenitally fused structure that covers the carpel (the yellow structure visible in the figure).
- *Whorl 4* - Gerbera flowers have one pistil made of two joined carpels. The ovary is inferior located below the floral organs.

Different level of sterility exists and plants could be divided into:

(i) Completely self-sterile plants,

(ii) Plants with distinct differences in seed set when pollination takes place within inflorescence, and when pollination takes place between neighbouring inflorescence on the same plant and

(iii) Plants in which these differences were less pronounced. For the production of hybrid seed first two types are suitable whereas third type was less favourable due to frequent selfing.

In gerbera, productivity is due to additive gene effects. High heritability in G. jamesonii for inflorescence diameter and number of ray florets and relatively low for disc diameter and stem length has been reported. The numerous cultivars of gerbera have been developed through mostly hybridization and through mutation.

The development of gerbera plants from seed till flowering takes 3-4 years. The seeds are to be sown immediately after harvest otherwise they lose viability. Seedling stage continues for about one month, the juvenile stage continues up to 4-5 months whereas the reproductive stage continuous 3-4 or more years.

Varietal Wealth of Gerbera:

Gerbera is very rich in its varietal wealth due to ease in hybridization and survival of seedlings. Thousands of cultivars have been developed which are highly suitable for commercial production of cut flowers under open as well as under green-house conditions. Several varieties suitable for pot culture which are characterized by their bushy nature, dwarf, bearing large number of flowers, may be, somewhat little smaller in size have also been developed.

According to flower size also cultivars are grouped into large and mini types.

Similarly according to flower stem length, varieties are grouped as follows:

Tall varieties—when flower stem length is more than 50 cm. e.g. Funda, Diablo, Sunanda, Dark Red ; medium—(40-50 cm)—Ornella, Sun set, Thalassa, Tavila, Kolika, Ruby Red, Pink Elegance, Rose bella; Dwarf—(30-40 cm)—J.S. Lai, Alemasa, V. Record, Janson Hybrid, Verasace, Indu Kumari, Yellow Queep, Gen Khaiser, Nebulusa, Red Monarch, Sangria. The performances of varieties greatly vary from region to region and flower quality differs area wise.

Under Indian conditions, the popular gerbera varieties amongst commercial growers are: Jaffa, Sangria, Rosula, Oprat, Romona, Salina, Tecora, Starlight, Aida, Venturi, Ornella, Aalasmeer, Goliath, Pink Elegance, Rosa lina, etc.

Other important varieties of gerbera from Terra Nigra, Holland are being propagated and marketed by M/s Germini Agro Pvt. Ltd., Pune. These varities are Cariba (Red), Lamborshini (Red), Bliss (Red), Dino (Yellow), Gucci (Yellow), Flow Basic (Pink), Grizzly (Pink), Cauca (Orange), Virginia (White), White Grizzly (White), Aligator (Violet), Crossroad (Yellow with red center), Solemio (Yellow with orange center), etc.

A white *Gerbera* × *hybrida*	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Asterales
Family:	Asteraceae
Subfamily:	Mutisioideae
Tribe:	Mutisieae
Genus:	*Gerbera*

L. 1758 *non* Boehmer, 1760 (Asteraceae) *nec* J.F.Gmel., 1791[1]

Synonyms[2]

- *Gerbera* sect. *Piloselloïdes* Less.
- *Lasiopus* Cass.
- *Piloselloides* (Less.) C.Jeffrey ex Cufod.
- *Berniera* DC.
- *Atasites* Neck.

The characteristics of different large and mini varieties as reported by nurserymen are given in following tables:

Important Varieties of Gerbera and Their Brief Characteristics

Name	*Colour*	*Type*	*Flower Diameter (gm)*	*Length*	*Production/m² (7 plants/m²) flower/year in igreen house*
Beauty	Red	Double	10-12 cm	Long	140-150
Red Favourite	Red	Double	10-12	Medium	130-140
Sângria	Red	Double	10-12	Long	130-140
Sunny Boy	Red	Double	10-12	Medium	140-150
Darobel	Pink	Double	10-12	Medium	140-150
Fiona	Pink	Dorbla	10-12	Long	140-150
Pinkas	Pink	Double	10-12	Long	140-150
Rosabella	Pink	Double	10-12	Long	140-150
Ornella	Orange	Double	12-13	Long	160-170
Optima	Orange	Double	10-12	Medium	140-150
Sunset	Orange	Double	10-12	Long	140-150
Tara	Orange	Double	10-12	Medium	130-140
Junkfrau	White	Double	10-12	Medium	140-150
Olivia	White	Double	10-11	Medium	130-140
White Sun	White	Single	10-11	Long	140-150
Lila bella	Violet	Double	12-13	Long	130-140
Blue bell	Violet	Double	10-12	Long	140-150
Aruba	Yellow	Semi Double	10-12	Long	130-140
Golden Fever	Yellow	Semi Double	10-12	Long	140-150
Golden Gate	Yellow	Semi Double	10-12	Medium	140-150
Gold Spot	Yellow	Semi Double	10-12	Medium	130-140
Sun Dance	Yellow/Orange	Semi Double	10-11	Long	130-140
Molina	Purple/Pink	Double	12-13	Long	150-160

China Aster

Its common names include **China aster** and annual **aster**. It is native to **China** and Korea. and it is cultivated worldwide as an ornamental plant in cottage gardens and as a cut flower.

Genus: Callistephus; Cass.

Species: C. chinensis

Family: Asteraceae

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
(unranked):	Asterids
Order:	Asterales
Family:	Asteraceae
Tribe:	Astereae
Genus:	***Callistephus*** Cass.
Species:	***C. chinensis***
Binomial name	
Callistephus chinensis	

Morphology

- It is a half hardy annual, plants are erect with branching habit.
- Plants are erect bearing alternate, broadly ovate or triangular-ovate, irregularly toothed leaves.
- Flowers are solitary. Blooms contain two kinds of florets: ray florets and disc florets. The discs are short and ray florets are long.
- Semi-double or double.
- It has a wide array of varieties and the height ranges from 6 inches to 3 feet.
- They have daisy-like or star-like flower heads (4-6" in diameter) with a yellow center often tall stems.

Their colors vary from white to creamy yellow, pink, blue, red and purple.

Floral Biology

- China aster is a self-pollinated crop, approximately 10% of natural crossing
- Flower head consists of both pistillate ray florets and perfect disc florets.

Normally, the stamens and pistils do not mature simultaneously in the individual flowers.

Floral characters:

Inflorescence: A head or capitulum, consisting of a few or large number of flowers or florets closely arranged on an axis surrounded by involucral bracts. The whole head or capitulum is apparently similar to a single flower because the involucral bracts perform the function of protection.

In Helianthus the outer or peripheral, ligulate and zygomorphic florets are called ray-florets; whereas inner or central, tubular and actinomorphic ones are called disc-florets.

In capitulum or head the form of flowers and distribution of sex also varies.

On the basis of form of flowers the heads are of three types:

1. Heterogamous or radiate heads. The outer or ray-florets are ligulate and zygomorphic and inner or disc-florets tubular and actinomorphic e.g. Helianthus.
2. Homogamous-rayed or ligulate heads. All the flowers in the head are ligulate, zygomorphic and alike; e.g. Sonchus.
3. Homogamous-non-rayed or discoid heads. All the flowers are tubular, actinomorphic and alike, e.g., Ageratum.

Distribution of sex:

The flowers of a head may be all hermaphrodite (Ageratum), or ray-florets are female or neuter and inner ones hermaphrodite, or male; rarely the complete head bears unisexual flowers.

Flower: Bracteate, sessile, (Sonchus, Ageratum), complete or incomplete, hermaphrodite or unisexual, pentamerous, tubular (actinomorphic) or ligulate (zygomorphic), epigynous and inconspicious.

Ray-florets: Zygomorphic, ligulate, pistillate, or neuter or sometimes also bisexual, epigynous.

Calyx: Modified into pappus or absent or scale-like.

Corolla: Petals 5, gamopetalous, highly coloured, ligulate, strap-shaped, valvate.

Androecium: Absent.

Gynoecium: Either absent or if present then bicarpellary, syncarpous, inferior, unilocular with basal placentation, one anatropous ovule; style one; stigma bifid.

Fruit: Absent; if present cypsela.

Seed: Non-endospermic.

Floral formula:

Br. ♂♀ ☿ or neuter K pappus C (5) A0 $\underline{G(\overline{2})}$ or 0.

Disc florets:

Flower: Bracteate, sessile, complete, hermaphrodite, actinomorphic, pentamerous, epigynous and tubular.

Calyx: Modified into pappus or scale, persistent.

Corolla: Petals 5, gamopetalous, tubular, coloured.

Androecium: Stamens 5, epipetalous, syngenesious, dithecous, introrse, dehiscing longitudinally.

Gynoecium: Bicarpellary, syncarpous, inferior, unilocular with single anatropous ovule, basal placentation; style simple, long, stigma bifid.

Fruit: Cypsela.

Seed: Non-endospermic.

Pollination: Entomophilous.

Floral formula:

Br ⊕ ☿ K pappus $\underset{(5)}{\overset{\frown}{C}}$ $A_{(5)}$ $G_{\underline{(\overline{2})}}$.

Distribution of Asteraceae:

The family is commonly known as Sunflower family. It is the largest family of dicotyledons, comprising 950 genera and 20,000 species, out of which 697 species occur in India. They are world wide in distribution and abundant in tropics and in cold arctic or alpines regions.

Gaillardia

Gaillardia (common name **blanket flower**) is a genus of flowering plants in the sunflower family, Asteraceae, native to North and South America. It was named after Maître Gaillard de Charentonneau,[5][6] an 18th-century French magistrate who was an enthusiastic botanist. The common name may refer to the resemblance of the inflorescence to the brightly patterned blankets made by Native Americans, or to the ability of wild taxa to blanket the ground with colonies. Many cultivars have been bred for ornamental use.

Gaillardia	
Gaillardia pulchella	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Asterales
Family:	Asteraceae
Subfamily:	Asteroideae
Supertribe:	Helianthodae
Tribe:	Helenieae
Genus:	*Gaillardia* Foug.
Synonyms	
• *Guentheria* Spreng.	
• *Galordia* Raeusch.	
• *Polypteris* Less.	
• *Calonnea* Buc'hoz	
• *Cercostylos* Less.	
• *Othake* Raf.	
• *Agassizia* A.Gray & Engelm.	

Description

These are annual or perennial herbs or subshrubs, sometimes with rhizomes. The stem is usually branching and erect to a maximum height around 80 centimeters (31.5 inches). The leaves are alternately arranged. Some taxa have only basal leaves. They vary in shape. They are glandular in most species. The inflorescence is a solitary flower head. The head can have 15 or more ray florets, while some taxa lack any ray florets. They can be almost any shade of yellow, orange, red, purplish, brown, white, or bicolored. They are sometimes rolled into a funnel shape. There are many tubular disc florets at the center of the head in a similar range of colors, and usually tipped with hairs. The fruit usually has a pappus of scales.

Ecology

Gaillardia species are used as food plants by the caterpillars of some Lepidoptera species, including *Schinia bina* (which has been recorded on *G. pulchella*), *Schinia masoni* (which feeds exclusively on *G. aristata*) and *Schinia volupia* (which feeds exclusively on *G. pulchella*).

Symbolism

The school colors of Texas State University are maroon and old gold, a combination inspired by the gaillardia.

Species

Species include:

- *Gaillardia aestivalis* (Walter) H.Rock – lanceleaf blanketflower southeastern USA
- *Gaillardia amblyodon* J.Gay – maroon blanketflower - Texas
- *Gaillardia aristata* Pursh – common gaillardia - Canada, northern + western USA
- *Gaillardia arizonica* A.Gray – Arizona blanketflower - Sonora, southwestern USA
- *Gaillardia cabrerae* (Lihue Calel, Argentina)
- *Gaillardia coahuilensis* B.L.Turner – bandanna daisy - Coahuila, Texas
- *Gaillardia comosa* A.Gray - northern Mexico
- *Gaillardia doniana* (Hook. & Arn.) Griseb. - Argentina
- *Gaillardia gypsophila* B.L.Turner - Coahuila
- *Gaillardia henricksonii* B.L.Turner - Coahuila
- *Gaillardia megapotamica* (Spreng.) Baker - Argentina – *boton de oro*
  - *Gaillardia megapotamica* var. *radiata* (San Luis, Argentina)
  - *Gaillardia megapotamica* var. *scabiosoides*
- *Gaillardia mexicana* A.Gray - northeastern Mexico
- *Gaillardia multiceps* Greene – onion blanketflower - Arizona, Texas, New Mexico
- *Gaillardia parryi* Greene – Parry's blanketflower - Utah, Arizona

- *Gaillardia pinnatifida* Torr. – red dome blanketflower - northern Mexico, western USA
- *Gaillardia powellii* B.L.Turner - Coahuila
- *Gaillardia pulchella* Foug. – firewheel - southern + central USA, central Canada, northern Mexico
- *Gaillardia serotina* (Walter) H. Rock - southeastern USA
- *Gaillardia spathulata* A.Gray – western blanketflower - Utah, Colorado
- *Gaillardia suavis* (A.Gray & Engelm.) Britton & Rusby – perfumeballs - northeastern Mexico, south-central USA
- *Gaillardia tontalensis* (San Juan Province, Argentina)
- *Gaillardia turneri* Averett & A.M.Powell - Chihuahua

Hybrids[edit]

- *Gaillardia* × *grandiflora* hort. ex Van Houtte [*G. aristata* × *G. pulchella*]

Formerly placed here

- *Helenium amarum* (Raf.) H.Rock var. *amarum* (as *G. amara* Raf.)
- *Tetraneuris acaulis* (Pursh) Greene var. *acaulis* (as *G. acaulis* Pursh)

Zinnia

Zinnia is a genus of plants of the sunflower tribe within the daisy family. They are native to scrub and dry grassland in an area stretching from the Southwestern United States to South America, with a centre of diversity in Mexico. Members of the genus are notable for their solitary long-stemmed flowers that come in a variety of bright colors. The genus name honors German master botanist Johann Gottfried Zinn (1727–59).

Zinnia flower	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Asterales
Family:	Asteraceae
Subfamily:	Asteroideae
Supertribe:	Helianthodae
Tribe:	Heliantheae
Genus:	*Zinnia* L.
Type species	
Chrysogonum peruvianum L.	
Synonyms[1][2]	
• *Sanvitaliopsis* Sch.Bip. ex Greenm. • *Sanvitaliopsis* Sch.Bip. ex Benth. & Hook.f. • *Tragoceros* Kunth • *Lejica* Hill ex DC. • *Lepia* Hill • *Diplothrix* DC. • *Crassina* Scepin	

Zinnias are annuals, shrubs, and sub-shrubs native primarily to North America, with a few species in South America. Most species have upright stems but some have a lax habit with

spreading stems that mound over the surface of the ground. They typically range in height from 10 to 100 cm tall (4" to 40"). The leaves are opposite and usually stalkless (sessile), with a shape ranging from linear to ovate, and a color ranging from pale to medium green. The flowers have a range of appearances, from a single row of petals to a dome shape. Zinnias may be white, chartreuse, yellow, orange, red, purple, or lilac.

Accepted species

- *Zinnia acerosa* – Arizona, New Mexico, Texas, and Utah in the United States; Coahuila, Durango, Michoacán, Nuevo León, San Luis Potosí, Sonora, and Zacatecas in Mexico.
- *Zinnia americana* – Chiapas, Guerrero, Honduras, Jalisco, Michoacán, México State, Nayarit, Nicaragua, Oaxaca, and Veracruz.
- *Zinnia angustifolia* – Chihuahua, Durango, Jalisco, San Luis Potosí, and Sinaloa.
- *Zinnia anomala* – Texas; Coahuila, and Nuevo León.
- *Zinnia bicolor* – Chihuahua, Durango, Guanajuato, Jalisco, Nayarit, and Sinaloa.
- *Zinnia citrea* – Chihuahua, Coahuila, and San Luis Potosí.
- *Zinnia elegans* from Jalisco to Paraguay; naturalized in parts of United States.
- *Zinnia flavicoma* – Guerrero, Jalisco, Michoacán, and Oaxaca.
- *Zinnia grandiflora* – Arizona, Colorado, Kansas, New Mexico, Oklahoma, and Texas; Chihuahua, Coahuila, Nuevo León, Sonora, and Tamaulipas.
- *Zinnia haageana* – Guanajuato, Jalisco, México State, Michoacán, and Oaxaca.
- *Zinnia juniperifolia* – Coahuila, Nuevo León, and Tamaulipas.
- *Zinnia maritima* – Colima, Guerrero, Jalisco, Nayarit, and Sinaloa.
- *Zinnia microglossa* – Guanajuato and Jalisco.
- *Zinnia oligantha* – Coahuila.
- *Zinnia palmeri* – Colima, Jalisco
- *Zinnia pauciflora* Phil.
- *Zinnia peruviana* – widespread from Chihuahua to Paraguay including Galápagos and West Indies; naturalized in parts of China, South Africa, and the United States.
- *Zinnia pumila* A.Gray
- *Zinnia purpusii* – Chiapas, Colima, Guerrero, Jalisco, and Puebla.
- *Zinnia tenuis* – Chihuahua.
- *Zinnia venusta* – Guerrero.
- *Zinnia zinnioides* (Kunth) Olorode & Torres

formerly included

see *Glossocardia Philactis*

- *Zinnia bidens* – *Glossocardia bidens*
- *Zinnia liebmannii* – *Philactis zinnioides*

Zinnia elegans, also known as *Zinnia violacea*, is the most familiar species, originally from the warm regions of Mexico being a warm–hot climate plant. Its leaves are lance-shaped and sandpapery in texture, and height ranges from 15 cm to 1 meter.[5]

Zinnia angustifolia is another Mexican species. It has a low bushy plant habit, linear foliage, and more delicate flowers than *Z. elegans* – usually single, and in shades of yellow, orange or white. It is also more resistant to powdery mildew than *Z. elegans*, and hybrids between the two species have been raised which impart this resistance on plants intermediate in appearance between the two. The *Profusion* series, with both single and double-flowered components, is bred by Sakata of Japan, and is among the most well-known of this hybrid group.

Carnation

Dianthus caryophyllus, commonly known as the **carnation** or **clove pink**, is a species of *Dianthus*. It is probably native to the Mediterranean region but its exact range is unknown due to extensive cultivation for the last 2,000 years.

Dianthus caryophyllus	
Red carnations	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Order:	Caryophyllales
Family:	Caryophyllaceae
Genus:	*Dianthus*
Species:	***D. caryophyllus***
Binomial name	
Dianthus caryophyllus L.	

Marigold

Tagetes erecta, the **Mexican marigold** or **Aztec marigold**, is a species of the genus *Tagetes* native to Mexico. Despite its being native to the Americas, it is often called **African marigold**. In Mexico, this plant is found in the wild in the states of México, Puebla, and Veracruz.

This plant reaches heights of between 20 and 90 cm (7.9 and 35.4 in). The Aztecs gathered the wild plant as well as cultivating it for medicinal, ceremonial and decorative purposes. It is widely cultivated commercially with many cultivars in use as ornamental plants, and for the cut-flower trade.

Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Asterales
Family:	Asteraceae
Genus:	*Tagetes*
Species:	***T. erecta***
Binomial name	
Tagetes erecta L.	

Lecture No. 17 - 19

Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental and flower crops *viz*.

Tuberose, Gladiolus, Lilium

Breeding of Tuberose

- Tuberose is a widely cultivated crop grown in India for use as a cut flower, loose flower and in perfumery industry.
- The haploid chromosome number of tuberose is 30, among these 5 are large and 25 are small.
- The somatic chromosome number is 2n=2x=50
- Single cultivars are fertile used in perfumery and seed setting erratic with 2n=2x=60.
- Double cultivars are fertile and used as cut flower. Seed setting is not observed in double cultivars.
- The genetic variability available in tuberose is very limited and available named varieties are very few in India
- Non-availability of genetic variability has become a major constraint in conventional breeding of tuberose.

Cultivars:

- There are three types of tuberose viz.
  - Single cultivars with one row of corolla segments. These are extensively used as loose and for extraction of essential oil.
  - Semi-double bearing flowers with two to three rows of corolla segments. Spikes are straight and flowers are usually white. It is generally cultivated for cut flower purpose.
  - Double cultivars with more than three rows of corolla segments. Flowers are also white in colour but tinged with pinkish red.
- Single cultivars is more fragrant and is widely cultivated than the other types. Rajat Rekha, Prajwal, Shringar, Calcutta Single and Mexican Single are examples of single cultivars.
- Double cultivars are mostly used as a cut flower and include Swarna Rekha, Suvasini, Vhaivav, Arka Nirantara, Calcutta Double, and Mexican Double.

Breeding objectives:

- To develop varieties with enhanced vase life.
- To develop varieties resistant to various diseases like Sclerotium wilt, leaf blight, etc.
- To develop varieties resistant to various insect pests.
- To develop varieties which are demanded in domestic and international market for varied colour and fragrance.
- To develop varieties for the production of tuberose oil.
- To develop varieties for improved yield and quality
- Develop varieties with new and rare colors.

Techniques of breeding:

Hybridization

- In 1899, the first hybrid in this group was produced by Polianthes (Bravoa) geminifera and P. (Prochnyanthes) bulliana.
- However, the first cross involving tuberose was reported in 1911 as *Polianthes* x *blissii*, a cross between *Polianthes geminiflora* and *P. tuberosa*.
- Tuberose (*Polianthes tuberosa* L.) has the characters of dichogamy and self-incompatibility.
- Crosses between single and double varieties produce fruits and seeds when the female parent is 2–3 days after anthesis.

Mutation breeding

- Mutation breeding can be utilized to develop improved strains.
- Several mutagens like radiation, ultraviolet light and a variety of chemicals have been utilized for this purpose.
- By treating the bulbs with gamma rays and fast neutrons, several mutants of ornamental value have been obtained by various workers. They showed colour variation in leaves but not flowers.
- Two mutants, viz. Rajat Rekha (single) and Swarna Rekha (double) were obtained through gamma irradiation (1 to 5 kr) at the NBRI.
- In Rajat Rekha there are silvery white streaks along the middle of the blade, whereas in Swarna Rekha golden-yellow streaks are present along the margins of the blade.

Breeding of Gladiolus

Gladiolus is one of the most important bulbous flowering crops grown commercially for cut flower trade in India.

- Breeding work in gladiolus has been carried out at IARI, New Delhi; IIHR, Bangalore; NBRI, Lucknow, IHBT, Palampur and Horticulture Experiment and Training Centre, Chaubattia.
- Gladiolus is hermaphrodite in nature, so new cultivars are evolved through hybridization and mutation. It belongs to family Iridaceae.
- The basic chromosome number in the genus is 30 but the number present in the typical modern gladiolus is 60.
- Many features and characteristics of gladiolus show a gradual variation from one extreme to another. It is primarily due to its polyploidy nature.
- Breeding work in gladiolus has been initiated with following objectives.

Objectives:

- To develop new cultivars with improved plant growth.
- To get better spike quantity.
- To develop new colour.
- To get desired size and form florets.
- Symmetrical arrangement of the florets on the spike.
- Bud counts and compactness.
- High rate of corm and cormel multiplication.
- Stem types such as slenderness and flexibility to high wind.
- Resistance to pests and diseases.

Important groups and species of gladiolus:

On the basis of their geographical origin, botanists listed the gladiolus species into four groups viz.

1. Eurasian group
2. East African group
3. Natalensis group

4. South African Cape species

Table. Species distribution and characteristics of some gladiolus groups

Group	Species	Distribution	Remarks
Eurasian	*G.atroviolaceous*	Syria, Jordan valley, Lebanon and Near East	Flat leaves and irrespective of weather conditions, shoots emerge during February and flower during May to July
	G. byzantinus	West and South East Europe	Narrow leaves and the first leaf is sword like and stem is branched. Cormels have net like husk and it protects even at -15°C
	G. communis	Near East, USSR, Western Asia and parts of eastern Europe	Unbranched stem with few leaves and 4-8 florets
	G. cardinalis	South Africa	Arching stem with 5-7 buds with scarlet red flowers reversing upward on the stem and grows in upland near waterfalls
	G. floribundus sp. *miniatus*	South Africa	Upright flowers which are large and plain rose pink and plant height is about 60 cm
	G. floribundus subsp. *rudis*	South Africa	Light pink flowers facing upright with three yellow lilac blotches formed on 40 cm tall plant
East Africa	*G. aequinoctalis*	South, South West and West Africa	Strong fragrance, thin drooping stem with 5-7 star shaped florets with tubular neck. Grows well in wetlands and is a triploid
Natalensis	*G. psittacinus* ***var***. *hookeri*	All over the world	Pentaploid (5n=75), grows 1.75 m tall, late flowering and takes 190 days from planting to flowering, self sterile and highly prolific
	G. psittacinus var. *cooperi*	Africa	Less prolific with muddy greenish yellow flowers
	G. psittacinus var. *dracocephalus*	Africa	Narrow pointed flower, maroon and green speckled
	G. primulinus	South Africa	Small sized flowers, clear yellow colour, heavily veined with orange lines
South African Cape	*G. maculatus*	South Africa	Strongly fragrant with freesia like flowers

Species			
	G. odoratus	South Africa	Slightly fragrant, 6-9 flowers fromed on 30-40 cm long, slender erect stem
	G. oppositiflorus	South Africa	Very tall plant, grows upto 15 cm with 20-30 buds of which 15-18 will fully open at a time in pairs and top petals is hooded
	G. orchidiflorus	South Africa	Florets resemble orchids with throat markings in 3 lower petals which appear in 15-25 cm long shoots and sweetly fragrant
	G. saundersii	South Africa	Fan shaped leaves arise from the centre of the flat corm, stem is erect with 5-7 buds
	G. sempervirens	South Africa	Evergreen leaves 10-12 in number and root is intermediate between corm and rhizome with a number of fleshy roots. Stem is very thin and the flowers held in erect in strong winds
	G. tristis	South Africa	Florets are 3-10, spaced widely on the stems which are fragrant during evening. All the six petals are of similar size facing upwards.

Introduction and Selection

Introduction

Evaluation of introduced material at various institutions has resulted into selection of promising cultivars for different regions.

- **IARI, New Delhi:** Apple Blossom, Bis Bis, Melody, Oscar, Sylvia, Patricia, Ratna's Butterfly, Snow Princess, George Mazure
- **Regional Station, Flowerdale, Shimla (IARI, New Delhi):** Camellia, Friendship, Green Woodpecker, Lady Killer, Life Flame, Rose Spire, Stormy Weather, Thunderbird, Old Gold, Blue Lilac, Australian Fair, Sam Smith, Winter Gladioli
- **Regional Fruit Research Station, Mashobra (Shimla):** Anne Virginia, Cardinal Spellman, Double Frills of Pink, La Paloma, Exotic Double Sister Elitz, Florence Nightingale, Kenny, Hawaii, King Lear, La Paloma, Spic and Span
- **IIHR, Bangalore:** Beauty Spot, Cherry Blossom, Friendship, Melody, Picardy, Snow Princess, Watermelon Pink, Wild Rose, Tropic Sea

Hybridization:

- Gladiolus being hermaphrodite has both the male and female organs in the same flower, so the desired combinations are made by choosing either of the parents as male or female.
- With the opening of the flower, the anthers are matured which may be used for pollinating already emasculated females.
- Emasculation and pollinations, both are done in the morning.
- The stigma generally becomes receptive in the third day of the opening of flower or anther maturity.
- If the pollens from freshly opened flowers of the same plant are applied, the seeds are set, provided other conditions remain favourable.
- Emasculation is carried out at bud stage when these have started swelling for opening.
- After pollinations, the flowers are bagged with butter paper bags and tagged with labels mentioning the parents and the date of pollination.

Some varieties developed through hybridization in India are:

- **IIHR, Bangalore:** Meera, Nazrana, Poonam, Sapna, Aarti, Apsara
- **IARI, New Delhi:** Agni Rekha, Mayur, Suchitra, Kum Kum, Dhiraj
- **NBRI, Lucknow:** Manmohan, Manohar, Mukta, Manisha, Mohini, Jwala, Archana, Arun, Sanyukta, Priyadarshini, Trilokhi, Gazal
- **Horticultural Experiment and Training Centre, Chaubattia, Uttar Pradesh:** Chaubattia 6/4, Chaubattia 14/23, Chaubattia 19/1, Chaubattia 21/10
- **IHBT, Palampur:** Anurag, Brick Beauty, Cute Munni, Palampur Princess, Palampur Queenand Tushar Mauli

Aneuploid Breeding

- Aneuploid varieties namely ‘Archana’ (2n=60) and ‘Arun’ (2n=67) were evolved through hybridization between *Gladiolus psittacinus* ‘Sylvia’ (2n=75) as the female parent with gladiolus ‘Friendship’ and ‘Fancy’ (2n=60) as male parents, repectively.

Mutation Breeding

- Many gladiolus cultivars are available in commerce by spontaneous mutations and only a few through induced ones.
- Two such sports have been reported in the cvs. Salman's Sensation and Ratna's Butterfly. The induced changes mostly revert back in further generations because of diplonitic selection.

Some of the varieties developed by mutations are:

- **Shubangini:** Mutant of 'Fidelo'
- **White Friendship:** Bud sport from cv. Friendship
- **Shakti:** Wild rose induced mutant
- **Swasnima:** Dhanvantari spontaneous mutant
- **IIHR, Bangalore:** Shobha, a mutant with shell pink floret colour of 'Wild Rose'

A. Varieties Evolved at IARI, New Delhi:

VARIETIES	PARENTAGE	REMARKS
Agnirekha	Sylvia Seedlings(1980)	Fire red with saffron yellow blotch and scarlet florets, mid season variety
Anjali	SancerreX Rose Spire(1997)	Florets are scarlet pink with yellow dusting on falls, mid season variety.
Archana	Creamy Green X Amercian Beauty(1997)	Florets are scarlet pink with yellow dusting on falls, mid season variety.
Bindiya	Ratna Butterfly Seedling(1997)	Florets are yellowish cream with fan-shaped red coloration on 2 side falls, it is also a mid season variety.
Chandni	Green Woodpecker X White Butterfly (1997)	Florets are greenish white and early season variety.
Chirag	Cygnet X Little Fawn(1997)	Florets are orange in colour with deeper throat and mid season variety.
Dhanvantri	Jr.Prom X Lucky Star (1995)	Florets are light yellow and mid season variety.
Kamini	Ava X Christian Jane(2000)	Floret colour orange-red with fan-shaped purple red lip on light yellow base on 2 side falls, early mid-season variety.
Lohit	Creamy Green X American Beauty (2000)	Floret colour is red with white mid-ribs on 2 side falls, early mid-season variety.
Mayur	Sylvia Seedlings(1980)	Florets lilac-purple with dark purple throat,

		mid season variety.
Mohini	Ave X Christian Jane(2000)	Floret colour red-purple with fan-shaped deep purple colour on yellow on 2 side fall, early mid-season variety
Neelam	Sylvia X Patricia(1987)	Deep mauve florets, mid season variety
Pusa Suhagin	Sylvia Seedlings(1987)	Florets ruby-red with barium yellow streaks on the lower tepals, late season variety.
Rangmahal	Red Bantam X Flaura Belli (2000)	Florets ruffled, red-purple and compactly arranged, mid season variety.
Sarang	White Oak Seedlings(1997)	Florets purple red and a mid season variety
Shweta	Wind Song X Pink Frost Seedlings(1997)	Florets frilled white with green-yellow throat, mid season variety.
Suchitra	Sylvia SeedlingsX Jo Wagenenaar (1980)	Florets camellia rose with vermillion and purple blotch, mid season variety.
Sukanya	Salmon Queen Seedlings(2000)	Floret colour white with Scarlet ring in the lip, early mid season variety.
Sunayna	George Mazure X Eurovision (1997)	Florets pink with red throat, early variety.
Swapnil	Viola Seedlings (2000)	Florets violet with creamy throat, early blooming
Swarnima	Dhanvantari spontaneous mutant(2000)	Florets coopery yellow, mid-season variety.
Urmil	Tinker Belle X Break O'Dawn (2000)	Florets violet with creamy throat, Early blooming
Vandana	George MazureX Eurovision (1997)	Orange coloured variety, early mid season variety.

B. Varieties Evolved at IIHR, Hessaraghatta, Bangalore

VARIETIES	PARENTAGE	REMARKS
Aarti	Shirley X Melody(1980)	Florets poppy-red with purple-red and canary-yellow blotch, it is a mid season variety
Apsara	Black Hack X Friendship (1980)	Florets ruby-red with barium yellow flecks in throat
Kum Kum	Watermelon Pink X Lady John (1993)	Florets are red with yellow blotch
Meera	G.P.I.X Friendship(1979)	Florets are white
Nazrana	Black Jack X Friendship(1979)	Florets are cardinal-red with barium yellow flash in throat
Poonam	Geliber Herald X R.N.121(1979)	Florets are yellow, spikes 98cm long with 17 florets.

Sagar	Melody X Wild rose(1994)	Florets are yellow, spikes 98cm long with 17 florets.
Sapna	Green Woodpecker X Friendship (1979)	Florets are greenish yellow
Shakti	Wild rose mutant(1981)	Florets are pink yellow throat
Sindur	(1994)	Florets are red with darker blotches and yellow splashes

C. Varieties Evolved at NBRI, Lucknow

VARIETIES	PARENTAGE	REMARKS
Archana	Sylvia X Friendship (1984)	Floret colour purple with yellow blotch and white mid-rib, mid-season variety
Arun	Sylvia X Fancy (1984)	Florets Vermillion and it is a late blooming variety
Basant Bahar	Unias Challenge Seedling	Florets are yellow with magenta specks in throat
Dhiraj	Beauty Spot X *Psittacinus* Hybrid(1993)	Florets are purple with deeper and yellow blotch
Gazel	White Friendship Seedlings	Floret are pink with darker lips and linear shading, having yellow throat
Hans	Friendship X *G.tristis* (1985)	Florets white with falls having mid-rib
Indrani	Friendship X *G.tristis* (1985)	Florets crimson with white mid-rib
Jwala	Psittacinus Hybrid Seedling	Floret vermillion with blotched yellow
Kalima	Sylvia Seedlings	Florets red with 2 side falls blotched yellow
Manhar	Friendship X *G.tristis*(1983)	Florets with rosy tips and yellow throat
Manisha	Friendship X *G.tirstis*(1983)	Florets yellow with purple splashes at tips and this is a late blooming variety
Manmohan	Friendship X *G.tristis* (1982)	Florets yellow with purple and splashes at tips and it is a late blooming variety
Manohar	Friendship X *G.tristis* (1982)	Floret are purple and throat yellow and it is a late blooming variety
Mohini	Friendship X *G.tristis* (1982)	Florets white splashed with rose and throat yellow and late bloomer
Mridula	Friendship X *G.tristis* (1985)	Florets purpled specked at edges with yellow throat and white mid-ribs, mid season bloomer
Mukta	Friendship X *G.tristis* (1981)	Florets sulphur-yellow splashed with purple, late bloomer
Pitamber	Friendship X *G.tristis* (1985)	Florets light green with purple steaks in the throat, a mid-season bloomer
Priyadarshini	Lavanesque seedling	Florets mauve and throat white

Sada Bahar	Sylvia seedling	Florets specked purple with sulphur yellow petal mid-ribs
Sanyukta	Friendship X G.tristis (1984)	Florets rose with primrose-yellow throat and mid-season bloomer
Smita	Lavanesque seedling	Floret rose with dark margins
Triloki	Friendship X G.tristis (1984)	Florets rose with yellow throat and it is a mid-seson blooming variety.

D. Varieties Evolved at HETC,Chaubattia

Horticulture Experiment and Training centre, Chaubattia (Almora) developed four varieties:

Chaubattia Ankur	**Oscar X Friendship**
Chaubattia Arunima	**Oscar X Motherfisher**
Chaubattia Shobhit	**Meria goretti x tropic Sea**
Chaubattia tripti	**Sunny Boy x Oscar**

E. Varieties Evolved at PAU, Ludhiana:

Punjab Dawn (Suchitra X Melody), Punjab Morning (Sancerre X White Prosperity) and Sher-e-Punjab
(Suchitra X Melody)

F. Varieties developed by GB Pant University of Agriculture and Technology, Pantnagar

- **Shubangini:** A mutant of 'Fidelio' developed through gamma radiation. Spikes are 95-100cm long each with 15-18florets. Florets are white, slightly ruffled and 12cm across. Very good multiplier.

G. Variety developed by M.P.K.V., Pune

- **Shree Ganesh:** This variety possesses yellow white floret. Spike length is 115 to 120cm with nearly 19 florets on each spike. The diameter of floret is 10-11cm. Each corm produces 2 corms and 70-80 cormels.

Two more varieties of gladiolus at pre-release stage from this center are Prerna (GK-GL-94-42) and Neelrekha (GK-GLK-94-55)

H. IHBT, Palampur

- Anurag (Her Majesty X Aldebran)
- Brick Beauty (Vink's Glory X Eurovision)
- Cute Munni (Bonfire X Eurovision)
- Palampur Princess (Bonfire X Aldebran)
- Palampur Queen (Green Woodpecker X Oscar)
- Tushar Mauli (Oscar X Friendship)

I. Varieties Developed by B.B.S.Bhadri in Himachal Pradesh

Bhadri (1963) developed some varieties suitable for cultivation in H.P.Some of these varieties are.

1. Bhadri May Blossom 2. Bhadri Dwarf 3. Bhadri Blue 4. Bhadri Bicoloured 5. Bhadri Purple Striped 6. Bhadri Salmon Glow 7. Bhadri Deep Purple Splashed 8. Cherry Glow

9. Bright Red Primulinus 10. Rose of Heaven 11. Morning Kiss 12. Bhadri's Red Giant 13. Bhadri Early Peace 14. Bhadri Yellow Crest 15. Zakir Hussain (6-petalled)

16. Border Gem 17. Zakir Hussain (8-petalled) 18. Bhadri's Simla Sunset 19. Light Mauve (deep mauve strips) 20. Bhadri's Milky Way 21. Light Salmon Pink (throat)

22. Yellow Beauty 23. Bhadri Violet Beauty 24. Bhadri Jupiter 25. Bhadri Elite 26. Bhadri Velvet 27. Bhadri Orange Glow 28. Bhadri Dazzier 29. Bhadri Queen of Pink

30. Bhadri Scarlet 31. Raj Niwas Pride 32. Bhadri's Baby Doll (lighter purple) 33. Bhadri Red & White 34. Bhadri's Red Prince 35. Bhadri Lemon Queen 36. Bhadri' Liliput

37. Bhadri Rose (deep rose, throat veined red) 38. Bhadri's Love Song 39. Bhadri Blazing Star 40. Bhadri Pearl 41. Bhadri Indian Chief 42. Bhadri Tricolour

43. Rare Colour Bhadri Royalty 44. Glory of Raj Niwas 45. Bhadri Bouquet 46. Bhandri Enchantment 47. Bhadri Oriental Charm 48. Bhadri Giant Flowered

49. Bhadri's Fire Dream 50. Bhadi Celestial 51. Bhadri Morning Glory 52. Bhadi Peach Glow 53. Bhadri's Souvenir

Breeding of Lilium

Lilium (members of which are **true lilies**) is a genus of herbaceous flowering plants growing from bulbs, all with large prominent flowers. Lilies are a group of flowering plants which are important in culture and literature in much of the world. Most species are native to the temperate northern hemisphere, though their range extends into the northern subtropics. Many other plants have "lily" in their common name but are not related to true lilies.

The flowers are large, often fragrant, and come in a wide range of colors including whites, yellows, oranges, pinks, reds and purples. Markings include spots and brush strokes. The plants are late spring- or summer-flowering. Flowers are borne in racemes or umbels at the tip of the stem, with six tepals spreading or reflexed, to give flowers varying from funnel shape to a "Turk's cap". The tepals are free from each other, and bear a nectary at the base of each flower. The ovary is 'superior', borne above the point of attachment of the anthers. The fruit is a three-celled capsule.

Species of genus Lilium originate from Asia, Europe, and North America (Bryan, 1989) are mostly vegetative propagated monocot perennials and are one of the economically most important flower bulbs. The genus Lilium (Liliaceae family) comprises around 100 species and more than 9,400 cultivars (International Lily register, http://www.lilyregister.com/). The species of this genus were taxonomically classified into seven sections based on 13 morphological and two germination characteristics. The seven sections are Martagon, Pseudolirium, Lilium (Liriotypus), Archelirion, Sinomartagon, Leucolirion, and Oxypetalum (Comber, 1949; De Jong, 1974). In general, wild species within each section are relatively easy to cross and the hybrids are fertile (McRae, 1990; Van Tuyl et al., 2002).

The interspecific hybrids within the sections especially those within the sections Leucolirion, Archelirion, and Sinomartagon represent the most important breeding groups which are:

1. Longiflorum hybrids (L genome). They originate from intra- or inter-specific hybridization with L. formosanum in the Leucolirion section, have trumpet-shaped, pure white flowers, a distinctive fragrance, year-round forcing ability and mostly outwardfacing flowers (McRae, 1990).

2. Asiatic hybrids (A genome). They are derived from interspecific crosses among at least 12 species of the Sinomartagon section (Leslie, 1982). Their cultivation can be traced to the early 1800s in Japan (Shimizu, 1987). Cultivars of Asiatic hybrid lily have a wide colorvariation in their tepals (orange, white, yellow, pink, red, purple, and salmon) and early to late flowering (Woodcock and Stearn, 1950). Some species in this section show resistance to Fusarium and viruses (McRae, 1998a).

3. Oriental hybrids (O genome). They result from hybridization among five species of the Archelirion section. Generally, Oriental hybrids are late-flowering, with big and showy flowers with a pleasant fragrance (McRae, 1998a). Most species are resistant to Botrytis elliptica that affects most of the lilies from the other sections (Barba-Gonzalez et al., 2005).

Lilies have a wide variety of valuable characters such as flower size, color, flowering time, and resistance to different pathogens. Combining these vital horticultural traits into one cultivar by crossing is almost the only way to obtain introgression of traits, since genetic transformation approaches are not well developed for lily yet. Possibilities for cross combinations in Lilium between the species of the seven sections are limited by incompatibility and incongruity which are due to: pre-fertilization and post-fertilization barriers. To overcome these barriers, integrated methods such as grafted-style, in vitro pollination, embryo rescue, and ovule culture techniques are needed (Van Tuyl et al., 1991).

Using these methods, many lily interspecific hybrids have successfully been made. For instance, *L. longiflorum* (Leucolirion) x *L. rubellum* (Pseudolirium section), *L. longiflorum* x *L. candidum* (Lilium section), *L. longiflorum* x *Asiatic hybrids* (Sinomartagon) (Van Tuyl et al., 2000). However, most of these inter-specific hybrids tend to be sterile (Van Tuyl et al., 2002). Chromosome doubling and 2n gametes (gametes with somatic chromosome numbers) (Ramanna and Jacobsen, 2003) have been used to restore the fertility of inter-specific hybrids in lily. Lilium species have been extensively used for cytological investigation. Basic studies on chromosome identification and karyotype analysis (Stewart, 1947) were conducted. The newer molecular cytogenetic techniques such as FISH (Fluorescent in situ hybridization) and GISH (Genomic in situ hybridization) have enabled researchers to investigate the meiosis and the homoeology of Lilium in detail. The restitution mechanisms that lead to unusual chromosome constitution in 2n gametes have been revealed by GISH (Karlov, 1999; Lim, 2000). BarbaGonzalez (2005) studied

the occurrence of 2n gametes in the F1 hybrids of Oriental × Asiatic lilies and used them for production of sexual polyploids from sterile Oriental × Asiatic hybrids. One of the most important advances has been achieved with the development of diploid backcross progenies (BC1 and BC2) from interspecific Longiflorum x Asiatic hybrids backcrossed to Asiatic cultivars (Khan, 2009; Zhou, 2007). Additionally, meiosis of interspecific hybrids was followed and cytological maps of three complete genomes of lilies (L, A, O) based on the recombination sites in the BC progeny of two interspecific hybrids (Khan et al., 2009) were constructed. On the other hand, genetic mapping of lily has not yet been well studied. So far, RAPD and ISSR markers were used to construct genetic linkage maps and to map anthocyanin and carotenoid pigmentations in the progeny of 'Montreux' x 'Connecticut King' (Asiatic hybrids) (Abe et al., 2002; Nakano et al., 2005). Additionally, RAPD and AFLP markers were used to construct genetic linkage maps and to map Fusarium resistance using progeny of 'Connecticut King' x 'Orlito' (Asiatic hybrids) (Straathof et al., 1996; Van Heusden et al., 2002). Those genetic maps are far from saturation and the marker types difficult to be converted into simple PCR markers. Therefore, more genetic markers need to be added to the map, preferable of a type that is universal.

Breeding objectives

The major objectives in breeding flower bulbs are: flower color, flower morphology, and plant architecture. Other increasingly important traits are: forcing time, yield, vase life, storability of the bulb, vulnerability of the flowers during transport, and disease resistance (Fusarium, Botrytis, and viruses), which are much more difficult to breed for since they are often polygenetic traits (Krens and Van Tuyl, 2011).

Lecture No. 20 & 21

Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental and flower crops *viz*.

Orchid, Anthurium, Heliconia, Antirrhinium (Snapdragon)

****

BREEDING OF ORCHIDS

SCIENTIFIC CLASSIFICATION

- Epidendroideae
- Cypripedioideae
- Apostasioideae Vanilloideae

♣INTRODUCTION

Kingdom: Plantae

Division: Magnoliophyta

Class: Liliopsida

Order: Asparagales

Family: Orchidaceae

ORIGIN:

• Native of tropical countries and found abundantly in humid forests of South and Central America, Mexico, India.

DESCRIPTION:

•Most of them are perennial herbs.

•The family Orchidaceae is largest among flowering plants.

•Orchids grow as Terrestial (land), Epiphytic (on trees), Lithophytic (on rocks) and semi-aquatic.

A}Terrestial orchids- Cymbidium, Paphiopedilum.

B}Epiphytic orchids- Dendrobium, Vanilla, Vanda.

C}Lithophytic orchids- Cymbidium munronianum, Diplomeris hirsute.

D}Semi-aquatic- Rhizanthelta and Cryptanthemis.

VEGETATIVE GROWTH OF ORCHIDS:

1. **Monopodials:** Single stem is the main characteristic of monopodials. They have

vertical growth habit and produce aerial roots. Eg: Arachnis and Vanda. Hanging vandas

2. **Sympodials**: They are characterized by presence of rhizomes or modified bulbs. Growth of stem ceases, usually at end of one seasons growth, and lateral shoots are produced in following season. Eg: *Dendrobium, Cattleya. Cattleya Orchid*

FLORAL BIOLOGY

- Flowers are complete, mostly bisexual.
- Sepals and petals are 3 each in number, in alternate whorls.
- At the top of column is male anther which contain packets of pollen called pollinia.
- Below the anther is stigma, usually sticky cavity.

IMPORTANT ORCHID SPECIES

1. AERIDES : Attractive inflorescence, generally called fox tail orchid Eg: *A.multiflorum, A.adoratum Aerides multiflorum*
2. Arachnis: Beautiful flowers, very popular cut flower
   Eg:*A.annamensis, A.cathcari, A. maggie oei. Arachnis annamensis Arachnis maggie oei 'Red Ribbon'*
3. Calanthe: Produce showy flowers ,prominent pseudo bulbs.
   eg: C.bilobo, C.verstita, C.chloroleuca, C.herbacea. Calanthe bilobo
4. Cattleya: Produce striking colors, flowers large size ,fragrant blooms.
   Eg: C.aurantiaca, C.bicolour, C.labiata, C.maxima Cattleya aurantiaca
5. Coelogyne: Pseudo bulbous stem , free flowering, attractive flowers.
   Eg: C.cristata,C.odoratissima Coelogyne cristata
6. Cymbidium: Most popular commercial orchid. Spikes long, suitable for decoration.
   Eg:C.elegans,C.pendulum,C.grandiflorum,C.longifolium, C.tigrinum Cymbidium elegans
7. Bulbophyllum: Decidious with pseudo bulbous creeping rhizome.
   Eg: B.caryanum, B.cylindracum ,B.rigidum Bulbophyllum caryanum

8. Dendrobium: Second largest genus next to Bulbophyllum . Very popular, produce marvelous large showy flowers, epiphytes.
   Eg:D.crysanthum, D.chrysotoxum, D.densiflorum, D.nobile, D.regium. Dendrobium crysanthum Dendrobium nobile
9. Oncidium: Leaves leathery, a single leaf arise on tip of small pseudo stem.
   Eg: O.ampliatum ,O.crispum,O.papilio, O.luridum Oncidium ampliatum
10. Phaphiopedilum: Called ladies slippers orchid. Spectacular handsome flowers, mostly terristrial, lithophytic and epiphytic.
    Eg: P.bellutulum, P.callosum, P.concolor, P.insigne ,P.venusium, P.farieanum. Phaphiopedilum bellutulum
11. Peristeria: Called as Dove orchid or holy ghost flower .Tall spikes ,white flower.
    Eg: P.elata. Peristeria elata
12. Phaius: Vigorous growing tall clustered stems, showy flowers in racemes.
    Eg: P.grandifolius, P.wallichi, P.blumei. Phaius grandifolius
13. Phalaenopsis: Called moth orchids, very popular, short stemmed, good for cut flower trade .
    Eg: P.amabilis, P.fuscata, P.speciosa ,P.violaceae. Phalaenopsis amabilis Phalaenopsis fuscata
14. Miltonia: Bears short pseudobulbs with two or more narrow flexible leaves flowers in single or in cluster.
    Eg: M.ancepts, M.candida, M.spectabilis, M.stenoglassa. Miltonia ancepts Miltonia spectabilis
15. Odontoglossum: Pseudostem is oval, green with 2-3 leaves, inflorescence in arch shape, large and showy.
    Eg : O.cardatum, O.grande, O.maculatum, O.nobile, O.rossi.
16. Renanthera: Epiphytic, tall growing, free flowering.
    Eg: R.coccinea, R.storie, R.elongata, R.pulchella. Renanthera coccinea Renanthera elongate
17. Rynchostylis : Flowers clustered closely in dense cylindrical drooping raceme, good for hanging baskets.
    Eg: R.retusa ,R.gignatea. Rynchostylis gignatea.Rynchostylis retusa

18. Spathoglottis: Tall and slender inflorescence, attractive, three lobed labellum.

    Eg: S.affinis,S.acerea,S.plicta,S.grandifolia. Spathoglottis affinis Spathoglottis plicta

19. Thunia: Tall bamboo like stems bearing cluster of flowers at top.

    Eg: T.alba, T.marshallina Thunia alba Thunia marshallina

20. Vanda: Very popular, monopodial, epiphytic roots prominent and stout. Produce attractive flowers.

    Eg: V.amesiana, V.bensoniui, V.coerulea, V.cristata. Vanda amesiana Vanda bensoniui

BREEDING OBJECTIVES

- To breed for better YIELD & QUALITY.
- To introduce EARLY FLOWERING.
- To increase the LENGTH OF INFLORESCENCE.
- To increase the number of FLOWERS PER INFLORESCENCE.
- To achieve better COLOUR, SIZE, SHAPE.
- To develop WIDER ADAPTABILITY. >To extend the BLOOMING PERIOD.
- To develop NON STAKING VARIETIES.
- To produce FRAGRANT VARIETIES.
- To develop varieties with better ROOT POLIFERATION.

BREEDING METHODS

1.HYBRIDIZATION

2.MUTATION BREEDING

3.POLYPLIODY BREEDING

4.BIOTECHONOLOGY

2. HYBRIDIZATION

First orchid hybrid is *Calanthe dominyi* (*C. masuca* X *C.fuscata*)

•In 1982, the first sexageneric hybrid *Brilliandeara gary* was registered.

•This is the first sexageneric hybrid in the whole of plant kingdom.

•It has been named in the honour of Gary brilliande, a famous orchid breeder

Steps in hybridization

1. SELECTION OF PARENTS: Select male and female parents depending on characters to be combined.
2. EMASCULATION: Remove pollens of female parent to prevent natural pollination.
3. POLLINATION: Collect pollens from male parent and remove anther cap. Put the pollens in stigmatic cavity and see that it sticks well to stigmatic surface.
4. BAGGING: Tie the bags giving details of male and female parents

Some of the important intergeneric hybrid are :

Aranda (*Arachnis* x V*anda*)θ

Aeridovanda (*Aerides* x *Vanda*)

Vandanopsis (*Phalaenopsis* x *Vanda*)

Important Hybrids

Cymbidium - *King Arthur, Beauty Fred, Sensation Chianti, King Arthur, Sparkle,Sung Gold.*

DENDROBIUM - *Sonia-17, Sonia- 28, Pravit white*

CATTLEYA - Chinese Beauty, Rain Gold, Vertue, Glorious Sunset. Glorious Sunset

VANDA - Princess Mikasa “Dark Blue”, Amphai Princess Mikasa “Dark Blue”

PAPHIOPEDILUM - Harrisianum, Charles Richman, Mint farm Harrisianum

PHALAENOPSIS - Happy Valentine, Sweet Valentine, Taipel Gold, Autumn Gold Happy Valentine

MILTONIA - Ambre London Conference, Playgirl Cha cha Playgirl Cha cha

ODONTOGLOSSUM Blando-nobile,Elegans, Crispania, Geyser Goldθ

ARACHNIS Maggieθ Oei

SONIA 17 MUTANT

3. **MUTATION BREEDING** Mutation induced through various mutagens MMS, EMS, 2,4-D ,Gamma rays, X-rays, radio isotopes

4. **POLYPLOIDY BREEDING**

- Colchicines has been used effectively in inducing doubling of chromosomes. ¬
- Submerging bulbs of Cymbidium in colchicines twice within an interval of 10 days has been reported to produce tetraploids.
- Similar technique has also been applied to Dendrobium and in Vanda

5. **BIOTECHNOLOGY**

1. American Orchid Society has taken a lead in stimulating interest in protoplast fusion research in orchid

2.It was possible to fuse protoplasts from different plants within the genus Eg. Phalaenopsis, Dendrobium and Renanthera.

3.The frequency of fusion was increased by polyethylene glycol.

4. Inter –generic fusion of terrestrial orchid protoplast induced by different fusion promoting agent was also found to be possible

INTERNATIONAL RULING VARIETIES

Arachnis - ` Maggie Oei'

Aranthera - `James Storie'

Aranda - `Christine'.

Dendrobium - `Pompadour'.

Dendrobium - `Tomie'.

Dendrobium - `Spell Bound'.

Dendrobium - `Ceasar'.

Vanda - `Miss Joaquim'.

Asconcenda - `Yip Sum Wah'

Oncidium - ` Golden Shower'.

Anthurium

Anthurium Schott, 1829), is a genus of about 1000 species of flowering plants, the largest genus of the arum family, Araceae. General common names include **anthurium**, **tailflower**, **flamingo flower**, and **laceleaf**.

The genus is native to the Americas, where it is distributed from northern Mexico to northern Argentina and parts of the Caribbean.

Anthurium is a genus of herbs often growing as epiphytes on other plants. Some are terrestrial. The leaves are often clustered and are variable in shape. The inflorescence bears small flowers which are perfect, containing male and female structures. The flowers are contained in dense spirals on the spadix. The spadix is often elongated into a spike shape, but it can be globe-shaped or club-shaped. Beneath the spadix is the spathe, a type of bract. This is variable in shape, as well, but it is lance-shaped in many species. It may extend out flat or in a curve. Sometimes it covers the spadix like a hood. The fruits develop from the flowers on the spadix. They are juicy berries varying in color, usually containing two seeds.

The spadix and spathe are a main focus of *Anthurium* breeders, who develop cultivars in bright colors and unique shapes. *Anthurium scherzerianum* and *A. andraeanum*, two of the most common taxa in cultivation, are the only species that grow bright red spathes. They have also been bred to produce spathes in many other colors and patterns.

Anthurium plants are poisonous due to calcium oxalate crystals. The sap is irritating to the skin and eyes.

Species

In 1860 there were 183 species known to science, and Heinrich Wilhelm Schott defined them in 28 sections in the book *Prodromus Systematis Aroidearum*.[13] In 1905 the genus was revised with a description of 18 sections.[14] In 1983 the genus was divided into the following sections:[15]

- *Belolonchium*
- *Calomystrium*
- *Cardiolonchium*
- *Chamaerepium*
- *Cordatopunctatum*
- *Dactylophyllium*
- *Decurrentia*
- *Digitinervium*
- *Gymnopodium*

- *Leptanthurium*
- *Pachyneurium*
- *Polyphyllium*
- *Polyneurium*
- *Porphyrochitonium*
- *Schizoplacium*
- *Semaeophyllium*
- *Tetraspermium*
- *Urospadix*
- *Xialophyllium*

Heliconia

Heliconia, derived from the Greek word is a genus of flowering plants in the monotypic family **Heliconiaceae**. Most of the ca 194 known species[3] are native to the tropical Americas, but a few are indigenous to certain islands of the western Pacific and Maluku. Many species of *Heliconia* are found in the tropical forests of these regions. Most species are listed as either "vulnerable" or "data deficient" by the IUCN Red List of threatened species.[4] Several species are widely cultivated as ornamentals, and a few are naturalized in Florida, Gambia and Thailand. Common names for the genus include **lobster-claws**, **toucan beak**, **wild plantains** or **false bird-of-paradise**. The last term refers to their close similarity to the bird-of-paradise flowers (*Strelitzia*). Collectively, these plants are also simply referred to as *heliconias*.

Heliconia latispatha inflorescences	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Monocots
Clade:	Commelinids
Order:	Zingiberales
Family:	Heliconiaceae Vines[1]
Genus:	*Heliconia* L.
Synonyms[2]	
• *Bihai* Mill. • *Heliconiopsis* Miq.	

These herbaceous plants range from 0.5 to nearly 4.5 meters (1.5–15 feet) tall depending on the species. The simple leaves of these plants are 15–300 cm (6 in–10 ft). They are characteristically long, oblong, alternate, or growing opposite one another on non-woody petioles often longer than the leaf, often forming large clumps with age. Their flowers are produced on long, erect or drooping panicles, and consist of brightly colored waxy bracts, with small true flowers peeping out from the bracts. The growth habit of heliconias is similar

to *Canna*, *Strelitzia*, and bananas, to which they are related.The flowers can be hues of reds, oranges, yellows, and greens, and are subtended by brightly colored bracts. Floral shape often limits pollination to a subset of the hummingbirds in the region.

Leaf

The leaves in different positions on the plant have a different absorption potential of sunlight for photosynthesis when exposed to different degrees of sunlight. droopy

Flower

The flowers produce ample nectar that attracts pollinators, most prevalent of which are hummingbirds.

Seeds

Fruits are blue-purple when ripe and primarily bird dispersed. Studies of post-dispersal seed survival showed that seed size was not a determinant. The highest amount of seed predation came from mammals.

Taxonomy

Heliconia is the only genus in the monotypic family Heliconiaceae, but was formerly included in the family Musaceae, which includes the bananas (e.g., Musa, Ensete;). However, the APG system of 1998, and its successor, the APG II system of 2003, confirm the Heliconiaceae as distinct and places them in the order Zingiberales, in the commelinid clade of monocots.

Species accepted by Kew Botanic Gardens

Scientific name	Distribution
Heliconia abaloi	Colombia
Heliconia acuminata	South America
Heliconia adflexa	S Mexico, Guatemala, Honduras
Heliconia aemygdiana	South America
Heliconia albicosta	Costa Rica
Heliconia angelica	Ecuador
Heliconia angusta	SE Brazil
Heliconia apparicioi	Ecuador, Peru, NW Brazil
Heliconia arrecta	Colombia
Heliconia atratensis	Colombia

Heliconia atropurpurea	Colombia, Panama, Costa Rica
Heliconia aurantiaca	S Mexico, Central America
Heliconia auriculata	Bahia
Heliconia badilloi	Colombia
Heliconia barryana	Chiriquí
Heliconia beckneri	Costa Rica
Heliconia bella	Panama
Heliconia berguidoi	E Panama
Heliconia berriziana	Colombia
Heliconia berryi	Napo, Ecuador
Heliconia bihai	West Indies, N South America
Heliconia bourgaeana	S Mexico, Central America
Heliconia brachyantha	Panama, Colombia, Venezuela
Heliconia brenneri	Ecuador
Heliconia burleana	Colombia, Ecuador, Peru
Heliconia caltheaphylla	Costa Rica
Heliconia caquetensis - Colombia	
Heliconia carajaensis	Pará
Heliconia caribaea	West Indies
Heliconia carmelae - Colombia	
Heliconia chartacea	N South America
Heliconia chrysocraspeda - Colombia	
Heliconia clinophila	Costa Rica, Panama
Heliconia colgantea	Costa Rica, Panama
Heliconia collinsiana	S Mexico, Central America
Heliconia combinata	Colombia
Heliconia cordata	Colombia, Ecuador
Heliconia crassa	Guatemala
Heliconia cristata	Panama
Heliconia cucullata	Costa Rica, Panama
Heliconia curtispatha	Colombia, Ecuador, Central America
Heliconia danielsiana	Costa Rica, Panama
Heliconia darienensis	Colombia, Panama

Heliconia dasyantha	Suriname, French Guiana
Heliconia densiflora	Trinidad, N South America
Heliconia dielsiana	NW South America
Heliconia donstonea	Colombia, Ecuador
Heliconia episcopalis	South America
Heliconia estherae	Colombia
Heliconia estiletioides	Colombia
Heliconia excelsa	Napo
Heliconia farinosa	SE Brazil, NE Argentina
Heliconia faunorum	Panama
Heliconia fernandezii	Antioquia, Colombia
Heliconia × flabellata	Ecuador
Heliconia foreroi	Colombia
Heliconia fragilis	Colombia
Heliconia fredberryana	Imbabura
Heliconia fugax	Peru
Heliconia gaiboriana	Los Ríos
Heliconia gigantea	Colombia
Heliconia gloriosa	Peru
Heliconia gracilis	Costa Rica
Heliconia griggsiana	Colombia, Ecuador
Heliconia harlingii	Ecuador
Heliconia hirsuta	Central + South America, Trinidad
Heliconia holmquistiana	Colombia
Heliconia huilensis	Colombia
Heliconia ignescens	Costa Rica, Panama
Heliconia imbricata	Costa Rica, Panama, Colombia
Heliconia impudica	Ecuador
Heliconia indica	Papuasia, Maluku
Heliconia intermedia	Colombia
Heliconia irrasa	Costa Rica, Panama, Nicaragua
Heliconia julianii	N South America
Heliconia juruana	Ecuador, Peru, NW Brazil

Heliconia kautzkiana	Espírito Santo
Heliconia lanata	Solomon Islands
Heliconia lankesteri - Costa Rica, Panama	
Heliconia lasiorachis	Colombia, Peru, NW Brazil
Heliconia latispatha	from S Mexico to Peru
Heliconia laufao	Samoa
Heliconia laxa	Colombia
Heliconia lentiginosa	Antioquia
Heliconia librata	S Mexico, Central America
Heliconia lingulata	Peru, Bolivia
Heliconia litana	Imbabura
Heliconia longiflora - Colombia, Ecuador, Central America	
Heliconia longissima	Colombia
Heliconia lophocarpa	Costa Rica, Panama
Heliconia lourteigiae	South America
Heliconia lozanoi	Colombia
Heliconia luciae	B Amazonas
Heliconia lutea	Panama
Heliconia luteoviridis	Colombia
Heliconia lutheri	Ecuador
Heliconia maculata	Panama
Heliconia magnifica	Panama
Heliconia × mantenensis - Minas Gerais	
Heliconia marginata - N South America, S Central America	
Heliconia mariae	NW South America, Central America
Heliconia markiana	Ecuador
Heliconia marthiasiae	S Mexico, Central America
Heliconia meridensis	Colombia, Venezuela
Heliconia metallica	N South America, Central America
Heliconia monteverdensis	Costa Rica

Heliconia mooreana	Guerrero
Heliconia mucilagina - Colombia	
Heliconia mucronata	Venezuela, NW Brazil
Heliconia mutisiana	Colombia
Heliconia nariniensis	Colombia, Ecuador
Heliconia necrobracteata	Panama
Heliconia × nickeriensis	Suriname, French Guiana
Heliconia nigripraefixa	Colombia, Ecuador, Panama
Heliconia nitida	Colombia
Heliconia nubigena	Costa Rica, Panama
Heliconia nutans	Costa Rica, Panama
Heliconia obscura - Ecuador, Peru	
Heliconia obscuroides	Colombia, Ecuador, Peru
Heliconia oleosa	Colombia
Heliconia ortotricha	Colombia, Ecuador, Peru
Heliconia osaensis - Colombia, Central America	
Heliconia paka	Fiji
Heliconia paludigena	Ecuador
Heliconia papuana	New Guinea
Heliconia pardoi	Ecuador
Heliconia pastazae	Ecuador
Heliconia peckenpaughii	Napo
Heliconia pendula	Guiana, Fr Guiana, NE Brazil
Heliconia penduloides	Peru
Heliconia peteriana	Ecuador
Heliconia × plagiotropa	Ecuador
Heliconia platystachys	NW South America, S Central America
Heliconia pogonantha	NW South America, S Central America
Heliconia pruinosa	Peru
Heliconia pseudoaemygdiana	Rio de Janeiro
Heliconia psittacorum	N South America, Panama, Trinidad
Heliconia ramonensis	Costa Rica, Panama

Heliconia × rauliniana	Venezuela
Heliconia regalis	Colombia, Ecuador
Heliconia reptans	Colombia
Heliconia reticulata	NW South America, S Central America
Heliconia revoluta	Colombia, Venezuela, NW Brazil
Heliconia rhodantha	Colombia
Heliconia richardiana	NE South America
Heliconia rigida	Colombia
Heliconia riopalenquensis	Ecuador
Heliconia rivularis	São Paulo, Brazil
Heliconia robertoi	Colombia
Heliconia robusta	Peru, Bolivia
Heliconia rodriguensis	Venezuela
Heliconia rodriguezii	Costa Rica
Heliconia rostrata	Colombia, Ecuador, Peru, Bolivia
Heliconia samperiana	Colombia
Heliconia sanctae-martae	Sierra Nevada de Santa Marta
Heliconia sanctae-theresae	Antioquia
Heliconia santaremensis	Pará
Heliconia sarapiquensis	Costa Rica, Panama
Heliconia scarlatina	Colombia, Panama, Peru
Heliconia schiedeana	Mexico
Heliconia schumanniana	Colombia, Ecuador, Peru, N Brazil
Heliconia sclerotricha	Ecuador
Heliconia secunda	Costa Rica, Nicaragua
Heliconia sessilis	Panama
Heliconia signa-hispanica	Colombia
Heliconia solomonensis	Solomon Islands, Bismarck Archipelago
Heliconia spathocircinata	South America, Panama, Trinidad
Heliconia spiralis	Colombia
Heliconia spissa	S Mexico, Central America
Heliconia standleyi	Ecuador, Peru
Heliconia stella-maris - Colombia	

Heliconia stilesii	Costa Rica, Panama
Heliconia stricta	N South America
Heliconia subulata	South America
Heliconia tacarcunae	Panama
Heliconia talamancana	Costa Rica, Panama
Heliconia tandayapensis	Ecuador
Heliconia tenebrosa	Colombia, NE Peru, NW Brazil
Heliconia terciopela	Colombia
Heliconia thomasiana	Panama
Heliconia timothei	NE Peru, NW Brazil
Heliconia titanum	Colombia
Heliconia tortuosa	S Mexico, Central America
Heliconia trichocarpa	Costa Rica, Panama, Colombia
Heliconia tridentata	Colombia
Heliconia triflora	B Amazonas
Heliconia umbrophila	Costa Rica
Heliconia uxpanapensis	Veracruz
Heliconia vaginalis	Costa Rica, Panama, Colombia, Ecuador
Heliconia vellerigera	Ecuador, Peru
Heliconia velutina	Colombia, Ecuador, Peru, NW Brazil
Heliconia venusta	Colombia, Ecuador
Heliconia villosa	Venezuela
Heliconia virginalis	Ecuador
Heliconia wagneriana	Central America, N South America, Trinidad
Heliconia willisiana	Pichincha
Heliconia wilsonii	Costa Rica, Panama
Heliconia xanthovillosa	Panama
Heliconia zebrina	Peru

Distribution and habitat

Most of the 194 known species are native to the tropical Americas, but a few are indigenous to certain islands of the western Pacific and Maluku. Many species of *Heliconia* are

found in the tropical forests of these regions. Several species are widely cultivated as ornamentals, and a few are naturalized in Florida, Gambia and Thailand.

Ecology

Heliconias are an important food source for forest hummingbirds, especially the hermits (Phathornithinae), some of which – such as the rufous-breasted hermit (*Glaucis hirsuta*) – also use the plant for nesting. The Honduran white bat (*Ectophylla alba*) also lives in tents it makes from heliconia leaves.

Bats

Pollination

Although *Heliconia* are almost exclusively pollinated by hummingbirds, some bat pollination has been found to occur. *Heliconia solomonensis* is pollinated by the macroglosine bat (*Melonycteris woodfordi*) in the Solomon Islands. *Heliconia solomonensis* has green inflorescences and flowers that open at night, which is typical of bat pollinated plants. The macroglosine bat is the only known nocturnal pollinator of *Heliconia solomonensis*.

Habitat

Many bats use *Heliconia* leaves for shelter. The Honduran white bat, *Ectohylla alba*, utilizes five species of *Heliconia* to make diurnal tent-shaped roosts. The bat cuts the side veins of the leaf extending from the midrib, causing the leaf to fold like a tent. This structure provides the bat with shelter from rain, sun, and predators. In addition, the stems of the *Heliconia* leaves are not strong enough to carry the weight of typical bat predators, so shaking of the leaf alerts roosting bats to presence of predators. The bats *Artibeus anderseni* and *A. phaeotis* form tents from the leaves of *Heliconia* in the same manner as the Honduran white bat. The neotropical disk-winged bat, *Thyroptera tricolor*, has suction disks on the wrists which allow it to cling to the smooth surfaces of the *Heliconia* leaves. This bat roosts head-up in the rolled young leaves of *Heliconia* plants.

***Antirrhinum* (Snapdragon)**

Antirrhinum is a genus of plants commonly known as **dragon flowers** or **snapdragons** because of the flowers' fancied resemblance to the face of a dragon that opens and closes its mouth when laterally squeezed. They are native to rocky areas of Europe, the United States, and North Africa.

Antirrhinum majus	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Lamiales
Family:	Plantaginaceae
Tribe:	Antirrhineae
Genus:	*Antirrhinum* L.
Type species	
Antirrhinum majus L.	
Sections	
• *Antirrhinum* • *Orontium* • *Saerorhinum*	

The genus is morphologically diverse, particularly the New World group (*Saerorhinum*). The genus is characterized by personate flowers with an inferior gibbous corolla.

Antirrhinum used to be treated within the family Scrophulariaceae, but studies of DNA sequences have led to its inclusion in a vastly enlarged family Plantaginaceae within the tribe Antirrhineae.

Circumscription

The taxonomy of this genus is complex and not yet fully resolved at present. In particular the exact circumscription of the genus, especially the inclusion of the New World species (Saerorhinum), is contentious.[2] The situation is further complicated by the variety of terms in

use for infrageneric ranks, especially of the Old World species, that is *Antirrhinum*, *sensu stricto* (e.g. Streptosepalum, Kicksiella, Meonantha).

The USDA Plants Database recognises only two species: *A. majus* (the garden snapdragon), the only species naturalised in North America, and *A. bellidifolium* (the lilac snapdragon), now considered to be *Anarrhinum bellidifolium* (L.) Willd. As of April 2017, The Plant List (Version 1.1) accepts 21 species.

A widely accepted scheme (Thompson 1988) placed 36 species in the genus in three sections. While many botanists accepted this broad circumscription (*sensu lato*), whose main departure from other classifications was the inclusion of the New World Saerorhinum, others did not, restricting the genus to the Old World. (For a comparison of Thompson with earlier systems, see Oyama and Baum, Table 1.) New species also continue to be discovered (see e.g. Romo *et al.*, 1995).

In 2004 research into the molecular systematics of this group and related species by Oyama and Baum confirmed that the genus *sensu lato* as described by Thompson is monophyletic, provided that one species (*A. cyathiferum*) is removed to the separate genus *Pseudorontium*, and the two species of *Mohavea* (*Mohavea confertiflora* and *M. breviflora*) are included. The species list given here follows these conclusions.[2]

This is the broad circumscription that includes the Old World *Misopates* and New World *Sairocarpus*. By contrast the narrow circumscription (*sensu stricto*) confines the genus to the monophyletic Old World perennial species with a diploid chromosome number of 16, distributed in the Mediterranean basin, approximately 25 species. (Tolety 2011), following the phylogenetic analysis of Vargas *et al.* (2004) suggesting they are a distinct group. Both *Misopates* and *Sairocarpus* are accepted names in *The Plant List*, and many of the New World species now have *Sairocarpus* as their accepted name, rather than *Antirrhinum*. It has been proposed that many of the New World *Antirrhinum* be now considered under *Sairocarpus*, in the forthcoming *Flora of North America*.

Infrageneric subdivision

It is widely agreed that this broad group should be subdivided into three or four subgroups, but the level at which this should be done, and exactly which species should be grouped together,

remain unclear. Some authors continue to follow Thompson in using a large genus *Antirrhinum*, which is then divided into several sections; others treat Thompson's genus as a tribe or subtribe, and divide it into several genera. For a comparison of earlier schemes see Mateu-Andrés and de Paco, Table 1 (2005)

If the broad circumscription is accepted, its three sections as described by Thompson are as follows (two Old World, one New):

- Section *Antirrhinum*: 19 Old World species of relatively large flowered perennial plants, including the type species *Antirrhinum majus*, mostly native to the western Mediterranean region with a focus on the Iberian Peninsula. Chromosomes n=8. (3 subsections: *Majora*, *Sicula*, *Hispanica*)
- Section *Orontium*: two species, also from the Mediterranean. Chromosome number=8. The species in this section, including the section type species *Antirrhinum orontium* (lesser Snapdragon) are often treated in the genus *Misopates*.
- Section *Saerorhinum*: 15 small flowered New World species, mostly annual plants and mostly native to California, though species are found from Oregon to Baja California Sur and as far east as Utah. Tetraploid (n=15-16). Like other authors, Thompson placed *A. cyathiferum* in this section, but Oyama and Baum, following earlier authors, suggest that it should be reclassified in genus *Pseudorontium*, while *Mohavea* should be included. Vargas *et al.*, strongly recommending segregation of the New World species suggest that the 14 species originally recognised by Sutton (1988) more properly belong to *Sairocarpus* (11 species), *Howelliella* (1 species), and *Neogarrhinum* (2 species). Other authors would also include *Galvezia glabrata*, *Galvezia juncea*, *Galvezia rupicola* and *Galvezia speciosa*. None of the names originally allocated to this section are now accepted (see List of Antirrhinum species).

Snapdragons

Snapdragon growing in Eastern Siberia

While *Antirrhinum majus* is the plant that is usually meant by the term of "snapdragon" if used on its own, many other species in the genus, and in the family Scrophulariaceae more widely,

have common names that include the word "snapdragon". Such as *Antirrhinum molle* is known as "dwarf snapdragon" in the UK.

Species

Main article: List of Antirrhinum species

Etymology

The word "antirrhinum" is derived from the Greek ἀντίρρινον *antirrhinon* "calf's snout, Antirrhinum Orontium" which in turn is derived from ἀντί *anti* "against, like", and ῥίς *rhis* "nose" (GEN *rhinos*); thus, possibly "noselike", possibly referring to the noselike capsule in its mature state.

Ecology

Snapdragons are often considered as cold-season annual plants and do best in full or partial sun, in well-drained soil (although they do require regular watering). They are classified commercially as a range of heights: *midget* (6–8 inches [15–20 cm]), *medium* (15–30 inches [38–76 cm]) and *tall* (30–48 inches [76–122 cm]).

They are ecologically diverse, particularly the New World species (*Saerorhinum*).

Lecture No. 22 & 23

Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental and flower crops *viz*.

Petunia, Dianthus, Pansy, Crossandra, Geranium

Petunia

Petunia is genus of 20 species of flowering plants of South American origin. The popular flower of the same name derived its epithet from the French, which took the word *petun*, meaning "tobacco," from a Tupi–Guarani language. An annual, most of the varieties seen in gardens are hybrids (*Petunia* × *atkinsiana*, also known as *Petunia* × *hybrida*).

Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Solanales
Family:	Solanaceae
Subfamily:	Petunioideae
Genus:	*Petunia* Juss.

Petunia is a genus in the family Solanaceae, subfamily Petunioideae. Well known members of Solanaceae in other subfamilies include tobacco (subfamily Nicotianoideae), and the cape gooseberry, tomato, potato, deadly nightshade and chili pepper (subfamily Solanoideae). Some botanists place the plants of the genus *Calibrachoa* in the genus *Petunia*,[3] but this is not accepted by others. *Petchoa* is a hybrid genus derived from crossing *Calibrachoa* and *Petunia*.

Species include

- *Petunia alpicola*
- *Petunia axillaris*
- *Petunia bajeensis*
- *Petunia bonjardinensis*
- *Petunia exserta*
- *Petunia guarapuavensis*
- *Petunia inflata*

- *Petunia integrifolia*
- *Petunia interior*
- *Petunia ledifolia*
- *Petunia littoralis*
- *Petunia mantiqueirensis*
- *Petunia occidentalis*
- *Petunia patagonica*
- *Petunia reitzii*
- *Petunia riograndensis*
- *Petunia saxicola*
- *Petunia scheideana*
- *Petunia villadiana*

Ecology

Petunias are generally insect pollinated, with the exception of *P. exserta*, which is a rare, red-flowered, hummingbird-pollinated species. Most petunias are diploid with 14 chromosomes and are interfertile with other petunia species.

The tubular flowers are favoured by some Lepidoptera species, including the Hummingbird hawk moth. The flowers are eaten by the larvae of the corn earworm, *Helicoverpa zea* and the cabbage looper, *Trichoplusia ni*.

Dianthus

Dianthus is a genus of about 300 species of flowering plants in the family Caryophyllaceae, native mainly to Europe and Asia, with a few species extending south to north Africa, and one species (*D. repens*) in arctic North America. Common names include **carnation** (*D. caryophyllus*), **pink** (*D. plumarius* and related species) and **sweet william** (*D. barbatus*).

Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Order:	Caryophyllales
Family:	Caryophyllaceae
Genus:	*Dianthus* L.

The species are mostly herbaceous perennials, a few are annual or biennial, and some are low subshrubs with woody basal stems. The leaves are opposite, simple, mostly linear and often strongly glaucous grey green to blue green. The flowers have five petals, typically with a frilled or pinked margin, and are (in almost all species) pale to dark pink. One species, *D. knappii*, has yellow flowers with a purple centre. Some species, particularly the perennial pinks, are noted for their strong spicy fragrance.

Species

- *Dianthus alpinus* – Alpine pink
- *Dianthus amurensis* – Amur pink
- *Dianthus anatolicus*
- *Dianthus arenarius* – sand pink
- *Dianthus armeria* – Deptford pink
- *Dianthus balbisii*
- *Dianthus barbatus* – sweet william
- *Dianthus biflorus*
- *Dianthus brevicaulis*
- *Dianthus burgasensis*
- *Dianthus callizonus*
- *Dianthus campestris*
- *Dianthus capitatus*
- *Dianthus carthusianorum* – Carthusian pink
- *Dianthus caryophyllus* – carnation or clove pink
- *Dianthus chinensis* – China pink
- *Dianthus cruentus*
- *Dianthus cyprius* – North Cyprus pink
- *Dianthus deltoides* – maiden pink
- *Dianthus erinaceus*
- *Dianthus fragrans*
- *Dianthus freynii*
- *Dianthus fruticosus*
- *Dianthus furcatus*
- *Dianthus gallicus* – French pink or Jersey pink
- *Dianthus giganteus*
- *Dianthus glacialis*
- *Dianthus gracilis*
- *Dianthus graniticus*
- *Dianthus gratianopolitanus* – Cheddar pink
- *Dianthus haematocalyx*
- *Dianthus japonicus*

- *Dianthus japigicus*
- *Dianthus kladovanus*
- *Dianthus knappii*
- *Dianthus libanotis* – Lebanon pink
- *Dianthus lusitanus*
- *Dianthus microlepis*
- *Dianthus moesiacus*
- *Dianthus monspessulanus* – fringed pink
- *Dianthus myrtinervius* – Albanian pink
- *Dianthus nardiformis*
- *Dianthus nitidus*
- *Dianthus pavonius*
- *Dianthus pendulus*
- *Dianthus petraeus*
- *Dianthus pinifolius*
- *Dianthus plumarius* – garden pinks, wild pink
- *Dianthus pungens*
- *Dianthus repens* – boreal carnation
- *Dianthus scardicus*
- *Dianthus seguieri* – Sequier's pink
- *Dianthus simulans*
- *Dianthus spiculifolius*
- *Dianthus squarrosus*
- *Dianthus strictus*
- *Dianthus subacaulis*
- *Dianthus superbus* – large pink
- *Dianthus sylvestris*
- *Dianthus tenuifolius*
- *Dianthus urumoffii*
- *Dianthus zonatus*

Hybrids include;

- 'Devon Xera' – Fire Star Dianthus[1]
- 'John Prichard'

The name *Dianthus* is from the Greek words Äéüò *Dios* ("of Zeus") and íèüò *anthos* ("flower"), and was cited by the Greek botanist Theophrastus. The color pink may be named after the flower, coming from the frilled edge of the flowers: the verb "to pink" dates from the 14th century and means "to decorate with a perforated or punched pattern". As is also demonstrated by the name of "pinking shears", special scissors for cloth that create a zigzag or decorative edge that discourages fraying.

Ecology

Dianthus species are used as food plants by the larvae of some Lepidoptera species including cabbage moth, double-striped pug, large yellow underwing and the lychnis. Also three species of *Coleophora* case-bearers feed exclusively on *Dianthus*; *C. dianthi*, *C. dianthivora* and *C. musculella* (which feeds exclusively on *D. superbus*).

Pansy

The **garden pansy** is a type of large-flowered hybrid plant cultivated as a garden flower. It is derived by hybridization from several species in the section *Melanium* ("the pansies") of the genus *Viola*, particularly *Viola tricolor*, a wildflower of Europe and western Asia known as heartsease. Some of these hybrids are referred to as *Viola* × *wittrockiana* Gams ex Nauenb. & Buttler. For simplicity, the older name *Viola tricolor* var. *hortensis* is often used.

The garden pansy flower is 5 to 8 centimetres (2 to 3 in) in diameter and has two slightly overlapping upper petals, two side petals, and a single bottom petal with a slight beard emanating from the flower's center. These petals are usually white or yellow, purplish, or blue. The plant may grow to 23 cm (9 in) in height, and prefers sun to varying degrees and well-draining soils.

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
(unranked):	Rosids
Order:	Malpighiales
Family:	Violaceae
Genus:	*Viola*
Section:	*Viola* section *Melanium*
Species:	*V. tricolor*
Subspecies:	***V. t.* var. *hortensis***
Trinomial name	
Viola tricolor* var. *hortensis DC.	

English common names, such as "pansy", "viola" and "violet" may be used interchangeably. One possible distinction is that plants considered to be "pansies" are classified in *Viola* sect. *Melanium*, and have four petals pointing upwards (the two side petals point upwards), and only one pointing down, whereas those considered to be "violets" are classified in *Viola* sect. *Viola*, and have two petals pointing up and three pointing down.[2][4][5] Another possible distinction is made by the American Violet Society – the International Cultivar

Registration Authority for the genus *Viola*. It divides cultivated varieties (cultivars) in *Viola* sect. *Melanium* into four subgroups: B1 – pansies, B2 – violas, B3 – violettas and B4 – cornuta hybrids. On this classification, modern "pansies" differ from the other three subgroups by possessing a well-defined "blotch" or "eye" in the middle of the flower.

Modern horticulturalists tend to use the term "pansy" for those multi-coloured large-flowered hybrids that are grown for bedding purposes every year, while "viola" is usually reserved for smaller, more delicate annuals and perennials.

Etymology

The name "pansy" is derived from the French word *pensée*, "thought", and was imported into Late Middle English as a name of *Viola* in the mid-15th century, as the flower was regarded as a symbol of remembrance. The name "love in idleness" was meant to imply the image of a lover who has little or no other employment than to think of his beloved.

The name "heart's-ease" came from St. Euphrasia, whose name in Greek signifies cheerfulness of mind. The woman, who refused marriage and took the veil, was considered a pattern of humility, hence the name "humble violet".

In Scandinavia, Scotland, and German-speaking countries, the pansy (or its wild parent *Viola tricolor*) is or was known as the "stepmother"; the name was accompanied by an aitiological tale about a selfish stepmother, told to children while the teller plucked off corresponding parts of the blossom to fit the plot.

In Italy the pansy is known as *flammola* (little flame).

Crossandra

Crossandra is a genus of plants in the family Acanthaceae, comprising 54[1] species that occur in Africa, Madagascar, Arabia and the Indian subcontinent. Some species, especially *Crossandra infundibuliformis*, are cultivated for their brightly colored flowers.

Crossandra infundibuliformis

Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Lamiales
Family:	Acanthaceae
Subfamily:	Acanthoideae
Tribe:	Acantheae
Genus:	*Crossandra* Salisb.

Species

- *Crossandra greenstockii*
- *Crossandra horrida*
- *Crossandra infundibuliformis*
- *Crossandra longipes*
- *Crossandra pungens*
- *Crossandra strobilifera*

Geranium

Geranium is a genus of 422 species of flowering annual, biennial, and perennial plants that are commonly known as **geraniums** or **cranesbills**. They are found throughout the temperate regions of the world and the mountains of the tropics, but mostly in the eastern part of the Mediterranean region.

The palmately cleft leaves are broadly circular in form. The flowers have five petals and are coloured white, pink, purple or blue, often with distinctive veining. Geraniums will grow in any soil as long as it is not waterlogged. Propagation is by semiripe cuttings in summer, by seed, or by division in autumn or spring.

Geraniums are eaten by the larvae of some Lepidoptera species including brown-tail, ghost moth, and mouse moth. At least several species of *Geranium* are gynodioecious. The species *Geranium viscosissimum* (sticky geranium) is considered to be protocarnivorous.

The genus name is derived from the Greek ‘crane’. The English name ‘cranesbill’ derives from the appearance of the fruit capsule of some of the species. Species in the genus *Geranium* have a distinctive mechanism for seed dispersal. This consists of a beak-like column which springs open when ripe and casts the seeds some distance. The fruit capsule consists of five cells, each containing one seed, joined to a column produced from the centre of the old flower. The common name ‘cranesbill’ comes from the shape of the unsprung column, which in some species is long and looks like the bill of a crane. However, many species in this genus do not have a long beak-like column.

Geranium dissectum	
Scientific classification	
Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Geraniales
Family:	Geraniaceae
Genus:	*Geranium* L.

Species

A number of geranium species are cultivated for horticultural use and for pharmaceutical products. Some of the more commonly grown species include:

- *Geranium cinereum*
- *Geranium clarkei* (Clarke's geranium)
- *Geranium dalmaticum*
- *Geranium endressii* (Endres's cranesbill)
- *Geranium erianthum* (wooly geranium)
- *Geranium fremontii* (Fremont's geranium)
- *Geranium himalayense*, often sold under *Geranium grandiflorum*
- *Geranium ibericum* (Caucasus geranium),
- *Geranium macrorrhizum* (bigroot cranesbill or bigroot geranium)
- *Geranium maculatum* (wild geranium)
- *Geranium maderense* (giant herb robert)
- *Geranium × magnificum* (showy geranium)
- *Geranium phaeum* (dusky cranesbill)
- *Geranium platypetalum* (broad-petaled geranium)
- *Geranium pratense* (meadow cranesbill)
- *Geranium psilostemon* (Armenian cranesbill)
- *Geranium renardii* (Renard geranium)
- *Geranium sanguineum* (bloody cranesbill)
- *Geranium subcaulescens* (grey cranesbill)
- *Geranium sylvaticum* (wood cranesbill)

All the above species are perennials and generally winter-hardy plants, grown for their attractive flowers and foliage. They are long-lived and most have a mounding habit, with palmately lobed foliage. Some species have spreading rhizomes. They are normally grown in part shade to full sun, in well-draining but moisture retentive soils, rich in humus. Other perennial species grown for their flowers and foliage include: *G. argenteum*, *G. eriostemon*, *G. farreri*, *G. nodosum*, *G. procurrens*, *G. pylzowianum*, *G. renardii*, *G. traversii*, *G. tuberosum*, *G. versicolor*, *G. wallichianum* and *G. wlassovianum*. Some of these are not winter-hardy in cold areas and are grown in specialized gardens like rock gardens. *Geranium* 'Johnson's Blue' is a hybrid between *G. himalayense* (southwestern China), with *G. pratense* (European meadow cranesbill).

Review Article for Lecture No. 11 - 23

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.

l Polyploidy due to somatic mutation may be caused by disruption in mitosis resulting in chromosome doubling, e.g. *Primula kewensis*.

l 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.

l Polyploidy is more frequent at high altitudes, high latitudes, in wet soils and meadows.

l 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*

6.11Polyploid 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:*

l *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.

l *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.

l *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.

l *Use of gametocide for chemical emasculation*. e.g. Sunflower

l *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*

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

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.

Lecture No. 24

Breeding for Disease Resistance

Resistance refers to the ability of the host to interfere with the normal growth and for development of the pathogen. The plant affected by the disease is known as host while the organism that produces the disease is known as pathogen. Therefore, disease is an abnormal condition in the plant produced by an organism/pathogen. Thus, the abnormalities produced by the non-biological environment or by the genetic factors present in the host are not diseases.

Economic significance of diseases :¬

The diseases reduce the total biomass (dry matter) production by the crop (host) in one or more of the following ways:

(i) Killing of plants

(ii) Killing of branches

(iii) General stunting

(iv) Damage of leaf tissues

(v) Damage to the reproductive organs including fruits and seeds

These disturbances in plant growth and development ultimately led to the consequent decrease in yield. The loss due to disease may range from a few 20 or 30 percent or in cases of severe infection, the total crop may be lost. A striking effect of diseases is the disappearance from cultivation of otherwise excellent but susceptible varieties, eg. Wheat variety 'Kalyan sona' dominated the Indian agriculture for more than a decade but had to be abandoned as it became susceptible to leaf rust. Similarly, another wheat variety 'Janak' was eliminated from cultivation due to its susceptibility to karnal bunt disease.

Historical background for breeding for disease resistance:¬

6. Theophrastus in the 3rd century B.C. noted that cultivated varieties differed in the ability to resist/avoid diseases.
7. In 1894, Erikson showed that pathogens although morphologically similar, differed from each other in their ability to attack different related host species.
8. In 1911, Barrus showed that different isolates of a microorganism differed in their ability to attack different varieties of the same host species. This finding made the basis for physiological races and pathotypes

It was subsequently established that the ability of a pathogen to infect a host strain i.e. PATHOGENECITY is genetically determined.

Thus, both the ability of the host to resist invasion by the pathogen as well as the ability of the pathogen to invade the host are genetically controlled.

In 1955, Flor postulated the hypothesis of gene-for-gene relationship between host and pathogen which holds true in most of the cases and is widely accepted.

It was subsequently established that the disease resistance of the host is not the function of the host genotype alone but is also determined by the genotype of the pathogen as well.

The host strains differ in resistance while those of the pathogen differ in pathogenicity, both variations have genetic basis. The pathogen has remarkable capacity to generate new variations in pathogenicity by a variety of reproduction methods and mutation. Thus, the task of the breeder is not only to develop varieties resistant to the prevalent pathotypes of the pathogen but also to be ready to face the challenge that is to be posed by new pathogen genotypes in future.

PHYSIOLOGICAL RACES AND PATHOTYPES vs. DIFFERENTIAL HOSTS:¬

Physiological races are strains of a single pathogen species differing in their ability to attack different varieties of same host species. The varieties of a host species used to identify physiological races of a pathogen are known as 'differential hosts' or 'host testers'. The differential hosts are chosen on the basis of differences in their resistance to the pathogen. Ideally, each of the differential hosts should possess a single resistance gene which is different from those present in the others.

CATEGORIZATION OF RESISTANCE TO DISEASES:¬

The host varieties are classified as susceptible or resistant according to their response to the pathogen. The various reactions of the host may be grouped into the following types:

(a) Susceptible Reaction: In case of susceptible reaction, the disease development is profuse and is not checked by the genotype.

(b) Resistance Reaction: Resistance denotes less disease development than the susceptible variety and is a relative attributes. Infection and establishment to take place but the growth of the pathogen in the host tissue is restricted. This results in smaller spots or pustules than in susceptible variety.

(c) Tolerance reaction: Tolerance implies that the host is attacked by the pathogen but there is no less in biomass production or yield. It is desirable not to use the word 'tolerance' unless it has been clearly shown to be the case.

VERTICAL AND HORIZONTAL RESISTANCE:¬

21. **Vertical Resistance:** It is also known as race-specific, pathotype specific or simply specific resistance. Vertical resistance is determined by the major genes and is characterized by pathotype specificity. Pathotype specificity denotes that the host carrying a gene for vertical resistance is attacked by only that pathotype which is virulent towards that resistant gene. To all other pathotypes, the host will **be resistant.**
22. **Horizontal Resistance:** It has many synonyms eg., race- nonspecific, partial, general and field resistance. Horizontal resistance is generally controlled by polygenes i.e., many genes with small individual effects and it is pathotype non specific. Thus, it is also known as general resistance. Horizontal resistance doesnot prevent the development of symptoms of the disease, but it slows down the rate of spread of disease in the population.

SYSTEMIC ACQUIRED RESISTANCE:¬

At the dawn of 20th century, it was recognized that plants previously infected by a pathogen become resistant to further infections. This involves viral cross-protection, bacterial and fungal antagonism and induced systemic resistance.

Induced systemic resistance processes in plants may be of several types, the most extensively studied of which is Systemic Acquired Resistance (SAR). It is a long lasting systemic resistance that is often effective against viral, bacterial and fungal pathogens and is induced by such pathogens that cause a necrotic reaction, which may range from a hypersensitive response to necrotic disease lesions.

SAR is accompanied by elevated levels of salicylic acid which is in some cases may be essential for the development of SAR. Salicylic acid may function as the phloem translocated signal that mediates SAR. Development of SAR is associated with the introduction of SAR genes which appear to be different in monocotyledonous and dicotyledonous plants. In tobacco, SAR genes comprise a set of non-allelic genes that can be broadly classified on the basis of proteins they encode such as the pathogenesis related (PR) genes.

SAR genes play an active role in the disease resistance process because their expression in transgenic plants can impart significant disease resistance. SAR genes expressed in different species differ to a considerable extent.

GENETICS OF DISEASE RESISTANCE:¬

Biffen (1905) reported the inheritance of resistant to leaf rust of wheat variety 'Rivet' in crosses with some susceptible varieties. In F2 , there were 3 susceptible:1 resistant plants indicating that the resistance was controlled by a single recessive gene. Subsequently, several other studies showed that resistance to various diseases are monogenically controlled but cases of duplicate, complementary and other interactions have also been reported taking into consideration the physiological differentiation o the pathogen.

The disease resistance may show following three modes of inheritance:

(i) oligogenic;

(ii) polygenic and

(iii)cytoplasmic.

(i) Oligogenic inheritance: In such cases, disease resistance is governed by one or few major genes and resistance is generally dominant to the susceptible reaction. In many cases, the action of major resistant genes may be altered by modifying the genes eg. Bunt resistance in wheat. But, in some other cases, modifying genes are not known eg. Resistance to X and Y viruses in potato.

Oligogenes generally produce immune reaction. The chief characteristic for oligogenic disease resistance is its pathotype specificity i.e., the resistance gene is effective against some pathotypes, while it is ineffective against the others. Oligogenic resistance is synonymous to vertical resistance. The inheritance of oligogenic disease resistance may be explained with the help of bean (Phaseolus vulgaris) anthracnose resistance. There are two physiological races, alpha and beta, of the pathogen; race alpha is virulent towards the bean variety Robust but not towards White marrow, while beta is virulent towards white marrow but not towards Robust.

When a cross between white marrow and Robust was tested against the alpha pathotype, the F1 was resistant and in F2 a 3:1 segregation was observed for resistance and susceptibility. Similar results were obtained when the same

cross was tested against the beta pathotype. This resistance of each of the two bean variety is governed by a single gene, which appear to be different.

Gene for gene relationship:

The gene for gene relationship between a host and its pathogen was postulated by Flor in 1951 based on his work on linseed rust. Gene for gene relationship has been studied exclusively and is widely accepted. It has been found that for every resistant gene present in the host, the pathogen has a gene for virulence. Susceptible reaction would result only when the patho gene is able to match all the resistant genes present in the host with appropriate virulence genes. If one or more genes is not matched by the pathogen with appropriable virulence genes, resistance reaction is the result. In most of the patho genes, virulence is recessive to avirulence (resistance).

(ii) Polygenic Inheritance:

In this case, disease resistance is governed by many genes with small effects, and a continuous variation for disease reaction is produced, ranging from low resistance (extreme susceptibility) to good resistance (low susceptibility). In case of polygenic resistance, disease resistance is not classifiable into clear cut resistant and susceptible class as is the case with oligogenes. The polygenes, show both additive and non-additive effects and there is a large environmental effect as is the case with most of the quantitative traits. Polygenic inheritance is quantitatively inherited and visually has a large SCA component.

The mechanism of resistance is not clearly known but resistance to infection is observed as in slow growth of pathogen and slow spore production. Presently, polygenic resistance doesnot show pathotype specificity as against the oligogenic resistance. Polygenic resistance is almost the same as horizontal resistance.

(iii) Cytoplasmic Inheritance:

In some cases, resistance is determined by cytoplasmic gene(s) or plasmagene(s). For example, maize strain having ‘T’ male sterile cytoplasm (cms-T) are extremely susceptible to Helimenthosporium leaf blight, while

those having the normal or non-T cytoplasm are resistant to this disease. Cases of cytoplasmic inheritance of disease resistance are rare.

METHODS OF BREEDING FOR DISEASE RESISTANCE

(i) Selection: Selection of resistant plants from a commercial variety is the cheapest and quickest method of developing a resistant variety.

(ii) Introduction: Resistant variety(ies) may be introduced for cultivation in a new area. This offers a relatively simple and quick means of obtaining resistant varieties.

(iii) Mutation: Selection of spontaneous and induced mutant plants with resistant to diseases through the use of mutagenesis.

(iv) Hybridization: It is the most common method of breeding for disease resistance. Hybridization serves two chief purposes:

(a) Transfer of disease resistance from an agronomically undesirable variety to a susceptible but otherwise a desirable variety (by backcross method).

(b) Combining disease resistance and some desirable characters of one variety with superior characteristics of another variety (by pedigree method).

Backcross method:

This is useful for transferring genes for resistance from a variety that is undesirable in agronomic characteristics to a susceptible variety which is widely adapted and is agronomically highly desirable. The resistant parent variety is the donor of the resistance gene and thus is known as the donor parent or non-recurrent parent. The susceptible variety to which the resistance gene is transferred is used as a parent in the recessive backcrosses, hence it is known as the recurrent parent. The backcross program would differ depending upon the allelic relationship of the resistance genes i.e., whether it is resistance or dominant to the allele for susceptibility. Generally, backcrosses are made for the recovery of recurrent parent phenotype along with transfer of disease resistance.

Pedigree method:

It is quite suited for breeding for horizontal or polygenic resistance. In breeding for disease resistance, artificial disease epidemics are generally produced to help in selection for disease resistance.

Lecture No. 25 & 26

Development of promising cultivars of important ornamentals and flower crops.

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.

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.

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:

l Selection of a large number of superior individuals from a genetically variable population.

l Raising of the self-progeny of each over several years under different environments. Unsuitable lines are eliminated in each generation.

l 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.

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.

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.

1. Intravarietal hybridization:

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

2. 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').

3. ***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.

4. ***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

5. ***Introgressive hybridization:***

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

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.

l China aster cultivars: ‘Kamini’, ‘Poornima’, ‘Shasank’, ‘Violet’, ‘Cushion’

l Hollyhock varieties: ‘Deepika’, ‘Dulhan’, ‘Gauri’, ‘Pusa Sweta’, ‘Pusa Krishna’, ‘Pusa Lalima’, ‘Pusa Gulabi’

l 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.

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).

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'.

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.

Advantages of polyploidy

l Ornamental haploids have more decorative value due to small flowers and prolonged blooming.

l Triploids have sterile flowers with longer flower life as reported in azaleas, lilies and hyacinths. Triploid chrysanthemum is used to produce pyrethrum.

l Tetraploids have luxuriant vegetative growth. Due to increased flower size, tetraploid cultivars are available in zinnia, antirrhinum and petunia.

l Somatically induced polyploids or allopolyploids contribute heterosis and hybrid vigour.

l 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.

l Meiotic polyploidization through homeologous recombination in the interspecific hybrids is reported in *Alstroemeria* and *Lilium*.

l Polyploids are more tolerant to drought, cold, mutagens, herbicides and poor soils.

Production of polyploids

l 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.

l Polyploidy due to somatic mutation may be caused by disruption in mitosis resulting in chromosome doubling, e.g. *Primula kewensis*.

l 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.

l Polyploidy is more frequent at high altitudes, high latitudes, in wet soils and meadows.

l 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.

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*

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’

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

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.

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.

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.

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*

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

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*

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*

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*

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*

Dahlia

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

(ii) Octaploid Dahlia : *D. imperialis* × *D. coccinea*

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)

Gerbera

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

Anthurium

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

Antirrhinum

Production of hybrids:

Antirrhinum majus × *A. molle* (Magic Carpet)

A. majus × *A. linkianum*

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*

Verbena

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

Hibiscus

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

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

Breeding Approaches for Disease Resistance

(1) Hybridization combined with pure line breeding

(2) Mutational approach

(3) Back cross breeding

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.

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 Lilium **segments of bulb scales** is used as explant source for propagation through ***in vitro*** techniques.

***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.

Lecture No. 27

Role of heterosis and its exploitation.

Objective: To teach students about the role of heterosis in hybrid seed production and importance of hybrid vigor in F1 hybrids over its parents.

Introduction to Heterosis

Heterosis refers to the gain in vigour on crossing of two inbreds. It is the phenomenon where F_1 population derived from crossing between two genetically diverse parents may show a gain or loss in morphological, physiological, yield and other traits over the parents.

Whereas F_1 refers to a cross between essentially two homozygous parents and the superior performance of this progeny over its patents is known as heterosis.

The classical term heterosis coined by Shull (1914) refers to the excellence of F_1 over strictly homozygous parents involved in its development.

The possible genetic cause for heterosis is:

1. **Partial to complete dominance:** Hybrid vigour is due to action and interaction of favourable dominant alleles. It hypothesizes decreased homozygosity for unfavorable recessive alleles.
2. **Over dominance:** Shull (1908), later expanded by Hull (1945): it states that the heterozygote (Aa) at one or more loci is superior to either homozygote (AA or aa)

Measurement of Heterosis

1. **Mid parent Heterosis:**

   Heterosis can also be expressed in terms of mid parent value i.e. the average of two parents. Thus, some of the hybrids may excel the mid parental value whereas others may not.

   Hybrid performance is measured relative to z mean of the parents (MP) (F1—MP)/MP X 100.

2. **High parent heterosis:** It is the comparison of hybrid to performance of best parent/high parent (HP). (F1-HP)/HPx100

3. **Positive and negative heterosis:** The beneficial effect of heterosis is termed as hybrid vigour and characterized by an increase in vigour, uniformity, size and yield parameters.

The negative heterosis, on the other hand is equally important as can be explained with the example in case of antirrhinum:

Character under Study: Number of spikes per plant

Character under Study: Days taken to flowering

Thus, for number of spikes per plant (yield), the hybrids between inbreds manifested positive heterosis, whereas for days taken to flowering it exhibited negative heterosis.

Both, however, are desirable for the character under study. Heterosis can also be calculated with respect to the standard or check variety of the given crop. It is the already established commercial variety under cultivation in a particular area.

Lecture No. 28

Production of F_1 hybrids and utilization of male sterility.

Role of male sterility in hybridization

- Developing non functional male part of female parent.
- Convenient to develop hybrids.
- It can be done by using chemicals or regulators.
- Otherwise manual crossing must which involves lot of skilled human resource.

Use in Marigold F1 hybrid production

- F1 Hybrid seeds in marigold were produced by using apetalous male sterile lines.
- Tester parents were maintained as inbred lines.
- Pusa Shankar- 1 was developed at IARI, New Delhi.
- Male sterile lines and tester parents were grown in separate polyhouses.
- Apetalous male sterile lines were maintained. These were exploited by making crosses with the respective tester parents from 9 a.m. to 2 p.m. by taking pollens from desirable male parents in a petri dish and dusting it on male sterile flowers with the help of a soft brush.
- The flowers were bagged with perforated butter paper bags.
- In French marigold and African marigold, Line x Tester was carried out by using tester parents.
- F1 hybrid seeds were collected and sown for evaluation in the subsequent seasons.

Procedure of Hybridization

Before starting a breeding programme it is essential to set out the objectives. Once the breeder has decided the objectives of programme, the hybridization work could be started.

The important steps involved in hybridization are:

(1) Slection of parents

(2) Evaluation of parents

(3) Emasculation

(4) Bagging

(5) Tagging

(6) Pollination

(7) Harvesting and Storage of F_1 seed.

Steps in hybridization

1) Selection of Parents:-

- The selection of parents mainly depends upon the objectives of breeding programme. Besides the targeted breeding objective, increased yields is always an objective of the breeder. Therefore, it is essential that at least one of the parents involved in a cross should be a well adapted and established variety in the area for which the new variety is being developed.
- The other variety/parent should be having the characters that we want to transfer into the new variety.
- It is essential that all the characters which we want to improve should be present in one or the other parent. If the desirable character is not present in either of the parents then one can go for use of three or more parents leading to a complex cross. Thus, the selection of parents is the basic step in a hybridization programme and often, more than anything else, determines its success of failure.

2) Evaluation of Parents:-

- Generally a variety well adapted to a particular area/location is selected for the hybridization. However, if the performance of parents in the area where breeding is to be done is not known, evaluation becomes necessary. There is a possibility that the introduced variety selected as a parent in the breeding programme may be susceptible to the new races of the pathogen occurring in the area, or even to new diseases present in the area for which their reaction may not be known.

3) Emasculation:-

- Emasculation is essential to prevent self-fertilization in the flowers of the female parent. Therefore, it involves the removal of stamens or anthers of a flower without affecting the female reproductive organs. Emasculation may also be carried out by killing of pollen grains of the selected female parent.

Techniques of emasculation

i) Hand Emasculation:

- It is the commonest method of emasculation in most of the floricultural crops. In species with relatively large flowers e.g. lilium, rose, aster, antirrhinum etc., stamens or anthers are removed with the help of forceps. The exact details of the procedure, however, varies from one crop species to the other.
- Emasculation is done before the anthers are mature and the stigma has become receptive. It is done to ensure any possibility of self-pollination. Usually, stigma receptivity is at its peak during the morning hours when the flowers open, but different crop species show considerable variation in the duration for which their stigmas remain highly receptive.
- After some experience, the breeder should be able to select such flowers without much difficulty. Generally, it is desirable to remove the older and the younger flowers located close to the flower to be emasculated in order to avoid confusion in the identification of crossed pods/fruits etc. For example, in antirrhinum emasculation is started when the lowermost flower is tight lipped but has started showing colour. Further, emasculation is done on successive days along with opening of the florets on the spike. Uppermost 1/2 to $1/3^{rd}$ portion of the spike is cut with a sharp scissors and not used for hybridization

- A general procedure for hand emasculation is as follows: The corolla of the selected flowers is opened and the anthers are carefully removed with the help of fine-tip forceps. Care must be taken to remove all the anthers from the flowers without breaking them and, the most important, the gynoecium must not be injured.
- An efficient emasculation technique should prevent self-pollination and produce high percentage of seed set on cross-pollination i.e. viability of the stigma should be judged critically.

ii) Suction Method:

- This method is useful in species with small flowers. Emasculation is done in the morning just before or immediately after the flowers open. The petals are generally moved with forceps exposing the anthers and the stigma.
- A rubber or glass tube attached to a suction- hose is used to suck the anthers from the flowers. The tube is also passed over the stigmas to suck any pollen grains present on their surface. The suction may be produced by an aspirator attached to a water tap, or by a small suction pump. The amount of suction used is very important.
- The suction should be enough to suck the stamens and pollen grains, but not the flowers or the gynoecium. With suction method, considerable self-pollination (up to 15 per cent) is likely to occur. Washing the stigma with a jet of water may help in reducing self-pollination. However self-pollination cannot be eliminated in this method.

iii) Hot Water Emasculation:

- Pollen grains are more sensitive than the female reproductive organs to both genetic and environmental factors.
- In the case of hot water emasculation, the temperature of water and the duration of treatment varies from crop to crop, and must be determined for every species. The hot water is generally carried in thermos flasks and the whole spike is immersed in the water. Emasculation with hot water is generally highly effective in killing all the pollen grains provided the correct temperature and treatment duration are used.

iv) Alcohol Treatments:

- It is not a commonly used method of emasculation. The method consists of immersing the flower or the inflorescence in alcohol of a suitable concentration for a brief period, followed by rinsing it with water.

v) Cold Treatment:

- Cold treatment, like hot water treatment, kills pollen grains without damaging gynoecium. Cold treatment is less effective than hot water treatment. The amount of self-pollination is generally greater in cold treatment than in the case of hot water treatment.

vi) Genetic Emasculation:

- Genetic or cytoplasmic male sterility is one of the most efficient attributes that can be utilized to eliminate the necessity of emasculation. Many species are self-incompatible. In such cases, emasculation is not necessary because self-fertilization will not take place. Many lilium species are self incompatible, and hence there is no need for emasculation.
- However, for commercial hybrid seed production, male sterility is the most feasible and efficient method of emasculation. Male sterility is commercially being exploited for the hybrid seed production in marigold and zinnia.

Steps involved in hybridization are:

4) Bagging:

- Immediately after emasculation, the flowers or the inflorescences are enclosed in suitable bags (preferably butter paper bags pierced with needle) of appropriate size to prevent random cross-pollination. In cross pollinated crops, the male flowers are also bagged to maintain the purity of pollen used for pollination.
- The bags may be made of paper, butter paper, glassier or fine cloth. The bags are tied to the base of inflorescence or to the stalk of flower with the help of thread, wire or pins designed for the purpose.
- The bags can be removed usually 2-3 days after pollination after the danger of cross-pollination is over.

5) Tagging:

- The emasculated flowers are tagged just after bagging. Tags are available indifferent sizes. In most of the crops, circular tags of about 3 cm diameter, or rectangular tags of 3 x 2 cm are used. The tags are attached to the flower or the inflorescence with the help of thread. The following information is recorded on the tags with a carbon pencil.
    - Date of emasculation
    - Date of pollination

- Details of the cross i.e. names of the female and the male parents. The name of the female parent is written first, and that of the male parent is written later e.g. A x B denotes that A is the female parent and B is the male parent.

6) Pollination:

- Application of mature, fertile and viable pollens on the top of receptive stigma with an objective to carry out fertilization is known as pollination.
- For carrying out hybridization it is a prerequisite that the pollens should be viable and stigma be receptive.
- Generally the fresh pollen from mature anthers should be used for pollination because in most cases the time of anther dehiscence falls within the duration of stigma receptivity and both generally coincide with the opening of flowers. Anthers generally dehisce during morning; the exact time varies with the species.
- The duration of pollen viability after anther dehiscence varies greatly from one species to another, e.g., a few minutes in wheat and oats to a few hours in maize.
- The pollination procedure consists of collecting pollen from freshly dehisced anthers of the male parent and dusting this pollen onto the stigmas of emasculated flowers.

Techniques of pollen application:

1. Pollen grains are collected in a petri dish/bag, and are used for dusting the stigmas of females inflorescence e.g. in antirrhinum, pansy etc.
2. Mature anthers are collected from the flowers of male parent. The pollen is liberated on a clean petri dish and applied to the stigmas with the help of a camel hair brush, pieces of paper, tooth pick or forceps.
3. Anthers are collected and allowed to burst directly over the stigmas.
4. The flower which has to act as male parent is plucked and pollens are dusted onto the stigmas with gentle tapping on female flowers e.g. in marigold female lines are dusted directly with the pollen parent to bring about pollination.
5. The spike of male inflorescence is shaken over the emasculated inflorescence just when the anthers are about to dehisce. As a result, the exposed stigmas are covered with pollen.

Harvesting and Storing the F_1 Seeds:

- The crossed heads or pods should be harvested and threshed. The seeds from each cross should be kept separately and, preferably the seeds should be kept along with the original tags.
- The seeds should be dried properly before storage. Improper drying of seeds may cause rotting of seeds, fungal attack or pests problem during storage.
- It is essential that the hybrid seed must not be mixed with any other seed.
- Hybridization has resulted in the development of new varieties in almost every floricultural crops including rose, chrysanthemum, gladiolus, lilium, marigold, petunia, pansy, stock, other annual crops etc.

Seed Production Procedure

A generation production routine has the following components:

1. Parental plant culture
2. Genetic quantity control
3. Pollination management
4. Seed harvest and seed extraction
5. Seed cleaning and conditioning.

Parental plant culture

- Parent plants of most hybrid flowers are raised from seed.
- The seeds are sown in seedling flats or plug trays in a specialized section of the greenhouse serving as the nursery.
- Parents of male sterile lines, for example some impatiens and petunia varieties, are propagated by vegetative cuttings.
- Tissue culture propagated plants are sometimes used for special parent lines of primula and Dianthus. These plants are also raised in the nursery.
- When a hybrid is produced from a cross between a seed and a vegetative raised parent, the time of planting have to be adjusted to ensure synchronization of flowering. Well developed young plants are transplanted into pots and put on benches in the production greenhouse.

- Plant nutrition, disease control and pest management are the most important components of plant culture.

Genetic quantity control

- Genetic purity tests are conducted on stock seed lots. Only seeds of high genetic purity are used in production.
- When the parent plants begin to flower, they are further checked for the presence of off types.
- Rouging is based on plant habit, foliage colour, earliness to flower, flower colour and flower form.
- Breeding companies are responsible for the purity of the stock plants in production contracts.
- All greenhouses used for hybrid seed production are equipped with insect proof screens to prevent accidental pollination by insects form the fields.

F_1 Hybrids of ornamentals

- An F_1 hybrid is produced by crossing between any two genetically different parental lines.
- The first F_1 hybrid was evolved during the 1940s in petunia amongst annuals.
- F_1 hybrids are characterized by increased vigour, uniform in growth habit, dwarf, compact, free flowering, early flowering, huge side tillering, doubleness, gigantic and attractive flower types and resistance towards biotic and abiotic stress.

Steps involved in F_1 hybrid seed production

1. Development of Inbred lines

- Standards open pollinated varieties or wild species are the sources of inbred lines.
- In self pollinated crops, homozygous varieties are used, whereas inbred lines are developed especially for cross pollinated crops.

2. Testing of combining ability

- Repeated test crosses and testing of F_1 hybrids are done to evaluate the parental lines.
- Suitable parental lines to carry out combing ability are developed in the following ways.

Collection of genetically divergent materials

Selection based on performance

1. Comparative evaluation of parents and F_1 crosses for self pollinated crop.
2. Comparison of the yield of inbreds with mean yield of their single cross.

- • Different types of crosses are made to test the combining ability of inbred lines.
- • The top cross and poly cross tests are used to determine Genetic Combining Ability(GCA), single or pair cross for Specific Combining Ability (SCA) and diallel analysis for both the GCA and SCA of male sterile line, respectively, equipped with insect proof screens to prevent accidental pollination by insects from the fields.

Utilization of male Sterility

- For the production of F_1 hybrid seeds under open field conditions by using genetic male sterility, the requirements are:
- an inbred line which is to be used as male parent.
- another inbred line which is maintained by crossing together known heterozygous (Ms ms) and male sterile (ms ms) plants i.e. femina line.
- Male sterility is governed by a single recessive gene and therefore the maintenance of the genetic stock is difficult as there will be continuous segregation of the fertile and sterile individuals in 1:1 proportion.
- This phenomenon is present in Tagetes, Zinnia, Delphinium, Antirrhinum, Calceolaria, Salvia and Impatiens.
- Seeds should always be harvested from (ms ms) plants
- The cross of ms ms x Ms ms should be repeated in every generation, as it will segregate in 1 Fertile: 1 Sterile ratio.
- For maintenance of male sterility, a ratio of male sterile line to pollinating fertile line is dependent on the size of hybrid block, but ratio of 3 male sterile: 1 male fertile has proved to be the optimum.

Male sterility for hybrid seed production in flowers:

- Ageratum: In this annual crop, both the male sterility and self incompatibility systems are prevalent and a choice can be made on the basis of economy in the seed production.
- Petunia: In petunia, cytoplasmic male sterility has been observed but the use of this type of male sterility is not so practically common because of breakdown of male sterility in the maternal parent or malformation of flowers in F_1 generation.

- Sunflower: Male sterility in sunflower has been used to produce ornamental varieties like 'Sunrich Orange' (Japan) and 'Orit' (Israel) which have no pollen grains and allergic effects like in other male fertile varieties grown for their seed.
- Marigold: Male sterility has been extensively utilized for the F_1 hybrid seed production in marigold. The notable hybrids developed in India with the use of male sterility are 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda'.

Characteristics of male sterile line/ femina line

- Used as a female parent in the hybridization programme.
- Male sterility should be stable.
- It should have desirable traits.
- It should have synchronous flowering with the male parent i.e. pollinator and maintainer plant
- Its genetic constitution is homozygous recessive (msms)

Characteristics of tester parent

- Used as a male parent in the hybridization programme.
- Pure with uniform population i.e. an inbred or pureline
- It should produce abundant pollens.
- Synchronous flowering with male sterile plants
- Its genetic constitution is homozygous dominant (MSMS)

Characteristics of maintainer line

- Used for maintenance of ms-line.
- Its genetic constitution is homozygous (Msms)
- Synchronous flowering with male sterile plants.

Lecture No. 29

Production of open pollinated seed.

There are substantial differences between the management of open field and greenhouse flower seed production:

- In the open field, seed crops are produced in blocks of one or more hectare. It is less labour intensive but more equipment and inputs are required.
- Most of the crops produced in the field are open pollinated varieties, though hybrids with self incompatible parents can also be produced.
- Unlike greenhouse production, which can be year round activity, outdoor production is seasonal.
- Identifying locations with suitable climates and producing the crops in the appropriate season are keys to reliable seed supply.

Basic steps in the production of open pollinated varieties

Site selection:

- Site selection is probably the most important factor in outdoor seed production.
- The production area should provide the required period of appropriate temperature, light and moisture condition for parent plants to develop and the seed to ripen fully.
- There should be a dry period at harvest time to allow field drying of seed
- Soil type is also an important factor in site selection. Some crops, e.g. pansy can tolerate heavy soils, while others, like nasturtium, only do well in well drained fields.
- Disease and pest pressures within the general production area are significant factors.

Isolation distance:

- An open pollinated variety is one that is genetically stable and generally reproduced by self or cross pollination.
- In the open field, pollination is done by wind or insects, depending on the specific floral morphology and properties of the crop species. These natural means of pollen transfer are random in nature.
- To ensure varietal purity, care has to be taken that different seed crops of the same species are not grown closely together.

- The isolation distance requirements generally range from 200 to 1000 m or more, depending on whether the crop is mostly insect or wind pollinated.
- The topography of the production site, as well as the direction of prevalent winds should be considered when determining by how fair different varieties of the same species should be separated from each other.
- Some crops, like sweet pea, have flower structures that allow self pollination as the flowers develop and mature. Different varieties of these crops can be produced as close as 5m apart.
- Seed producers have to keep the required isolation distance in mind when they plan the placement of production fields.

Crop culture:

- Agronomic practices used for flower seed production are generally similar between crops within a production area, but they vary greatly between different production areas.
- The parent plants are usually grown in beds to facilitate irrigation, fertilizers application, and fungicide and insecticide sprays.
- The plants are checked for genetic uniformity when they begin to flower.
- Removal of off types in the population is an intensive activity. A few rounds of rouging are often necessary to ensure high genetic purity because not all plants begin to flower at the same time.
- Weeding is another labour intensive aspect of field production. There is an increasing use of plastic mulches in seed production fields for weed control and moisture conservation.
- Unpredictable weather condition, as well as pest and disease pressure requires day to day judgment on irrigation and pest management needs.
- Good seed yield and quantity occur when the environmental conditions are favourable.

Pollination:

- Pollination management for open pollinated crops begins with selecting production locations naturally conducive to good seed set.
- Optimum climatic conditions must fit the crops temperature and light requirements for flowering, pollen production and stigma receptively.

- Insect pollinated crops are best placed in locations where populations of natural pollinators are high. In marginal cases, beehives can be placed in production fields to increase pollination activity.
- Honey bees are the most common pollinators. Other commercially available insect pollinators include bumble bees, leaf cutter bees and flies.
- Applications of fungicides and insecticides during the flowering period can negatively affect seed set. Some pesticides and fungicides cause damage to the stigma and interfere with pollen tube development. Insecticides commonly used for insect pest control also kill pollinating insects and reduce seed yield.

Harvesting and drying:

- Since the seed is harvested only once in the field, determining the proper time to harvest is a critical decision and is based on a compromise between optimum yield and potential seed quality.
- When the crop is judged for harvesting, the plants are cut and placed on canvas tarpaulin to dry in the field. The dried plant materials are threshed.
- Adverse field conditions, especially rain during the drying period, can cause seed deterioration.
- Covering the harvested seed materials before the rain, or moving them to dry indoor, are extra efforts required in these situations.
- Field harvested seed is partially cleaned by scalpers in the open air before being transported to the seed company mill.
- A crop that is harvested too early may germinate well initially but the seed does not store well.
- Since the field produced seed population is inherently more heterogeneous in maturity, the seed drying and conditioning processes have a great influences on seed quality.
- Some seed procedures use portable seed dryers in the field. Other set up permanent drying facilities close to the major production areas.

Seed cleaning

- Field grown seed contains substantial amount of debris, from less than 20% to over 80% by volume, depending on the crop and the harvest methods.

- The seed of low growing plants cut at the soil line e.g. alyssum, contains more field dirt. This seed is first put through an air screen cleaner, which is the most widely used equipment for removing both plants parts and soil particles.
- Additional size separation by gravity deck or air column may be needed before the seed is cleaned to a commercially acceptable standard.

List of some important companies dealing with the seed production of flowers:

1. Indo American Hybrid Seeds (India) Pvt.Ltd

- 2nd Main, 17th Cross, K.R.Rd,
  BSK 2ndStage, Bangalore
  Tel: (080) 6650111
  Namdhari Seeds (Pvt) Ltd
  119, Arasappa Complex,
  9th Main Road, Ideal House,
  Raj Rajeshwari Nagar,
  Bangalore:39
  Tel: (080) 2210987, Fax: 8602168

2. Novartis India – Seeds Division

- Seeds Divn. ,Seeds House,
  1170/27,
  Revenue Colony,
  Shivaji Nagar,
  Pune: 411 005
  Tel: (020) 5539311-13

3. **Ball Horticultural Company**

- M&B Flora Co., Ltd. – Distribution
  3181-4 Kamisasao Kobuchizawa
  Kitakoma-gun Yamanashi 408-0041
  Japan
  Phone: 81-551-36-5677
  Fax: 81-551-36-5636
  www.mbflora.co.jp

Lecture No. 30

Harvesting, processing and storage of seeds.

Harvesting of Seeds

- Commercial flower seed production is an international business involving highly specialized growers.
- The production activities include harvesting and processing (drying, seed sizing, pelleting and storage) of seeds.

Harvesting of Seeds

- Optimum stage and time of harvest are critical factors in the production of optimum quality seeds.
- Seeds are generally harvested when they are completely ripe on the plant.
- The basic rule of harvesting is to allow the seed to mature as long as possible on the plant without the seed or fruit becoming diseased, or overly ripe.
  - Each type of plant has an optimum time for collecting the seed, but factors such as climate, weather, disease, insects, birds, or predatory mammals may require that the seed be collected at less than the optimum time
  - When the crops are judged ready for harvesting the plants are either cut as a whole or seeds harvested with different procedures.
  - Some seeds of annuals and perennials fall from the plant at ripening either due to bursting of the fruit or due to wind. Such seed capsules should be covered with muslin cloth or butter paper bags before ripening to collect the shedding seeds in bag.
  - Adverse field conditions, especially rain during the drying period, can cause seed deterioration.
  - Covering the harvested seed materials before the rain, or moving them to dry indoor, are extra efforts required in these situations.
  - In floricultural crops, the flowers are produced in a succession of about 30-60 days or even more. They mature in different times, resulting in seed harvesting at different intervals.
  - After harvest, seeds are threshed to remove the seed from the surrounding plant material. A period of air-drying is important before seeds are threshed.

- Plant material should be spread out in thin layers until all plant material is dry; otherwise, mold, decay, and heat from decay will cause damage to the seeds. As the plant material dries, seed pods may split open or shed seed.
- Plant material that is ready to be threshed should be brittle. Threshing is best done outside on a dry day.
- The threshing process involves application of mechanical force using a controlled pressure and a shearing motion., and is accomplished by hand or by machine.
- The seeds are then sieved with different types of sieve of iron mesh/plastic mesh and finally cleaned by hand winnowing to separate out the light/unviable seeds and dust particles.
- The seeds after proper cleaning are packed in HDPE bags and kept in shady and well ventilated rooms.
- A crop that is harvested too early may germinate well initially but the seed does not store well.

Table 1: The stage of seed harvest of different annual flower crops

	Plant	**Stages of collection**
1	*Alyssum maritimum*	The seeds shatter easily. Remove pods when just about to dry.
2	*Antirrhinum majus*	Cut when just about to dry, spikes mature from lower branches onwards.
3	*Arctotis stoechadifolia*	Cut the whole plant when maximum amount of seed matures and then dry on canvas
4	*Calendula officinalis*	Seeds shatter when too dry. Collect heads when partially dry.
5	*Campanula spp.*	Whole plants may be harvested
6	*Celosia spp.*	Collect the heads when dry on the plant. Protect drying heads from rain
7	*Chrysanthemum coronarium*	Cut when almost all the flower heads dry.
8	*Clarkia elegans*	Remove seeds as they begin drying
9	*Cosmos bipinnatus*	Collect the seeds as pods dry
10	*Dahlia variabilis*	Collect the seeds as the heads dry on the plants.
11	*Delphinium sp.*	Collect heads of flowers as they dry. Take out tubers when plant almost dry. Store in dry and cool place.
12	*Dianthus sp.*	Cut the whole plant when the lower capsules begin to dry and dry in shade.
13	*Dimorphotheca sp.*	Seeds may shatter if allowed to dry too much on the

		plant. Collect individual heads as they begin to dry.
14	*Gaillardia pulchella*	Cut the whole plant when the maximum amount of seed is mature.
15	*Gazania splendens*	Cut the entire plant when the maximum amount of seed is mature and dry on canvas.
16	*Godetia grandiflora*	Cut the entire plant when the maximum amount of seed is mature and dry on canvas
17	*Gomphrena globosa*	When lower capsules open and begin drying, cut the entire plant and dry in shade.
18	*Gypsophilia elegans*	When the heads dry, collect individually.
19	*Helianthus annus*	When the majority of the capsules have turned brown, cut whole plant and on canvas
20	*Iberis amara*	When the flower heads dry, collect individually
21	*Helichrysum bracteatum*	Cut the whole plant and dry in sun set at the first signs of seeds becoming dry
22	*Impatiens balsamina*	When the heads become fuzzy, collect individually.
23	*Lathyrus odoratus*	Cut the entire plant when the maximum amount of seed is mature and spread on canvas to dry.
24	*Limonium sinuatum*	When the lower pods commence drying remove the entire plant and dry in shade.
25	*Linaria bipartita*	Cut the whole plant when the maximum amount of seed is mature and spread on canvas to dry.
26	*Linum grandiflora*	When the lower pods begin drying, remove the entire plant and dry in shade
27	*Lupines hartwegii*	Cut the entire plant when the maximum amount of seed is mature and dry on canvas.
28	*Mathiola incanna*	Remove individual seed pods as they dry. If allowed to dry in excess on the plants, they would burst.
29	*Mesembryanthemum crimifolium*	Remove the plant when seed pods begin drying. Dry in sun or shade. Single flower seeds produce 50% or more double flowering plants.
30	*Molucella laevis*	Whole plant should be harvested and seed should be extracted.
31	*Papaver roheas*	Whole plant should be harvested and seeds should be extracted by beating the plants with stick.
32	*Petunia hybrida*	Remove seed pods as they begin drying
33	*Phlox drumondii*	Remove seeds when just about to dry to prevent shattering.
34	*Pimpinella monoica*	Harvest umbels when completely dry and collect seeds by threshing.
35	*Portulaca grandiflora*	Collect when capsules begin to dry
36	*Rudbeckia bicolor*	When flower heads become fuzzy collect them and dry in shade
37	*Salvia splendens*	When seed cap dries, remove plant and dry in shade.
38	*Tagetes sp.*	Collect flower-heads as they dry. Plants of dwarf

		species should be removed when all the flower heads are dry.
39	*Tithonia speciosa*	Collect the flower heads as they become fuzzy and dry in shade.
40	*Tropaelum majus*	Collect seeds as they dry. If allowed too long on the plant they fall off
41	*Viola wittrockiana*	Collect seed pods when just about to dry and shatter when over dried on the plant
42	*Venidium fastuosum*	When flower heads become fuzzy collect them and dry in shade.
43	*Zinnia elegans*	Cut flower heads as they dry. Dwarf varieties may be removed when the entire flower heads dry out.

Seed Processing

- Seed processing includes different operations starting with seed cleaning, drying, sizing, pelleting and storage.
- The freshly harvested seeds are dried under shade to facilitate easy seed shattering and collection under controlled environments.

Stages of seed processing

Seed Cleaning:

- Field grown seeds contains substantial amount of debris from less than 20% to over 80% by volume, depending upon the crop and method of harvest.
- The seeds of low growing plants are cut at the soil line e.g. Alyssum, contains more field dirt.
- The seeds are cleaned manually or mechanically.
- In mechanical method, the seed is first put through a screen cleaner, which is the most widely used equipment for removing both plant parts and soil particles.
- After the initial removal of plant and field debris, additional rounds of seed cleaning are required if the seed contain outer coat structures that impede simulation in packaging and sowing, or water uptake during germination.
- It is customary to remove hairy layers on the seed coats of gazania.

- The development of seed cleaning and grading methods begin with mechanical separation of seed particles based on difference in their physical properties.
- Mechanical seed separation techniques are effective in cleaning out field debris from the crop seeds besides removal of broken and immature seeds.

Seed Sizing:

- Seed sizing is a process in which a heterogeneous population is physically separated by size to create a more homogeneous group of seeds.
- The traditional method for sizing the seed is to pass it through a set of stacked screens declining sequentially in aperture size.
- The screen types are generally made up of a wire or nylon woven mesh or a perforated metal sheet.
- Seed sizing is a challenging factor in extremely small sized seeds. For example there are approximately 10,000 petunia seeds in one gram.
- For very small seeded crops, a sonic sieve can be used for size separation.

Pelleting

- A seed pellet is a substance applied to the seed which obscures its shape, thereby making flat or irregularly shaped seeds more round, and making small and light seeds larger and heavier, thus enhancing precision planting and accurate placement by seeders.
- Most seeds are pelleted in a rotating drum to which the pelleting material and water are periodically added.
- Pellets are typically composed of fillers such as clays, diatomaceous earth, graphite, powdered perlite, or a combination of these and other materials
- A binding or cementing agent is also applied at specific concentrations which facilitates adhesion of the filler to the seed, thereby adding durability.
- The filler materials, as well as the binder, can be modified to regulate the water-holding capacity of the pellet.
- Since the pelleting process employs water as the solvent/binder for the pelleting material and cementing agents, it can also be absorbed by the seed during the pelleting process. As a result, seed storage life can be reduced for pelleted seed if the pelleting process is not carefully controlled during its application.

- Seed pellet is one of the most important recent seed enhancement innovations in flower plug production because they improve seed plantability and performance.

Seed Packaging

- Seeds are packed in different containers to protect them from extraneous environmental factors, to facilitate easier handling during storage and to enhance their marketability.
- Normally seeds are packed in cotton, jute, paper bags, polythene bags, laminated aluminum foil pouches, or aluminum cans.
- For long time storage hermetic containers such as laminated aluminum foil pouches or cans are used.
- Pouches are effective in maintaining desired levels of seed moisture for fairly long periods.
- Laminated pouches are handy and attractive, can withstand temperatures from 20 to 40° C, and occupy less space during storage.
- In open storage, humidity is controlled using a dehumidifier, while at low temperatures moisture proof containers are used to protect seeds from high humidity.

Storage of seeds

The main objective of seed storage is to preserve planting stocks from one season to the next.

- The seeds are considered in storage from their physiological stage of maturity to germination.
- A complete storage period should have the following essential steps:
- Storage on plants
- Storage from harvest until processing
- Warehouse storage
- Storage in transit
- Retail storage
- On the user's farm

Seed Storage:

On the basis of duration of seed storage, the annual seeds are classified as seeds with short, medium and long storage life.

- **Short Storage life (less than 1 year):** Anemone, Aquilegia, Arabis, Asclepias, Asparagus, Aster, Begonia, Bellis, Browallia, Calceolaria, Callistephus, Catharanthus, Cleome, Fuchsia, Gaillardia, Gerbera, Helichrysum, Hippeastrum, Iberis, Phlox, Impatiens, Iris, Lantana, Liatris, Lillium, Limonium, Nemesia, Pansy, Salvia etc.
- **Medium Storage life (1 to 3 years):** Achillea, Ageratum, Alyssum, Antirrhinum, Brachycome, Campanula, Cineraria, Clarkia, Coleus, Cyclamen, Dahlia, Delphinium, Dianthus, Euphorbia, Gaillardia, Gomphrena, Helianthus, Hibiscus, Lathyrus, Lavandula, Lisianthus, Lotus, Lupinus, Marigold, Matthiola, Nicotiana, Paeonia, Papaver, Pelargonium, Petunia, Portulaca, Rudbeckia, Saintpaulia, Tagetes, Verbena etc.
- **Long Storage life (more than 3 years):** Brassica, Calendula, Mimulus, Celosia, Centaurea, Chrysanthemum, Gypsophila, Sweet pea, Morning glory, Zinnia etc.

Table 2: Specific Seed Storage conditions for some flower crops

Sr No.	Crop	Temperature	Relative Humidity	Duration of storage
1	*Delphinium*	15°C	20-40% RH	6 months
2	*Pelargonium x hortorum*	25°C	11-32%	6 months
3	*Gerbera jamesonii*	25°C	11-32%	9 months
4	*Impatiens walleriana*	25°C	32%	9 months
5	*Tagetes erecta*	25°C	11-32%	8 months
6	*Viola x wittrockiana*	25°C	32-52%	4.5 months
7	*Petunia hybrida*	25°C	32%	12 months
8	*Phlox drumondii*	25°C	20%	12 months
9	*Salvia splendens*	25°C	32%	12 months
10	*Catharanthus roseus*	25°C	11-52%	12 months

Lecture No. 31

Seed certification.

- Seeds are vehicles for the spread of new life from one place to another.
- Good quality seed is defined as the seed that is genetically uniform, highly viable and free from seed borne pathogens.
- Flower seed production seems to have great scope for expansion in developing countries like India, especially under northern Indian climatic conditions having favourable growing conditions, skilled and cheap labour, marginal recourses from small landholding and need for crop diversification.
- Presently, annual flowers such as petunia, Coreopsis, Helichrysum, phlox, nasturtium, marigold, Gaillardia, salvia, ice plant, Verbena, Nemesia, pansy, poppy, larkspur and chrysanthemum, etc. are being widely grown for seed production.

Classes of Seeds

Nucleus seeds

- This is the initial amount of pure seed of an improved variety available with the concerned plant breeder.
- It is always cent percent pure genetically as well as physically and it is very limited in quantity.
- It is produced under the direct supervision of a plant breeder at the main breeding station.

Breeder seed

- This is the seed obtained from the progeny of nucleus seed.
- It is a seed or a vegetative propagating material produced by the breeder, who has developed a particular variety.
- It is produced by the institution where the variety was developed in case the breeder is not available.
- Breeder seed is used to produce the foundation seed.
- It is produced under the direct supervision of the breeder and is 99.9-100% pure genetically as well as physically.

Foundation seed

- It is obtained from breeder's seed by direct increase or multiplication.
- Foundation seed is genetically pure and it is the source of registered and certified seed.
- Any seed which is produced on government multiplication farms is usually called as foundation seed in spite of whether it has been produced directly from nucleus seed or breeder's seed.
- Production of foundation seed is the responsibility of National Seed Corporation (NSC) and State Seed Corporation (SSC).
- It is also produced at the experimental stations, agricultural university or on cultivator's field under strict supervision of research scientists and Seed Certification Agency (SCA).
- It is recommended that foundation seed is 99% pure.

Registered seed

- It is the name given to the seed raised form the progeny of nucleus, breeder or foundation seed.
- The registered seed is produced by registered growers who are selected among the progressive educated farmers and who are well known with the work of seed multiplication.
- They are given instructions of technical staff of NSC or SSC and issued the instruction and improved seed for further multiplication.
- It is also genetically pure and is further used to produce certified seed or again registered seed.
- Often registered seed is omitted and certified seed is produced directly from the foundation seed.

Certified seed

- Certified seed is produced from foundation, registered or certified seed. This is known as certified seed since it is annually produced by programmed farmers according to the standard seed production practices.
- To be certified, the seed must meet certain rigid requirements regarding purity and quality. These standards vary from crop to crop.
- Certified seed is available for general distribution to farmers for commercial crop production.
- Seeds are vehicles for the spread of new life from one place to another.
- Good quality seed is defined as the seed that is genetically uniform, highly viable and free from seed borne pathogens.
- Flower seed production seems to have great scope for expansion in developing countries like India, especially under northern Indian climatic conditions having favourable growing conditions, skilled and cheap labour, marginal recourses from small landholding and need for crop diversification.
- Presently, annual flowers such as petunia, Coreopsis, Helichrysum, phlox, nasturtium, marigold, Gaillardia, salvia, ice plant, Verbena, Nemesia, pansy, poppy, larkspur and chrysanthemum, etc. are being widely grown for seed production.
