Breeding and Seed Production of Ornamental Plants

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2. Breeding and Seed Production of Ornamental Crops (HPF 101) 3(2+1)

History of improvements of ornamental plants, objectives and techniques in ornamental plant breeding. Introduction, selection, hybridization, mutation and biotechnological technique for improvement of ornamental plants. Breeding for disease resistance. Development of promising cultivars of important ornamentals. 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.*

Lecture 1 - History of Improvement of Ornamental Plants- Part I

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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 of Breeding

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).

History of Improvement in Ro

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 (NBR1), 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.

History of improvement of Gladiolus

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.

History of improvement of Chrysanthemum

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.

Lecture 2 - History of Improvement of Ornamental Plants- Part II

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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.

History of improvement of Bougainvillea

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.

Annual Flowers

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).

Lecture 3: Objectives in Plant Breeding

Objective: To teach the students the need for carrying out improvement work in ornamental crops. The chapter also discusses the objectives of breeding in general, like improved quality, induction of variation, high flower yield, and resistance against abiotic stresses etc.

Objectives in Plant Breeding

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.

Lecture 4: Techniques/Methods of crop Improvement

Objective: To teach the students various techniques (like introduction, selection, hybridization, mutation, polyploidy and genetic engineering) used for crop improvement in ornamental crops.

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.

Methods of Crop Improvement

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.

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.

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)

Lecture 5 : Plant Introduction

Objective: Introduction is one of the oldest methods of crop improvement. In this chapter students will be able to get information about the role of introduction in crop improvement types and methods of plant introduction for introducing a new variety.

Plant Introduction

The agencies involved in plant introduction and the procedure of plant introduction is also given in brief.

Plant Introduction

- It consists of taking a genotype or group of genotypes into a new environment where they have not been grown before.
- The introduction may involve introducing new varieties of the crop already grown in the area, wild relatives of the crop species or a totally new crop species for the area.
- It can be done within the country or from other countries of continents.

Types: Introduction can be categorized as:-

4. Primary Introduction
5. Secondary Introduction

1. Primary Introduction

• An introduction is said to be primary introduction when the introduced variety is well suited for new environment.

• It is released for commercial cultivation without any alteration in original genotype.

• In floricultural crops, the commercial varieties of rose, carnation, gerbera etc. which are presently being grown for commercial cut flower production or export have been introduced from different
parts of the world.

2. Secondary Introduction

• The introduced variety may not be suitable for direct cultivation and can be subjected to selection to isolate a superior variety suitable for a particular area.

• The introduced variety may also be hybridized with local variety to transfer one or two characters from it to local variety.

Plant Introduction Agencies

- A centralized plant introduction agency was initiated in 1946 at IARI, New Delhi.
- The agency began a plant introduction scheme in Division of Botany and was funded by ICAR.
- Subsequently in 1961 it was made on independent division and subsequently called as National Bureau of Plant Genetic Resources in 1976.
- Other plant introduction agencies are:
- NBPGR (National Bureau of Plant Genetic Resources, New Delhi)
- FRI (Forest Research Institute ,Dehradun)

- The Botanical Survey of India
- Central Research Institutes for different crops.
- NRC Orchids, Gangtok, Sikkim

Procedure of Plant Introduction

Plant introduction is one of the oldest and very effective methods of plant breeding. The main function of plant introduction is to make available the germplasm that can be utilized in plant breeding programme.

Introduction consists of various steps:-

1. Procurement.
2. Quarantine
3. Cataloging
4. Evaluation
5. Multiplication

1) Procurement of germplasm

- The new germplasm is procured through NBPGR, New Delhi.
- Scientists, individuals and institutions can submit their requirement to Director, NBPGR, Pusa Complex N.Delhi-12.
- If the bureau is unable to meet the request from its own stock or from known source it attempts to procure them from the counterparts in other countries.
- Generally the material is obtained through correspondence as gifts or exchange of germplasm in consideration of past gifts to the Bureau

or in anticipation of future gifts.

• The Bureau participation in the activities of NBPGR aims at free exchange of germplasm and is helpful in arranging supply of needed germplasm.

• The plant part depending on the crop species e.g. seeds; tubers; suckers, bulbs or cuttings etc. can be procured.

2) Quarantine

• It is to keep the material in isolation to prevent spreading of diseases etc.

• All introduced material is thoroughly inspected for contamination with diseases, weeds and insects. Plants that are suspected to be contaminated are fumigated or are given other isolation for treatments and observed for insect pests and disease.

• The entire process is known as quarantine and the rules which are used for this are known as Quarantine rules.

• It is essential that all the material being introduced must be accompanied by an authentic phytosanitary certificate.

• The plant material being introduced or exported must confirm to certain quarantine regulations and quarantine control is exercised by NBPGR at different points of entry.

• The phytosanitary certificate is thoroughly inspected and returned back to the sender or owner.

3) Cataloging

All the plant material which is introduced is given an entry number and information regarding agency, place of origin, adaptation etc and is well documented.

Plant material is classified in three categories

- Exotic collection (EC)
- Indigenous collection(IC)
- Indigenous wild collection

4) Evaluation

• The plant material is sent to sub stations of the bureau and evaluated with respect to various characters to assess the potential of new introductions.

5) Acclimatization

• It is the process that leads to the adaptation of a variety to a new environment.

• Variability must be present in original population so that natural selection could lead to acclimatization. The extent of acclimatization is determined by range of genetic variability in original population and duration of life cycle of crop.

• Cross pollination leads to far more gene recombination than self pollination. The greater the initial variation the more is acclimatization.

6) Multiplication and distribution

• Plant material which is introduced is to be multiplied and further tested at various locations. The suitability of cultivation in different regions of the country should be assessed before using it as a commercial variety.

Role of Plant Introduction in Floricultural Crops

Main purpose of introduction is to improve the economy of the country. Introduction has proved to be one of the most potential methods of crop improvement in commercial cut flower production because most of the commercial cultivars of different crops have been introduced in India.

Advantages of plant Introduction:
1. It provides entirely new crop plant which has not being grown earlier e.g. alstroemeria, bird-of-paradise etc.
2. It may provide superior variety directly or after selection or hybridization. Many superior varieties of different floricultural crops roses have been introduced in the country for direct cultivation e.g. 'Passion', 'Grand Gala' in rose.
3. Introduction and export are the only feasible and fastest means of collecting germplasm and to prevent variability from genetic erosion.
4. It is quick and economical method for crop improvement particularly when introductions are released as a variety directly or after simple selection.
5. If a particular location is prone to some particular disease or insect attack, plants may be introduced in new disease free areas directly to protect them from damage.

Some prominent introductions in Ornamentals:
Cut Flowers Cultivars
Rose: Golden Gate, Passion, Grand Gala, Superstar, Queen Elizabeth
Carnation: Master, Sangaria, Dover, Yellow Dot Com, Tasman, Farida.
Alstroemeria: Alladin, Serena, Pluto, Capri, Cindrella
Annuals: Marigold, Antirrhinum, Pansy, Petunia, Stock, Zinnia, Calendula etc.
Trees: *Bauhinia esculenta*, *Cryptomeria japonica*, *Cupressus* species, *Sepium sebiferum*
Shrubs: Different species and varieties of Bougainvillea, *Buddeleia davidii* etc.

First Red

Konfetti

Golden Gate

Grand Gala

Farida

Malga

Pink Dover

Elite (Asiatic)

Brindisii (LA)

Pollyana (Asiatic)

Alladin

Serena

Pluto

Fiji

Thai Ching Queen

Tata Century

Elite (Asiatic)

Brindisii (LA)

Pollyana (Asiatic)

Lecture 6 : Selection

Objective: To teach the students about the procedure of selection involved in breeding of ornamental crops. The requirements and limitations of the method are also being discussed.

Introduction to Selection

Selection is the oldest method of crop improvement and was developed as an art in the olden days. Selection consists of permitting the reproduction of some desirable genotypes from a given population and using it further for commercial cultivation.

Types of selection

1) Natural Selection

2) Artificial Selection

1) Natural Selection:

- Selection is a continuous process and in nature it is governed by natural environmental conditions e.g. temperature, soil, weather, prevalence of pest and disease etc. In this process, the genotypes showing adaptability to a given environment leaves behind more progeny. It can be used for further multiplication and termed as natural selection.

2) Artificial selection:

- The selection, which is carried out by man is called as artificial selection. It often permits only the selected plants to reproduce. The progeny from remaining plants is generally discarded. Artificial selection progressively reduces the variability. Artificial selection is essentially based on phenotype of the plants.

- The effectiveness of selection primarily depends on the degree to which the phenotype reflects the genotypes. Selection has two basic limitations

    1. Selection is effective for heritable difference only. Its effectiveness is greatly affected by heritability of character under selection.
    2. Selection does not create variation; it only utilizes the variation already present in population.

Therefore, the requirements of selection are:

1. Variation must be present in the population.
2. Variation must be heritable.

Progeny Test

• It is the evaluation of worth of plant on the bases of performance of their progeny The Progeny Test was developed by Louis de-Vilmorin. Therefore it is also known as Vilmorin Isolation Principle or Vilmorin Principal.

• The Progeny Test serves two valuable functions

1. To determine the breeding behavior of plant whether homozygous or heterozygous eg. AA or Aa, respectively.
2. To find out whether the character for which the plant is selected is heritable i.e. due to genotypes.

Pure line

• A pureline is a progeny of a single homozygous plant of a self pollinated spp. Therefore, all the plants in a pure line will have the same genotype. The phenotypic differences within a pure line are due to environment and have no genetic basis. Therefore variation in a pure line is not heritable and selection within a pureline is ineffective.

• The concept of pureline was proposed by Johannsen,1903 on the basis of his studies with beans (*Phaseolus vulgaris*) variety Princess.

Effects of self pollination on genotypes

• Self pollination increases homozygosity with a corresponding decrease in heterozygosity. Inbreeding also increases homozygosity and reduces heterozygosity. Inbreeding is the mating between individuals related by descent that is, having a common parent or parents in their ancestry. Some examples of inbreeding are:

• Sib mating: mating between brother-sister

• Half sib mating: brother-step sister mating. Self pollination is the most intense form of inbreeding, since in this case the same individual functions as the male as well as female parent. Increase of homozygosity by self pollination is shown in the figure:

After 10 generarations of selfing, all the plants in the population would be homozygous i.e. AA or aa, whereas the frequency of heterozygosity would be negligible.

Therefore, self pollination has two main effects on a crop:

1. All plants in population becomes completely homozygous.

2. The population is the mixture of several homozygous genotypes.

Origin of variation in Pure Lines

The variation in a pureline can only be observed due to:

(1) Mechanical mixture during harvesting: During threshing, cleaning or storage of seeds, other genotypes may get mixed with a pureline. Such contaminations are quite common and may be removed with careful handling.

(2) Natural Hybridization:- In most self pollinated species, a low amount of cross pollination does occur. Natural hybrids can be avoided by isolating a pure line from other genotypes with a couple of rows of the same pure line. In nature, the frequency of mutations affecting quantitative characters is not known. The frequency of spontaneous mutation is 10^{-6} .

Lecture 7 : Mass Selection

Objective: To teach the students the procedure of mas selection. Merits and demands of mass selection have also been discussed.

Mass Selection

Mass selection: In mass selection a large number of plants of different desirable phenotypes are selected and their seeds are mixed together to constitute a new variety. The plants are selected on the basis of their appearance or phenotype. The population obtained from the selected plants would be more uniform than the original population.

Applications of mass selection:

1. Improvement of local varieties.
2. Purification of existing pure line varieties.

- In breeding of cross pollinated species, mass selection has been very important. In such crops, inbreeding must be avoided since it leads to a loss in vigour and yield. Since in mass selection several plants are selected and their seeds are mixed together to raise the next generation, inbreeding is avoided or kept to a minimum. Further, because of the heterozygous nature of the population, several cycles of mass selection may effectively be practiced.
- In mass selection, the inferior plants are roughed out before beginning of flowering. Some marker genes are identified at juvenile stage. For example pigmentation in leaves and stem of Antirrhinum has been commercially

used to select plants. Gene markers have also been identified in Coleus and Dahlia at seedling stage for selecting a particular variety.

Procedure:

- First year: A large number of phenotypically similar plants are selected for their vigrous plant type, resistance and other desirable characters. The seeds from the selected plants are composited to raise the next generation.
- 2nd year: The composite seed is planted in a preliminary yield trial along with standard variety as checks. The variety from which selection was made should also be included as a check to determine if there has been an improvement due to selection. Phenotypic characteristics of the variety are critically observed.
- 3rd to 6th year: The variety is evaluated in coordinated yield trials at several locations. This is done to test the performance of the new variety at different locations within an agro climatic zone. If promising, the variety will be identified for release.
- 7th year: The variety may be released for cultivar if found suitable and recommended by the central on state variety release committee.

Merits of Mass selection:-

1. Since a large number of plants are selected the adoption of the original variety is not changed. It is generally accepted that a mix of closely related pure lines is more stable in performance over different environment than a single pure line. Thus varieties developed through

mass selection are more widely adapted than pure lines.

2. Often extensive and prolonged yield trials are not necessary. This reduces the time and cost needed for developing a new variety.

3. It is a less demanding method. The breeder can devote more time to other breeding programmes.

Demerits:

1. The varieties developed through mass selection show variation and are not as uniform as pure line varieties.

2. The improvement through mass selection is generally less than they through pure line selection.

3. In the absence of progeny test, it is not possible to determine if the selected plants are homozygous.

4. Due to popularity of pure line varieties, mass selection is not commonly used in improvement of self palliated crops. But it is quick and convenient method of improving old local variety in the areas or crop spp where crop improvement has just begun.

5. Varieties developed by mass selection are more difficult to identify than pure line in seed certification programme.

Lecture 8 - Hybridization: Techniques and Consequences

Lecture 8 : Hybridization- Techniques and Consequences

Objective: Hybridization is one of the most important techniques of crop improvement. In this chapter, students will be able to know about the technique and steps of hybridization being utilized for the improvement of ornamental crops.

Introduction to Hybridization

Hybridization: Hybridization is the most important technique of inducing variation in floricultural crops. The mating or crossing of two plants or lines of dissimilar genotype are known as hybridization. Crossing involves placing pollen grains from one genotype, the male parent, on to the stigma of flowers of the other genotype, the female parent.

- Although natural variability is present in self-pollinated populations but is lost quickly when they are subjected to selection. Individual plant selection or pure line selection is the most common method used for the improvement of self pollinated crops.
- Continuous selection followed by multiplication of the selected lines leads to the replacement of larger variability with the pure lines. Selection also leads to restricted gene pool and may also lead to lesser adaptation of a variety over wider climatic conditions.
- In this condition new genetic variability can only be introduced by crossing two different pure lines.

- While selecting for hybridization, some precautions and prerequisites must be met with. Firstly, it is essential to prevent self-pollination as well as chance cross-pollination in the flowers of the female parent. On the other hand, it must be ensured that the pollen from desired male parent reaches the stigma of female flowers for successful fertilization. The seeds as well as the progeny resulting from the hybridization are known as hybrid or F1.

Objectives of Hybridization

- The chief objective of hybridization is to create genetic variation. For achieving this, two genotypically different plants are crossed. The genes from both the parents are brought together in F_1 resulting in a progeny that contains the genomes of both the parents.
- In floricultural crops the breeding objectives vary from crop to crop, and according to the uses yet some common objectives are; introduction of new colours, size and shape of flowers, their orientation, stem/ spike length, fragrance, resistance to insect, pest and diseases, resistance to stress etc.(discussed in chapter 3).

Hybrid Varieties

- For the production of hybrids, two genotypically different plants are crossed. In most self-pollinated crops, F_1 is more vigorous and higher yielding than the parents. Wherever it is commercially feasible, F_1

may be used directly as a variety. In such cases, it is important that the two parents should produce an outstanding F_1.

Types of Hybridization

Types of Hybridization:

- The plants or lines involved in hybridization may belong to the same variety, different varieties of the same species, different species of the same genus or species from different genera.
- Based on the taxonomic relationships of the two parents, hybridization may be classified into two broad groups: (1) intervarietal and (2) distant hybridization.

Intervarietal Hybridization

- The parents involved in hybridization belong to the same species; they may be two strains, varieties or races of the same species. It is also known as intraspecific hybridization.
- In crop improvement programmes, intervarietal hybridization is the most commonly used. In fact, it is so common that it may often appear to be the only form of hybridization used in crop improvement

Simple Cross:

- In a simple cross, two parents are crossed to produce the F1. The F1 is selfed to produce F2 or is used in a backcross programme, e.g., A x B → F1 (A x B).

Example: In gladiolus, simple cross has resulted in the development of commercially Important hybrids:

Example 1:

Sylvia × Jo Waggener
↓
Suchitra

Example 2:

Black Jack × Friendship
↓
Apsara

Complex Cross:

- More than two parents are crossed to produce the hybrid which is then used to produce F2 or is used in a backcross. Such a cross is also known as convergent cross because this crossing programme aims a converging, i.e., bringing together, genes from several parents into a single hybrid. A few examples of convergent cross are described in figure.

Three Parents (A, B, C)

A × B

↓

F_1 (A × B) × C

↓

Complex hybrid (A × B) × C

Example: In gladiolus, three way cross has resulted in the development of commercially Important hybrids:

Example 1:

Sylvia × Jo Waggener

↓

Suchitra × Melody

↓

Punjab Dawn (commercial variety)

Example 2:

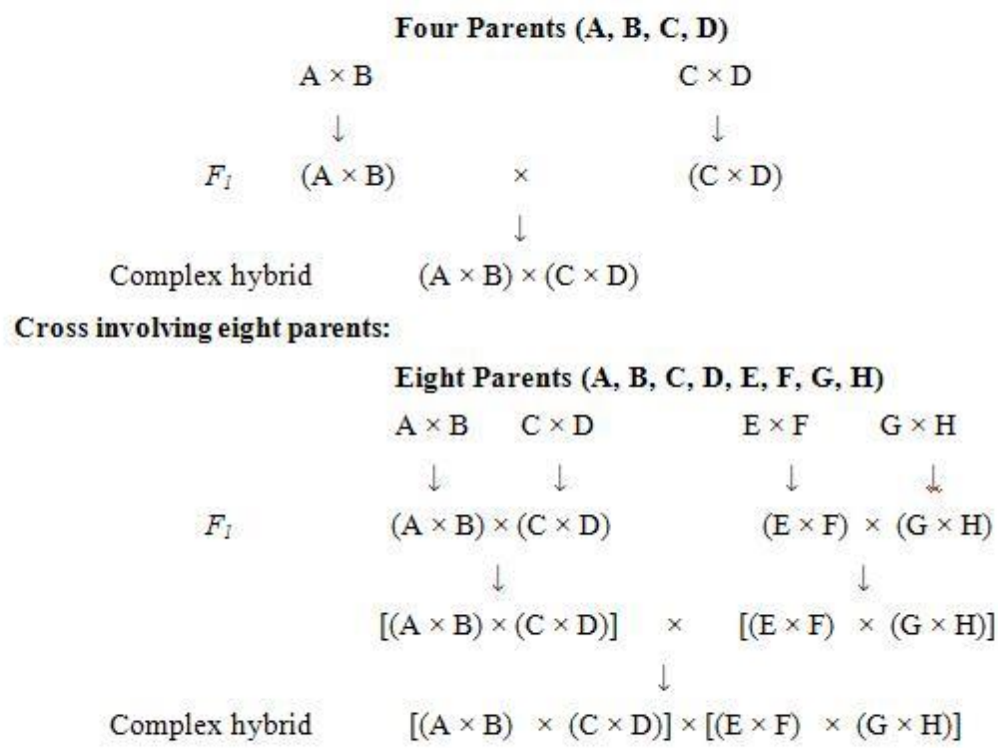
Sylvia × Jo Waggener

↓

Suchitra × Melody

↓

Shan-e-Punjab (commercial variety)



Cross involving four parents:

Development of hybrids in gladiolus:

- Breeding work in gladiolus was started in the year 1999 involving 11 parents in the Department of Floriculture and Landscaping , Nauni, Soaln (HP). The hybrids were evaluated and some of newly developed hybrids are:

Distant Hybridization:

- Distant hybridization includes crosses between different species of the same genus or of different genera. When two species of the same genus are crossed, it is known as interspecific hybridization, but when they belong to two different genera, it is termed as intergeneric hybridization as in orchids.

Lecture 9: Procedure of Hybridization

Objective: To teach the students the procedure of hybridization and various steps involved in hybridization for the improvement of ornamentals.

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.

Procedure of Hybridization

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

1/3rd 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.

Procedure of Hybridization (Contd..)

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:

10. 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.
11. 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.
12. Anthers are collected and allowed to burst directly over the stigmas.

13. 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.
14. 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.

Lecture -10 : Mutation Breeding

Objective: To teach the students about different types of mutation and various methods employed for the induction of mutation for improvement of flower crops.

Mutation Breeding

Mutation: A sudden heritable change in characteristics of an organism is known as mutation. The term mutation was introduced by Hugo de Vries in 1900. Since most of the floricultural crops are clonally propagated, mutation breeding has proved to be one of the most effective methods of crop improvement and development of varieties in these crops. It has particularly been used for the induction of variegated characters into different floricultural crops.

Sites for mutation:

- 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.
- Mutations produced by changes in the base sequences of genes are known as gene or point mutations.
- Some mutations may be produced by changes in chromosome structure, or even in chromosome number; they are termed as chromosome mutations.

Types of mutations:

4. Spontaneous mutation

5. Induced mutation

1. Spontaneous Mutations:

- The mutations that occur in natural population, are known as spontaneous mutations. Man has no role in this type of variations. The frequency of spontaneous mutations is generally as low as one in 10 lacs, i.e., 10^{-6}.

2. Induced Mutations:

- When the mutations are artificially induced by a treatment with certain physical or chemical agents; such mutations are known as induced mutations. The agents used for producing them are termed as mutagens.

Mutagens:

- Agents used for the induction of mutations are known as mutagens. Mutagens may be different kinds of radiations known as physical mutagens or some chemicals known as chemical mutagens. The different mutagens may be grouped as follows:

Physical mutagens:

1. Ionising radiations :

a) Particulate radiations, e.g., α-rays, β-rays, fast neurons, and thermal neutrons

b) Nonparticulate radiations (electromagnetic radiations), e.g., X-rays and γ-rays.

2. Non ionising radiations, e.g., ultraviolet radiation (UV).

Chemical mutagens:

- Alkylating agents e.g, sulphur mustards, nitrogen mustards epoxies, ethylene-imines, (e.g., ethylene imine or EI), sulphates and sulphonates (e.g., ethymethane sulp-honate or EMS, methylmethane sulphonate or MMS), diazoalkanes, nitroso compounds, e.g. N'-methyl-N-nitro-N-nitroso-guanidine or MNNG).
- Acridine dyes e.g., acriflavine, proflavine, acridine orange, acridine yellow ethidium bromide.
- Base analogues, e.g., 5-bromouarcil, 5-chlorouracil
- Others, e.g. nitrous acid, hydroxyl amine, sodium azide

Lecture 11: Applications of Mutation Breeding

Objective: To teach students about the applications of mutation breeding in improving the characteristics of flower crops and the limitations of the technique.

Applications of Mutation Breeding

Mutation breeding has been used for improving morphological and physiological characters, disease resistance and quantitative characters including yielding ability. The various applications of mutation breeding are as under.

1. It is useful in improving certain specific characteristics of a well adapted high yielding variety. This is particularly useful in floricultural crops which are mostly clonally propagated. These crops show highly heterozygous nature and therefore, in such a case, mutagenesis is the only method available to improve the specific characteristics of clones without changing their genetic makeup.
2. Inductions of desirable mutant alleles which may not be present in the normal population or germplasm or may be present but may not be available to the breeder due to political or geographical reasons.
3. Mutation breeding can also be used on F_1 hybrids or progenies resulting from inter-varietal crosses. These may be treated with mutagens in order to increase genetic variability by inducing mutations and to facilitate recombination among linked genes.

4. Irradiation of inter-specific (distant) hybrids has been done to produce translocations.

Limitations of Mutation Breeding:

The experience with mutation breeding has brought out certain limitations

5. Mutation is a process that results in the individual with desirable or non desirable characteristics. The frequency of desirable mutations is very low, about 0.1 per cent of the total mutations. Therefore, large M_2 and subsequent populations have to be grown and carefully studied. This involves considerable time, labour and other resources.
6. The breeder has to screen large population to select desirable mutations. Therefore efficient, quick and inexpensive selection techniques are required to screen large populations.

Development of cultivar through spontaneous mutation in floricultural crops:

- Variety 'Pusa Tara': Spontaneous mutant of Coreopsis

Development of cultivars through physical mutations in floricultural crops :

- Bougainvillea:
- 'Los Banos Variegata': Gamma-ray induced mutant of multibracted bougainvillea cultivar 'Los Banos Beauty'
- 'Los Banos Variegata Silver Margin': Gamma-ray induced mutant of multibracted bougainvillea cultivar 'Los Banos Beauty'

- 'Mahara Variegata': Gamma-ray induced mutant of multibracted bougainvillea cultivar 'Mahara'.
- Gladiolus:
- 'Shobha': Induced mutant of 'Wild Rose'

Development of cultivars through chemical mutations in floricultural crops:

- Bougainvillea:
- Los Banos Variegata 'Jayanthi': Ethyl Methane Sulphonate (EMS) induced chlorophyll variegated mutant of bougainvillea cv. 'Los Banos Beauty'.

Lecture 12 - Biotechnological Techniques for the Improvement of Ornamental Plants

Lecture 12: Biotechnological Techniques for the Improvement of Ornamental Plants

Objective: To teach the students about biotechnological techniques (like micropropagation, embryo rescue, anther culture, protoplast culture etc) in improvement of flower crops.

Introduction to Biotechnological techniques

Introduction:

- Although the contribution of the conventional breeding methods to the ornamental crop improvement had been very significant in building up the floriculture industry so far, yet ornamentals are a group of plants where biotechnology has made tremendous impact both scientifically and economically.
- The three key areas in which plant cell and tissue culture has direct application in ornamental horticulture are large scale propagation of elite clones from a hybrid or specific parent lines through micro-propagation and somatic embryogenesis, production of disease free propagules and meaningful development of plant varieties through cellular and molecular techniques in conjunction with the whole plant breeding.
- Biotechnology has been applied to flower crops for producing new flower colours and flower forms.
- The value addition may be in the form of changed architecture, promoting *in vivo* or *in vitro* propagation of recalcitrant genotypes, resistance to biotic

and abiotic stresses, improved vase life or modification in flower colour, shape and period of blooming.

- Biotechnology can play a vital role in modifying these in terms of varietal development and multiplication and popularization of newly bred varieties.
- Techniques of biotechnology have long been used by the floricultural industry, in both propagation and breeding. Meristem culture and micro-propagation are used to generate virus-free, high- quality propagation stock by plant propagators.
- Breeders commonly use other tissue culture techniques to supplement breeding programs such as anther culture and embryo rescue.

Biotechnological techniques used in ornamentals:

Micro-propagation:-

- One of the major aspects of plant biotechnology is the production of a large number of identical individuals via i*n vitro* cloning. The plants produced through this technique are uniform and true to type with distinctive characteristics of increased vigour due to their higher health status.
- By the use of axillary shoot proliferation methods, micro-propagation can be carried out successfully in chimeras, which are very important in ornamentals. It has been particularly useful in clonal multiplication of a naturally occurring mutants under *in vitro* conditions for their further exploitation in breeding programmes.

- The techniques of meristem culture are now being used worldwide on commercial scale for micro-propagation of almost all important genera of orchids, thus placing orchids within the reach of an average person.

Production of specific pathogen free plants:-

- Tissue culture is being used to produce virus free propagules and facilitate their mass propagation. Generally, ornamental plants are vegetatively propagated and the viruses and virus like pathogen are transmitted mechanically.
- Currently, the technology for production of disease free propagule is available for alstroemeria, carnation, chrysanthemum, dahlia, lilium, iris, freesia, gladiolus, hyacinth, etc.

Use of cellular and molecular techniques in development of plant varieties:

- Successful creation of variation is of prime importance for breeding plants of desired traits. Techniques like protoplast culture, somaclonal variation, limited gene transfer; embryo rescue techniques, anther culture, gametoclonal variation, etc. speed up the process of introduction and induction of variation at cellular level.

In vitro pollination and embryo rescue:

- The techniques of *in vitro* pollination appears to be very promising for overcoming pre-fertilization barriers to incompatibility and raising new genotypes. The most critical step of *in vitro* pollination technique is the development of viable seeds from ovules and ovaries following fertilization.

- Ovule culture holds a great potential for raising hybrids which normally fail due to abortion of embryo at a rather early stage.
- Embryo culture or ovule culture has proven useful in reducing the breeding cycles of new varieties where long dormancy or slow growth of seedlings resulting long breeding cycles. It is also being used to test seed viability.
- In case of lilium, alstroemeria, impatiens, helianthus, new varieties have been produced using the technique of *in vitro* pollination and embryo rescue to overcome the pre-zygotic and post-zygotic compatibility, respectively.

Another culture:

- In haploids, mutations can be easily detected as they have only one set of genes. These haploids can be picked up and their chromosome duplicated to get fertile diploids with all desirable mutations in a single generation.
- Haploidy offers an easier and faster approach for raising an isogenic pureline. It has been successfully used in petunia, begonia and lilies.

Protoplast culture:

- In plants where fairly distant speces can be crossed, it has always not been possible to obtain full hybrids between desired individuals because of sexual incompatibility barriers. In this respect, cell fusion offers an entirely new and potential approach to distant hybridization.
- Plant protoplasts represent the finest single cell system and offers exciting possibilities in the field of somatic cell genetics and crop improvement.

Somaclonal variation:

- Regenerants from tissue culture often show much genetic variation. Such variation induced by culturing condition is called somaclonal variation. It may result in some advantageous trait by mutation of a single gene. Somaclonal variants have been obtained in chrysanthemum, begonia, lisianthus and day lily.

Somatic embryogenesis:

- Somatic embryogenesis is the formation of embryo from a cell other than a gamete or the product of gametic fusion.
- Somatic embryogenesis is a powerful tool for the improvement of ornamentals, not only with regard to clonal propagation but for other biotechnological applications as well. It has been successfully exploited in the improvement of crops like anthurium, alstroemeria, gladiolus, iris, lily etc.

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

27. The insertion of genetic material into plant cells
28. 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 13: Breeding for Disease Resistance

Objective: To teach students about the various types of host reactions in disease resistance and the source of resistance used in breeding for development of resistance.

Introduction to Diseases

Introduction:

- Disease is an abnormal condition in the plant produced by an organism. The plant affected by a disease is known as *host*, while the organism that produces the disease is termed as *pathogen*.
- Diseases are produced by a variety of organisms from plant and animal kingdoms, viz., fungi, bacteria, viruses, nematodes and insects. Different crops are attacked to different degrees by the different kinds of pathogens, but it may be emphasized that all the crop species are attacked by them.
- Much of the breeding effort has been directed against diseases caused by fungi, which may be greater than the effort against all the other pathogens put together. Host varieties are classified as susceptible or resistant according to their response to the pathogen. The various reactions of the hosts to the various pathogens may be grouped into the following types; susceptible, immune, resistant and tolerant.
- In case of some diseases, the host strains either show or do not show the disease, hence the classification of disease reaction is simple. But in most cases, the host reaction is not so sharply defined and shows a graded

variation. Such reactions or infections are classified according to an arbitrary, but practically sound, scale in which the disease score may vary from 0 (with no disease) to 5 or 9 (most susceptible).

Susceptible Reaction:

- In the case of susceptible reaction, disease development is profuse and is presumably reaction not checked by the genotype of host.
- In practice, the susceptible reaction is classified in relative terms only, that is, in reaction to the reaction of other host varieties available and the prevailing environment.

Immune Reaction:

- When the host does not show the symptoms of a disease is known as immune reaction. Immunity may result from the prevention of pathogen to reach the appropriate parts of the host.
- But more generally, it is produced by hypersensitive reaction of the host, usually, immediately after the infection has occurred in hypersensitive reaction, a group of host cells around the point of infection dies.
- This severely restricts the establishment of pathogen and eliminates its reproduction. Thus in immune reaction, the rate of reproduction of the pathogen is zero.

Resistance:

- Resistance denotes a less disease development than in the susceptible variety and is a relative attribute. Infection and establishment do take place, but growth of the pathogen is less than in the susceptible variety.
- Generally, the rate of reproduction is considerably reduced which limits the spread of disease.
- In case of resistance, disease symptoms do develop and the rate of reproduction is never zero, but it is sufficiently lower than 1(the rate of reproduction on the susceptible variety) to be useful. The inhibition of growth of pathogens is believed in nature, and in some cases chemical growth inhibitors may be involved.

Tolerance:

- Tolerance implies that the host is attacked by the pathogen in the same manner as the susceptible variety, but there is little or no loss in biomass production or yield. In certain situations this may be so, but often this term is used without sufficient evidence.

Sources of Diseases Resistance:

Resistance to disease may be obtained from four different sources:

(1) A known variety

(2) Germplasm collection

(3) Related species

(4) Mutations

1. A known Variety:

- Disease reaction of most of the cultivated varieties is documented, and a breeder may find the resistance he needs in a cultivated variety. Resistant plants were isolated from commercial a variety which is further used for induction of resistance in other varieties through hybridization.

2. Germplasm Collection:

- When resistance to a new disease or a new pathotype of a disease is not known in a cultivated variety, germplasam collections should be screened. There are numerous instances where resistance to a disease was obtained from germplasm collections.

3. Related Species:

- Often resistance to a disease may not be present in the varieties of the concerned crop species. In such cases, it would be necessary to transfer resistance gene from related species through interspecific hybridization. Despite many problems in such gene transfers, it has been successfully and extensively used in many cases.

4. Mutations:

- Resistance to some disease may be obtained through mutations arising spontaneously

Breeding approaches for disease resistance:

1) Hybridization combined with pure line breeding

2) Mutational approach

3) Back cross breeding

1. Hybridization combined with pure line breeding: In this, crosses are made in such a way that one of the parent must possess disease resistance. The crosses and the early segregating (F_2 and F_3) are grown under artificial disease conditions. Productive and resistant recombinants are selected and carried forward through pedigree method. This is the least expensive but most effective method as no additional effort has to be made by the breeder to develop a resistant variety coupled with high productivity.

2. Mutational approach: This approach is not being used extensively but it would become an important approach in future, because the natural variation is being depleted at a fast rate.

3. Back cross breeding: This approach is also being used for the induction of disease resistance in various crop plants.

Development of disease resistance in ornamental crops:

Rose:

- Black spot is a major disease of roses that causes severe losses to commercial and home gardens. The breeding lines 'Spotless Gold' (Floribunda, F_3 selection: Goldlocks x *Rosa rugosa*), 'Spotless Yellow' (Floribunda, F_3 selection: Goldlocks x *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 found 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 x 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 limitation 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.

Breeding of Carnation for disease resistance:

- *Fusarium* wilt, bacterial wilt, stems rot and *Alternaria* leaf spot are major diseases 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.

Breeding of Chrysanthemum for disease resistance:

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

Lecture 14: 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 F_1 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

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

zmean of the parents (MP)

$(F_1—MP)/MP \times 100$

High parent heterosis:
It is the comparison of hybrid to performance of best parent/high parent (HP).
$(F_1\text{-HP})/\text{HP}\times100$

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 15 - Use of Inbred Lines for the Development of New Varieties

Lecture 15 : Use of Inbred for the Development of New Varieties

Objective: To teach students about the uses of inbred lines and methods used to develop varieties by using inbred lines viz. single cross, double cross, three way cross method, convergent method etc.

Introduction to Inbred

Inbred line: An inbred line is the progeny of a single self pollinated plant. It is the result of repeated selfing as a result all the alleles in an inbred are in the homozygous form.

The suggested methods for using of inbred lines for the development of varieties are outlined below:

Single Cross Method

- In this method, crosses involve two inbred lines and the resulting F_1 hybrids are evaluated. This technique came into existence only when in 1909, Shull suggested the inbred lines as parents for production of F_1 hybrids. He also recommended the use of single cross method for production of superior hybrids.
- In African marigold a cross between Alaska × Hawaii, Alaska × Cupid Orange Mum and Local variety from Katrain × Cupid Orange Mum showed maximum heterosis for flower size, flower weight, early flowering and number of flowers.

Double Cross Method

- The double cross method is suggested to overcome the problems associated with the single cross method. It was observed it produces the seeds much better in shape with higher germination percentage.
- The resulting seeds were also found very uniform in shape and produced vigorous seedlings as compared to those obtained from the single cross method. In this method, the hybrids are produced by crossing two resulting F1 hybrids involving four inbred lines as given below.

A x B   C x D
AB   x   CD
ABCD

In case of rose:

Independence × Papillon Rose   Charlotte Armstrong × Floradora
AB   x   CD
'Bel Ange'

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.

Three Way Cross

- In this type of cross three inbred lines are involved. Firstly F_1 hybrid is produced by two lines which is further crossed with a third line as follows:

A x B

AB x C

ABC

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*)

Convergent Method

- In this method, the desirable character from a number of inbreds are combined and as a result the genes from each inbred converge upon one another. In this type of hybridization, all the desired characters may not be present in the final segregating population.
- This system can be used in partially cross-pollinated species where the resulting population will be highly heterozygous. If 8 inbreds are used together, the system is as follows

Ist crosses A x B, C x D, E x F, G x H

2nd crosses F_1, s (no need of selection)

AB x CD, EF x GH

3rd crosses (segregating F_1.s)

ABCD x EFGH

Top Cross Method

- This method is suitable to test the general combining ability of inbreds and in identifying promising ones. The inbreds are crossed with the varieties as follows:
- A x variety, B x variety, C x variety, D x variety, E x variety, F x variety, G x variety, etc.

Diallel Cross Method

- This is pair cross method which allows the use of every plant in pair crosses with every other plant in selected groups. Homozygous diploid lines are essential to obtain satisfactory results. It also requires sufficient number of individuals or progeny to get a large number of crosses.

- On the basis of number of parents (n), the number of crosses are calculated as n (n-1)/2. If 8 parents are involved in the diallel cross, it will lead to a total number of 28 crosses.

Exploitation of heterosis

- Heterosis breeding is being extensively used for the hybrid seed production in almost all annual flower crops which have been discussed in detail in the chapter dealing with hybrid seed production.

Lecture 16 - Production of F1 hybrids

Introduction

Introduction

- F_1 hybrids are the result of crossing of two homozygous but genetically distinct parental lines. Hybrid vigour is defined as the increase in the size or vigour of a hybrid over its parents.
- Shull (1911) gave his idea and coined the term heterosis and explained hybrid vigour in connection with the optional uniformity, a heterozygosity giving rise to the strong, segregation of characters in F_2 and necessity of being reproduced by constant new crossing of two parental lines bred to homozygosity.
- Hybrid vigour is entirely due to bringing together, a large number of favorable dominant genes contributing to vigour in the first generation period. F_1 hybrids are of immense importance particularly in floricultural crops where the hunt for new flower colors or yield is unending
- F_1 hybrids in ornamental crops were known even before Shull propounded the classical theory of hybrid vigour in plant breeding for the first time. Hybrid variety 'Prima Donna' in begonia (*Begonia semperflorens* Link et Otto) was probably the first F_1 released in floricultural crops by Benary Seed Company in Germany in 1909.
- The breeding for F_1 hybrid seed production, however gained importance only after 1942 and onwards when Japan produced the first commercial F_1 hybrids in Petunia.
- Later, F_1 hybrids were produced in flower crops like *Ageratum, Anemone, Gerbera, Primula, Petunia, Tagetes, Cyclamen, Pansy, Begonia, Geranium, Portulaca, Dianthus*, balsam, stock, wall flower, ornamental sunflower (*Helianthus annus*), Gazania, hollyhock, Calceolaria and Zinnia by several seed companies in the U.S.A., China, Japan, the Netherlands, Denmark, Germany, the United Kingdom and Israel.
- For the production of F_1 hybrid we require purelines in self pollinated species or inbred lines in case of cross pollinated species.
- A pureline is the progeny of a single, homozygous, cross pollinated plant.
- An inbred line is the progeny of a single, homozygous self pollinated plant.

Advantages of F_1 hybrids

- All the F_1 hybrids resulting from a cross are uniform in growth and yield.
- They show a greater vigour over parents which is expressed in terms of yield and other targeted desirable traits.

- Since the genetic constitution of F_1 hybrids is constant and show homozygous, they show greater adaptability to different environmental conditions.
- Breeder has all the control of the F_1 hybrids produced by him/her as the parental lines are maintained by the breeder.
- The variety shows stability over a period of years.

Techniques for the production of F_1 hybrid seeds

- The conventional method of F_l hybrid production involves selection of inbred lines for desired characters, testing their combining ability and production of hybrid seeds, evaluation of F_l hybrid performance. However there are special techniques which can be exploited for F_l hybrid production in ornamentals e.g. use of femina lines in marigold.

Two basic requirements for hybrid seed production are:
1. Easy emasculation of the female parent
2. Effective pollen disposal from the male parent to ensure a satisfactory seed set in the female parent.

Both these factors are largely governed by the floral structures of the crop species in question.

Lecture 17 - Techniques of hybrid seed production, methods of making a cross

Introduction

Use of Self-incompatibility

- This system takes the advantage of the natural breeding system. The self incompatibility systems are of two types, gametophytic and sporophytic system.
- Among ornamentals, the self-incompatibility system is present in *Nicotiana* and *Petunia* is gametophytic and can be utilised in cross pollination under open field conditions. However, in these two flowering plants one additional advantage in that there are enough seeds per pollination, which can adequately compensate the high cost of F_1 hybrid seeds.
- Sporophytic system of self-incompatibility is observed in Verbena, and dominance relationship between two self-incompatibility (SI) alleles influences the seed set.
- In such species/cultivars the degree of self-incompatibility can be assessed by examining flower styles with the ultra-violet fluorescent microscope, a few hours after the pollination.
- Pollen tubes which have penetrated the stigma and are thus able to grow down the style unimpeded, are able to be counted since they identify themselves by fluorescence. The lack of or a small number of pollen tubes throughout their length, indicate a strong incompatibility reaction.
- If the incompatibility reaction is weak, counting will prove impossible since numerous pollen tubes will be visible as a tangled mass within the stylar tissues. With the advent of tissue culture technology, maintenance of the female parent carrying SI alleles can be managed under protected conditions.
- In Sweet Williams the head of the flowers comprises individuals which mature at different times, usually starting with the centre flower of a cluster. Therefore, pollination, either by all but a single cluster, or by pollinating members of the head which have reached maturity followed by removal of all other buds will be effective.

Double Flower Condition

- In double type of flowers all the anthers are modified to form ray florets. This is a character of family compositae/ asteraceae where double form is achieved because of numerous petals but a central disc may be seen when petals are pulled aside and make a composite head such as in ageratum, aster, chrysanthemum, cornflower, dahlia, daisy, gaillardia, marigold, rudbeckia and sunflower.

- Sunflower illustrates most clearly the satisfactory example of pollination where each floret bears only a single ovary. In most cases, double flower results from a transformation of the anthers into petals. Therefore, the double flower character can be regarded as a form of the male-sterility.
- Further, this double flower character should be inherited as a dominant character to be manifested in F_1 hybrids. However, in the case of gerbera, where the pistils are hidden by petals, manual hand pollination is tedious for maintenance of the female parent.
- Reimann-Philip (1969) developed a breeding scheme using the double flower character in garden carnation (*Dianthus caryophyllus*) as a form of male sterility.
- There are also some floral abnormalities, like the 'cinderella' character in begonia and 'femina' in marigold and zinnia resulting in the male-sterility.

Triploidy

- The advantage of growing triploid varieties is that of continuous blooming period as there is little or no seed set. Among the flower species, in *Tagetes*, commercial triploid hybrid (2n = 36) results from a cross between diploid female T*agetes erecta* (2n = 24) and tetraploid male *Tagetes patula* (2n = 48).
- The triploid hybrid 'Nugget' (*Tagetes erecta* x *Tagetes patula*) has the unique ability of holding the flowers on the plants for a longer period. However, in *Begonia semperflorens*, the loss of uniformity in triploids has been reported by Reimann-Philip (1983).

Pollen Sterility

- Wherever pollen sterility is governed by a single recessive gene, 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*.
- In Ageratum, however, 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.
- In Petunia, cytoplasmic male sterility has been observed but the use of this type of male sterility is not practically common because of breakdown of male-sterility in the maternal parent or malformation of flowers in F_1 plants.
- 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.

Lecture 18 - Hybrid Seed Production in some important annual flower Crops- Part I

Hybrid Seed production

Methods of making a Cross Hybrid seed production can be achieved by:

1. Hand emasculation and hand pollination.
2. Hand emasculation and natural pollination.
3. Hand elimination of male plants.
4. Genetic male sterility as in marigold and zinnia, ageratum and calceolaria.
5. Cytoplasmic male sterility as in petunia.
6. Self incompatibility as in petunia, pansy, stocks and ornamental kale.
7. Chemical emasculation- selective elimination of pollen production, that is, use of gameticides.
8. Use of marker genes to identify the selfs so that they can be eliminated as seedlings.

Need for hybrids Seed Production in Ornamental Crops

- The shapes, forms and colours of present day ornamentals differ from those of their ancestors on account of man's intervention.
- Progress in producing ornamentals of new types and forms has accelerated largely due to need for higher yields, novelty and disease resistance.
- Every year about 10,000 new varieties of ornamental crops are being released.
- Novelty and the quest for new varieties has remained the aim of flower breeding since years.
- All the present day cultivars and the novelties are the result of extensive hybridization, spontaneous and induced mutation, selection and molecular breeding. Since in flowers a specimen cannot maintain interest for a long time, people have desire to develop new forms through various methods of breeding.
- Presently, many peculiar shades and forms like dwarf hollyhocks, dwarf delphiniums; red and white marigolds, etc. are available in seasonal flowers.
- The possibilities for creating different forms and improving ornamentals are infinite.

Mode of reproduction:

- Based on the mode of reproduction, the ornamentals are broadly divided into two groups, viz. sexually propagated and asexually propagated.
- Sexual cycle utilizes seed propagation as a means of producing offspring plants whose characters reflect the genetic contributions of the two parents.
- Reproduction by seeds results in certain amount of variation among the progeny. Improvement of sexual forms takes a number of generations. During this period, the best types are selected from segregating material.
- Among ornamentals, seasonal flowers are propagated by seeds whenever genetic improvement of a particular plant is done through hybridization.

Breeding System:

- In seasonal flowers, breeding system fall into two groups, viz. self-pollinated (inbreeding types) and cross-pollinated (outbreeding types).
- Many species have an intermediate type of breeding system with varying proportions of crossing and selfing. They are grouped in the following breeding systems.

Inbreeders:

- Obligate inbreeders are rarely cross-pollinated.
- Highly self-pollinated. Seed propagated herbaceous annual flowers include China aster, balsam, sweet pea, lupin, clianthus, gypsophilla, bells of Ireland, salvia, saponaria, sweet William and dianthus. In these flowers, there is negligible cross-pollination in nature.

Outbreeders:

- Obligate outbreeders are cross-pollinated because of the presence of a built in system preventing self-pollination.
- The group of outbreeding seed propagated herbaceous annuals and biennial flowers include ageratum, hollyhock, arctotis, cornflower, antirrhinum, delphinium, verbena, calendula, cosmos, gazania, poppy, marigold, zinnia, primula, pansy and viola.
- Self incompatibility occurs in ageratum, gerbera, daisy, petunia and antirrhinum.
- In primula, self sterility is due to heterostyly i.e. pin and thrum type of flowers
- Cytoplasmic male sterility has been reported in petunia, ageratum and sunflower.
- Monogenic recessive factor for male-sterilty exists in marigold, zinnia, calceolaria and salvia.

Breeding Objectives in annual flower Crops:

- In ornamentals, floral quality is the major consideration for evaluation of a particular genotype.
- In commercial seasonal flowers, besides quality, total flower yield is also an important criterion for genetic improvement as is in china aster, marigold and antirrhinum,
- All the varieties do not behave in a similar manner in all the agroclimatic conditions, therefore, breeding suitable varieties for various climatic zones is necessary.
- In India, F_1 hybrid varieties in view of their superiority over open pollinated varieties have a great potential.
- Since ornamentals are affected by a number of diseases and pests, breeders should consider this aspect also while breeding for different parameters.
- Varieties resistant to abiotic stresses need to be bred in commercially viable crops.
- Transgenics can be utilized for production of transgenics in flowering plants, viz. for blue colour in rose, yellow colour in sweet peas, disease resistance in various flower crops, etc.
- Genetic improvement in ornamentals has been done through introduction of important germplasm from other countries.
- The germplasm is evaluated and some introductions are directly recommended for cultivation, which are called primary introductions, whereas others, utilized in breeding programmes, are called secondary introductions.
- Besides introduction, other methods of improvement are hybridization, mutation breeding, polyploidy breeding, heterosis breeding and biotechnology.

Institutes involved in development of varieties in India:

- The management of genetic resources of ornamental plants with an emphasis on their genetic improvement was started at Indian Agriculture Institute (IARI), New Delhi, during 1950s under the leadership of Late Dr. B. P. Pal.
- Other institutes like National Botanical Research Institute (NBRI), Lucknow; Indian Institute of Horticultural Research (IIHR), Bangalore and Bhabha Atomic Research Centre (BARC), Mumbai also contributed significantly in the genetic improvement of seasonal flowers.
- The work was greatly strengthened and streamlined with the establishment of All India Co-ordinated Floriculture Improvement Project in 1972 onwards throughout the country.

Lecture 19 - Hybrid Seed Production in some important annual flower Crops- Part II

Hybrids in Annual Crops

Hybrids in Annual Crops:

- The main advantage of F_1 hybrids is the unique combination of appreciable vigour and uniformity.
- Apart from this, F_1 are dwarf, compact with basal branching, free- flowering with larger flowers, prolonged duration of flowering and may have insect-pest and disease resistance.

Marigold

- Marigold is a member of Asteraceae family.
- It is native to Central and South America, especially Mexico.
- 'Pusa Basanti Gainda' (yellow coloured flowers) and 'Pusa Narangi Gainda' (orange coloured flowers) have been developed in India through pedigree method of breeding in African marigold.
- 'Pusa Arpita' has been developed through selection in french marigold.


Pusa Arpita

- F_1 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.
- F_1 hybrid seeds were collected and sown for evaluation in the subsequent seasons.

Antirrhinum

- Antirrhinum belongs to family Scrophulariaceae and is a native of Southern Europe.
- Flower form is controlled by a single dominant gene. F_1 hybrid.
- Seeds in antirrhinum were produced by using hand emasculation technique.
- The female parent was emasculated by removing anthers from the florets when the lowermost floret is fully opened.
- Emasculation is done on lower one third length of the spikes and rest of the spike is chopped off.
- With the help of a pair of forceps, the petals were peeled and anthers were removed and bagged with muslin cloth bag.
- Fresh flowers should be plucked from intended male parent which have been previously bagged and pollen dusted on the stigmas of emasculated flowers.
- Crossing is done during 10 am to 12 noon.
- The pollinated spike is then bagged with perforated butter paper bag to prevent cross pollination.
- The hybrids seeds of all the crosses are collected when spikes are matured.
- F_1 hybrid seeds are collected and sown for evaluation in the subsequent seasons.
- 'Tetra Giant' variety developed by polyploidy has higher number of flowering stems with large, deeper coloured flowers which are longer lasting than diploid counterpart.

Pansy

- Pansy belongs to the family Violaceae.
- In Pansy, selections were put to evaluation and maintained as pure lines F_1 hybrid seed in pansy was produced by using hand emasculation technique and making crosses among the selected tester parents.
- The female parent was emasculated by removing anthers from the flowers when the flower starts showing colour.
- The emasculated flower is then bagged with perforated butter paper bag to prevent cross pollination.
- Crossing was done during 10 am to 12 pm, by taking pollens from desirable male parents in a petri-dish and dusting it on male sterile flowers with the help of soft caramel brush.
- The flowers were bagged with perforated butter paper bags.

- The pollinated flowers were tagged showing male, female parents and date of crossing.
- Same procedure of crossing with the same male parent was repeated the next day to ensure proper pollination and seed set.


China aster

- China Aster belongs to family Asteraceae, is native to China.
- Four varieties namely, Kamini, Poornima, Shashank and Violet Cushion have been developed by pedigree method.
- Appreciable heterosis was observed for all the characters.
- Based on the economic characters like flower size, flower per plant and stalk length, three crosses Shell Pink Azure Blue, AST-20 Azure Blue and AST-20 AST-16 were recommended for exploitation of heterosis on commercial scale.



Petunia

- Petunia, a member of Solanaceae family, is native of South America.
- A large number of F_1 hybrid varieties have been developed in Single and double petunias of multiflora and gradiflora types in the U.S.A., U.K. and Japan.
- In India, a number of hybrids have been developed by Indo- American Hybrid Seeds Company, Bangalore

Balsam

- *Impatiens balsamina*, is native of India, China and Malaysia.
- It belongs to Balsaminae.
- One pink coloured, double flowered seedling selection has been maintained and the seed is being produced every year in Nauni.

Gloxinia

- *Sinningia speciosa* which normally does not produce seeds under Nauni- Solan conditions, seed was produced through artificial pollination and from the first progeny one variant which produced large red flowers with white frilled margins was obtained.
- In *Gomphrena globosa* two selections were made in 1996 and evaluated in Nauni.
- Similarly, in Salvia (*Salvia splendens*) two selections red and purple have been maintained.
- Many seedling selections in Phlox (*Phlox* x *drummondii*) have been maintained and are being evaluated.

Lecture 20 - Utilization of male sterility for hybrid Seed Production

Utilization of male Sterility

Introduction:

- 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.

Male sterile flower of Zinnia

- 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 21 - Field production of open pollinated varieties-I

Production of Open Pollinated varieties

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 judgement 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.

Lecture 22 - Field Production of Open Pollinated varieties

Production of Open Pollinated varieties

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 23 - Harvesting of Seeds, Stages of Seed harvesting of different annual flower Crops

Harvesting of Seeds

Introduction:

- 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.

Lecture 24 - Seed Processing, Cleaning, Sizing and PackagingSeed Processing

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.

Lecture 25 - Seed Storage, Storage Conditions for different flower Crops

Seed Storage and Conditions

Introduction:
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^{o}C	11-32%	8 months
6	*Viola x wittrockiana*	25^{o}C	32-52%	4.5 months
7	*Petunia hybrida*	25^{o}C	32%	12 months
8	*Phlox drumondii*	25^{o}C	20%	12 months
9	*Salvia splendens*	25^{o}C	32%	12 months
10	*Catharanthus roseus*	25^{o}C	11-52%	12 months

Lecture 26 - Seed Certification

Introduction to Seed Certification

Introduction:

- 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.

Lecture 27 - Seed Production Procedures Part-I

Seed Production Procedures

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.

Lecture 27 - Seed Production Procedures Part-I

Pollination management, Seed harvest and Seed Cleaning

1. Pollination management

- It defines the seed yield and genetic purity of seeds
- For hybrid seed production, pollination work is very labour intensive and requires training.
- Consequently it is also the most expensive part of the production process.
- The pollination process consists of 3 separate steps.

1. Pollen collection
2. Emasculation
3. Pollination

Pollen Collection

- Pollen collection can be a simple procedure for plants that shed large quantities of loose pollen grains.
- For cyclamen, the flowers can be shaken by a mechanical device and the pollen collected on a flat dish or in a glass vial.
- For up facing flowers like marigold, pollen can be harvested by a suction device.
- Anthers of some flowers can be collected prior to anthesis. Anthers are then dried, ground and pollen grains extracted from the remaining tissue by sieving.
- Extracted pollen can be cold stored and can be used for weeks and months.

Emasculation

- Emasculation is the process by which the anthers of each flower in the female parent line are manually removed.
- Next to genetic purity of the parental plants, this is the most important factor in obtaining genetically pure commercial hybrid seeds.
- In order to completely prevent selfing, emasculation has to be carried out prior to anthesis, usually in a young bud stage. Petals are gently peeled back to expose the immature anthers which are removed.
- Organs are very small and any damage to the stigmas will result in poor seed set.
- The need for emasculation is not as critical for protandrous flower like impatiens, or heterozygous flower like primula.
- Some female line of petunia and snapdragon are male sterile. Since no pollen is produced by the male sterile flowers, emasculation is not required.

Pollination

- For pollination, flowers are ready a day or two after emasculation.
- Flower to flower pollination is practiced when fresh pollen is applied. Either the entire flower (e.g. impatiens) or the filament with the dehisced anthers attached from the male parent is held by hand and the pollen contents smeared on to the exposed stigma of the female flower.
- For crops pollinated with extracted pollen, the pollen is placed on the stigmatic surfaces by means of a brush at the correct location.

2. Seed harvest

- Subsequent to successful pollination, the seed develops and matures on the mother plant.
- The seed harvest and seed drying steps are paramount in obtaining high quality seed. Determining the correct stage of seed development for seed harvest is important and the seeds harvested too late will allow the inclusion of deteriorated seeds.
- The timing of harvest may also influence the propagation of seeds like when the pods are dry and cracked open, or when the fruits are soft in the case of fresh berries.
- Traditionally, seeds are harvested close to the time of seed dispersal, i.e. when the seed pods are dry and cracked open, or when the fruits are soft in the case of fleshy berries.
- Seeds are considered mature at the point of maximal dry weight accumulation (physiological maturity) and there may be a strong link between chlorophyll degradation and seed vigor.
- Physiologically mature seeds are desiccation tolerant as they progress into a quiescent state.
- All sizeable greenhouse seed production facilities are equipped with proper seed drying devices. Heated drying chambers are most commonly used.
- After the seed pods are dried, the loose seeds are separated from other plant parts by using sieve.
- Seed pods are hard and do not break open naturally and are crushed mechanically before the sieving process.

3. Seed Cleaning

- Seed cleaning is generally a simple process and mainly involves removing the very small or light seeds in order to improve the overall quantity of the seed lot.
- Hand screens and small air columns are commonly used to remove the small amounts of plants parts and small seeds.

Lecture 29 - Breeding of Rose, Objectives and techniques

Lecture 29 - Breeding of Rose, Objectives and techniques

Objective: To teach the students about genetics of rose, its breeding objectives, different rose breeders and the techniques involved in rose breeding.

Breeding objectives

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.

Rosa chinensis

Rosa moschata

Rosa gigantea

Rosa multiflora

Rosa wichuriana

Rosa gallica

Rosa gallica

Rosa damascene

Rosa centifolia

Techniques of Breeding

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.

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.

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

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

Abhisarika

Jawahar

Raktgandha

Suchitra

Arunima

Nav Sadabahar

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

Different Varieties evolved in India

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	Meilland,1949

		Capucine Chambari)	
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 30 - Breeding of gladiolus: objectives and techniques

Lecture 30 - Breeding of gladiolus: objectives and techniques

Objective: To teach the students about the genetics of gladiolus, different methods involved in breeding of gladiolus, varieties evolved through various methods and institutions.

Breeding of gladiolus

Introduction:

- 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	*G. maculatus*	South Africa	Strongly fragrant with freesia

African Cape Species			like flowers
	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

Arka Gold

Arka Naveen

Arka Amar

Varieties developed in India

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 American 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

Lecture 31 - Breeding of tuberose: objectives and techniques

Breeding of tuberose

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.

Lecture 32 - Breeding of Jasmine and Hibiscus

Jasmine Breeding

INTRODUCTION

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

- **Introduction**

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'.

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