# BREEDING OF FRUITS AND PLANTATION CROPS

## Course No. FRS 222

### B.SC. HORTICULTURE II YEAR

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## Lecture.1

## History, Development and Importance of Fruit Breeding

India is bestowed with a wide range of agro climatic and soil conditions. Therefore, almost all types of fruits can be grown in one or the other parts of the country. India is the second largest producer of fruits next to China. In India, horticultural crops occupy about 6.7% of gross area,contribute about 18% of gross value of agricultural output and 52% of export earnings in agriculture.

The inherent nature of a long gestation period, high heterozygosity, scanty information on inheritance pattern, often cross pollination, excessive fruit drop, parthenocarpy and low seed number restricting the availability of hybrid seedlings for evaluation are the real challenges in crop improvement. Even though, planned hybridization and clonal selections have been attempted in a number of fruit crops and these efforts have resulted in the development of promising varieties in mango, grape, guava, papaya, sapota, banana, etc. Systematic much more and dedicated efforts are required for the development of ideal varieties through modern tools.

More focus on search for desired genes, critical study of inheritance pattern and use of biotechnological tools are needed in combining ideal characteristics in varietal improvement programme of fruit crops.

### History of fruit research

Fruit research in India was started at the Departments of botany in six Agricultural Colleges established in 1905 at Pune, Coimbatore, Lyallpur, Nagpur, Sabour and Kanpur. Almost at the same time, the Imperial Agricultural Research Institute was set up at Pusa (Bihar) and the Provincial and Central Departments of Agriculture were organized which were to look after the work on horticultural crops. At that time, the responsibility of research on fruit crops was mainly of the State Governments. During this period, some of the European settlers like Lee in Kullu Valley, Coutts and Stokes in Shimla hills and some European Missionaries in South India introduced new varieties of

fruit crops from UK, France and East Indies etc. A pomological Station was established at Coonoor near Ooty in 1920 to study the adaptability of temperate fruit varieties.

The initiative by the Imperial Council of Agricultural Research to provide financial assistance to the Provincial Governments in the year 1929 gave considerable boost to research activities. Several schemes were sanctioned to the State Governments to carryout work on important problems. E.g. Citrus dieback, fruit preservation, nutritional value of fruits and control of pests such as San Jose scale of temperate fruits.

**Fruit Breeding**

Fruit breeding is the manipulation of a biological system that requires many generations to achieve result. It is also a dynamic, exciting and challenging profession, operating under continually changing conditions.

**Major problems in fruit breeding**

- Most of the fruit crops have long generation cycle of 2-10 years depending upon species and cultivars and hence more recombinations are not possible.
- Fruit crops have long juvenile period and making it difficult for early assessment of strains e.g. mango, *Madhuka latifolia*, jack fruit etc.

***Madhuka latifolia***

- Majority of the fruit species are highly heterozygous, requiring large populations for an effective selection
- Most fruit species are polyploidy in nature e.g. ber, banana etc.
- Polyembryony nature of fruit species e.g. citrus, mango
- Presence of parthenocarpy and seedlessness e.g. banana, pineapple etc.

- Presence of sexual incompatibility e.g. mango, apple, pear, loquat etc.
- More number of chromosome hinders genetic analysis e.g. ber, mulberry.
- Excessive fruit drop e.g. mango, citrus, grape etc
- Presence of single seed in most of the cases warrants more number of crosses e.g. mango, litchi, mahua etc.

**Objectives of fruit breeding**

The objectives of fruit breeding depends on the fruit crops, location and requirements of the consumers. The main objectives of fruit breeding is to get maximum quality production per unit area with low cost, besides tolerance to biotic and abiotic stresses, the objectives are distinct and variable in respect of breeding for rootstocks and scions.

**For rootstock**

- Wide geographical adaptability
- Easily propagated, preferably through asexual means
- Compatibility with most of the scion cultivars having strong scion stock union and more longevity
- Resistance to biotic and abiotic stresses
- Induction of dwarfing without affecting the productivity of scion cultivars
- Should possess strong root system with out brittleness e.g. EM 9 root stock of apple
- It should be free from suckering habit

**For scion cultivars**

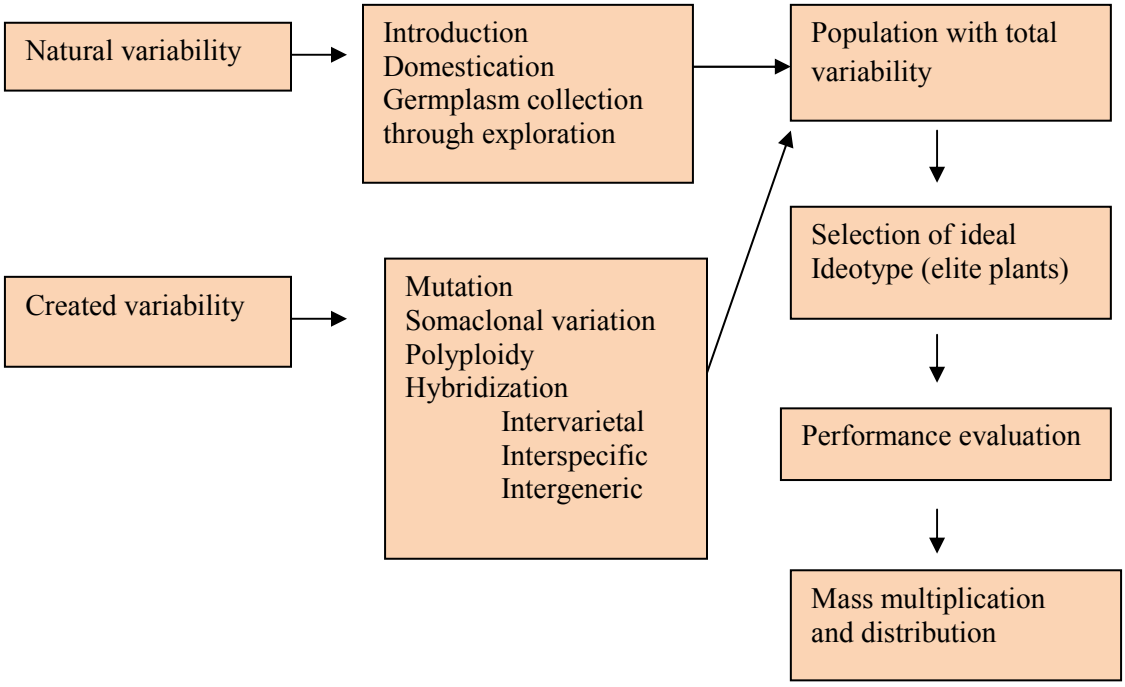
- Dwarf stature
- Regular, precocious and prolific bearing per unit canopy area
- High productivity with good quality fruits
- Resistance to biotic and abiotic stresses
- Attractive fruit colour with pleasant aroma
- Suitable for processing and export

- Good keeping and transport quality

**Importance of fruit breeding**

Although cultivation and utilization of fruits have been known in India since the Vedic age, a modest beginning for systematic research was made only during the twenties. Owing to the growing awareness on the importance of fruits in daily diet and the need to increase their supply position to the growing population, more emphasis was laid on fruit research during the sixties. Especially during the last fifteen years, development in horticulture has gradually moved from rural to urban areas and from traditional agricultural enterprise to corporate sector adopting improved technology, greater commercialization and professionalism in the management of production and marketing. During the last two decades, research approach on fruits has undergone considerable change with ever-increasing multi-location, inter-disciplinary and inter-institutional involvement to solve specific problems in a coordinated manner. Intensive research in horticulture has been taken up in many ICAR institutions, Agricultural Universities for the last 50 years with the result that many improved cultivars have been made available for planting by the horticulturist despite the fact that the problems are encountered in breeding of horticultural crops are enormous. Research on crop improvement in fruit crops is receiving considerable augmentation on account of the newly emerging production constraints due to pest, diseases, drought, salinity and climate change.

**General steps in fruit breeding**




**Questions**

1. Fruit research in India was started during 1905.

**Ans: True**

2. What do you understand by the terminology "Fruit breeding"?

**Ans:** Fruit breeding is the manipulation of a biological system that requires many generations to achieve result. It is also a dynamic, exciting and challenging profession, operating under continually changing conditions

3. Polyembryony exists in mango, citrus.

**Ans: True**

4. Excessive fruit drop is found in grapes.

**Ans: True**

5. Rootstocks should be resistant to biotic and abiotic stresses.

**Ans: True**

## Lecture.2

## Centers Of Diversity, Distribution And Domestication Of Fruit Species

### Centre of origin (Primary and secondary)

The concept of centre of origin was conceived by N.I. Vavilov based on his studies of a vast collection of plants at the Institute of Plant Industry, Leningrad during his tenure as Director from 1916 to 1936. According to Vavilov, crop plants evolved from wild species in the areas showing great diversity and termed them as primary centers of origin. But in some areas, certain crop species show considerable diversity of forms although, they have not originated from such areas which are known as secondary centers. Eight main centers of origin are recognized as proposed by Vavilov.

### China

This is one of the largest and oldest center of origin. It includes mountainous parts of Central and Western China besides, neighboring lowlands.

### Examples

- Pear (*Pyrus communis*)
- Peach (*Prunus persica*)
- Apricot (*Prunus armeniaca*)
- Plum (*Prunus salicina)*
- Mandarin (*Citrus reticulata*)

### Hindustan

This centre includes Burma, Assam, Malayan Archipelago, Java, Borneo, Sumatra and Philippines. But, this centre does not include North West India, Punjab and North Western Frontier Provinces. Later on, this center of origin is divided into Indo-Burma and Siam-Malaya-Java centre of origin.

**Examples**

- Mango (*Mangifera indica*)
- Sour lime (*Citrus aurantifolia*)
- Mandarin (*Citrus reticulata*)
- Coconut (*Cocos nucifera*)
- Banana (*Musa sapientum*)

**Central Asia**

It is also known as the Afghanistan centre of origin. It includes North West India (Punjab, North-West Frontier Provinces and Kashmir), all Afghanistan, Soviet Republics of Tajikistan and Uzbekistan and Tian-Shan;

**Examples**

- Pistachio nut (*Pistacia vera*)
- Almond (*Prunus amygdalis*)
- Grape (*Vitis vinifera*)
- Apple (*Malus sp*.)

Some species of apricot (*Prunus armeniaca*) and pear (*Pyrus spp*).

**Asia Minor**

It includes the interior of Asia Minor, the whole of Transcaucasia, Iran, and high lands of Turkmenistan. This centre is also known as the Near East or Persian centre of origin.

**Primary centre of origin**

- Fig (*Ficus carica*)
- Pomegranate (*Punica granatum*)
- Some species of apple, *Pyrus, Prunus* and grape

**Secondary centre of origin**

Chestnut and pistachio nut

**Mediterranean centre of origin** – Example Pippermint (*Mentha* sp.)

**Abyssinian**

It includes Ethiopia and hilly country of Eritrea. Example: Coffee.

**Central America**

This includes region of South Mexico and Central America. It is also known as Mexican centre of origin.

**Examples**

- Papaya (*Carica papaya*)
- Guava (*Psidium guajava*)
- Avocado(*Persia americana*)

**South America**

This centre includes the high mount regions of Peru, Bolivia, Ecuador, Colombia, parts of Chile and Brazil and whole of Paraguay. Further, this centre was sub-divided into three centres i.e. Peru, Chile and Brazil-Paraguay centre of origin.

**Examples:** Pineapple and a few species of guava.

**Diversity in Horticultural crops**

Genetic resources constitute the foundation upon which horticulture is based. Of these, the least understood and most undervalued are the Horticultural Genetic Resources (HGR). These resources consist of diversity of genetic material in the form of traditional varieties and modern cultivars grown by farmers as well as wild relatives and other wild plants occurring in nature. Over the years, hundreds of different plant species have been domesticated and within each species, human and natural selection have combined to produce thousands of different varieties. In developed world, 'primitive cultivars' or 'landraces' have given way to more productive, uniform, modern cultivars.

Another important aspect of HGR is their requirement of specific management strategy. For instance, some genetic resources can be conserved in seed gene bank while others will need field gene bank, some genetic resources are propagated by seed, whereas others by vegetative methods and some genetic resources are annual herbs while others are perennial trees. Therefore, management of genetic resources of horticultural crops is gigantic tasks offering both challenges and opportunities which cannot be accomplished by one or a few institutions but a large number of institutions are required to join hands together.

**HGR in indian gene centre**

The horticultural diversity existing in India today comprises both indigenous and exotic genetic resources. Among native horticultural crops of India, rich diversity exists in 50 different indigenous fruits and their wild relatives, totaling about 400 species. The North Eastern region has maximum concentration of wild relatives of fruits followed by the Western Himalayas. Rich diversity in North –eastern region is reported in citrus, mango and banana. The Indian wild orange, *C,indica*, is found in the Naga hills, Garo hills of Meghalaya and Kaziranga forests of Assam. Similarly, in mango, wild forms of *Mangifera indica* and its allied species of *M. sylvatica* are native to Andaman Islands. Rich diversity occurs in North –Western and Eastern Himalayan regions for *Pyrus ,Rubus,* Ribes and *Prunus*. The Shillong plateau of Khasi hills in Meghalya accounts for many *Prunus* species such as *P.nepaulensis, P.undulata and P.cerasoides.* There are many minor fruit plants that have potential for exploitation. These include bael fruit *(Aegle marmelos),* Indian gooseberry

*(Emblica officinalis),* papaya (*Carica papaya)*, Jack fruit *(Artocarpus hetrophyllus*), custard-apple (*Annona sp),* Karonda (*Carissa sp)*, cordia or (*cordia myxa*) and phalsa (*Grewia asiatica*).

**HGR management in India**

| | | |
|---|---|---|
| North – Eastern region | | Pumpkin, cucumber, Okra, eggplant, chilli, pointed gourd, ash gourd, taro, yams, *citrus* spp. *Citrus lemon, C.medica, C. jambhiri, C.ichagensis, C.latipes, C.macroptera, C.assamensis, C,indica* and *C.aurantium*, banana, tea, tree cotton, and mesta, large cardamom, ginger, long pepper and sugarcane |
| Western Himalayas | | Pumpkin, cucumber, *Allium* spp., ginger, brassicae, pome, stone, soft and nut fruits, chayote, tree tomato, medicinal plants. |
| Eastern Himalayas | | Pumpkin, cucumber, *Allium* spp., ginger, chayote, tree tomato, brassicae, pome and stone fruits |
| Eastern peninsular region | | Taro,yams, elephant foot yam, banana, mango, lemon / lime, jackfruit, niger, brassicae, sesame, ginger, turmeric chilli, sugarcane, coconut and cotton |
| Gangetic plains | | Okra, eggplant, bitter gourd, *Cucumis* spp., *Luffa* spp., Jackfruit, mango, lemon / lime, orange jujube, Indian gooseberry, jamun, melons, linseed, niger, sesame, brassicae, sugarcane and mulberry |
| Indus plains | | Okra, *Cucumis* spp., khirni and phalsa |
| Western peninsular region | | Okra, eggplant, cucumber, chilli, taro, yams, elephant foot yam, jackfruit, banana, lemon/ lime, orange, jamun, sugacane, black pepper, turmeric ginger, coconut, arecanut and cotton |
| Island regions | | Coconut, bread fruit, chilli, taro, yams and xanthosoma |

Management of HGR is an important issue, especially for a country like India, which is predominantly an agrarian society and also richly endowed with HGR. In fact, HGR management is more complex as compared to the field crops, and requires different management strategies.

**Regions in India with rich HGR diversity**

The National Bureau of Plant Genetic Resources (NBPGR), New Delhi, is the nodal institute working on survey, collection, exchange, quarantine, characterization, evaluation, conservation and documentation of PGR, including HGR. It plays a pivotal role in crop improvement and development and diversification of agriculture in India through germplasm introduction from various foreign sources collection within the country and abroad and germplasm supply to plant breeders and other users. (International collaboration and infrastructural facilitates were strengthened manifold during 1980s. A cold-storage module with a seed storage – of- the state of –art technology. National Gene bank (NGB) was established in 1996 with a storage capacity of 1 million seed accessions. Well-equipped cryo preservation and *in vitro* conservation facilities were developed to cater to the conservation of HGR, especially recalcitrant seed species and vegetatively propagated materials in 1986.

**Acclimatization**

When a plant material is introduced into a new area, it has to adapt itself to the new environment. Thus, the process of adaptation of an individual to a changed climate, or the adjustment of a species or a population to a changed environment over a number of generations is called "acclimatization" or acclimation. A naturally cross-pollinated crop will adapt itself to the new environment more quickly than a self-pollinated crop. In gene recombinations, some of the genes be well adapted to the new environment, will be present very often in the cross pollinated crops due to frequent cross pollination. Similarly, the chances of a genetically variable population of a self-pollinated crop to become adapted to its new environment are greater than those of a pure-line. Newly introduced materials of unselected bulk may be promising in the initial phases of introduction but should prove very well in later years. This is because nature selects from the heterogeneous population superior

genotypes that are better suited to the new environment from among the heterogenous population and multiplies them in the course of a few years. A pure-line, on the other hand, has practically no genetic variability and hence it does not offer much scope for making selection adaptable to the newer place in which it has been introduced. A pure-line thus very rarely succeeds as an introduction.

Some of the most important commercial crops cultivated extensively in India today are introductions from other countries. Para rubber (*Hevea sp*), was first introduced from Brazil in 1873. One or two attempts of introduction of this crop did not prove to be successful, but now, India particularly Kerala has extensive plantations of rubber. Tapioca (*Manihot esculenta*) has been introduced into India by the Portuguese and the Dutch. It is now grown extensively in Kerala where, it is a staple food. Cinchona was first introduced into the Nilgiris from Peru in 1860. Later it was introduced into Darjeeling. Coffee (*Coffea arabica*) was first introduced into India in 1700 by a Muslim who returned from a pilgrimage to Mecca. Today, coffee is grown extensively in South India and is an important commercial crop both for internal consumption and for export.

**Questions**

1. Which one of the following has china as centre of origin?

a) Pears (*Pyrus communis*)
b) Grape (*Vitis vinifera*)
c) Fig (*Ficus carica*)
d) Pomegranate (*Punica granatum*)
**Ans: Pears (*Pyrus communis*)**

2. Which one of the following has Mediterranean centre as origin Pippermint (*Mentha* sp.)

**Ans: True**

3. Name crops from Hindustan centre of origin.

**Ans:**

- Mango (*Mangifera indica*)
- Sour lime (*Citrus aurantifolia*)

- Mandarin (*Citrus reticulata*)
- Coconut (*Cocos nucifera*)
- Banana (*Musa sapientum*)

4. Central Asia is known as the Afghanistan centre of origin.

**Ans: True**

5. Which one of the following crops has Central American as centre of origin?

**Ans:**

- Apple (*Malus sp*.)
- Mandarin (*Citrus reticulata*)
- Plum (*Prunus divaricata*)
- Papaya (*Carica papaya*)

6. Expand HGR- **Horticultural Genetic Resources**

7. Expand (NBPGR) - **National Bureau of Plant Genetic Resources.**

8. National Gene bank (NGB) was established in the year 1996.

**Ans: True**

9. Give examples for introduced crop commercially cultivated extensively in India Rubber (*Hevea brasiliensis*)

**Ans: True**

10. Coffee (*Coffea arabica*) was first introduced into India in 1700 by a Muslim.

**Ans: True**

## Lecture.3
## Problems in fruit breeding - poly ploidy and heterozygosity

### Polyploidy

An organism having more than two sets of homologous chromosomes is known as a polyploid. Polyploidy is of general occurrence in plants while it is rare amongst animals. If the somatic chromosome sets in a diploid be represented by AA BB CC then the genome, i.e., the number in the genomes will be A B C. If this is represented by 'n' then the simple polyploid series would be:

- 2n – diploid
- 3n – triploid
- 4n – tetraploid
- 5n – pentaploid
- 6n – hexaploid
- 7n – heptaploid
- 8n – octaploid
- 9n – Nonaploid
- 10n – decaploid and so on

Polyploidy is pervasive in plants and some estimates suggest that 30-80% of living plant species are polyploids, and many lineage show evidence of ancient polyploidy (paleopolyploidy) in their genomes. Polyploid plants can arise spontaneously in nature by several mechanisms, including meiotic or mitotic failures, and fusion of unreduced (2n) gametes. Both autopolyploids (e.g. Potato) and allopolyploids (e.g. canola, wheat and cotton) can be found among both wild and domesticated plant species. Most polyploids display heterosis relative to their parental species. The mechanisms leading to novel variation in newly formed allopolyploids may include gene dosage effects (resulting from more numerous copies of genome content), the reunion of divergent gene regulatory hierarchies, chromosomal rearrangements, and epigenetic remodeling, all of which affect gene content and or expression levels. Many of these rapid changes contribute to reproductive isolation and speciation.

**Behaviour of polyploid crops**

Polyploid plants tend to be larger and better at thriving in early succession habitats such as farm fields. In the breeding of crops, the tallest and best thriving plants are selected for. Thus, many crops (and agricultural weeds) may have unintentionally been bred to a higher level of ploidy. The induction of polyploidy is a common technique to overcome sterility of a hybrid species in plant breeding. In some situations, polyploid crops are preferred because they are sterile. For example, many seedless fruit varieties are seedless as a result of polyploidy. Such crops are propagated using asexual techniques such as grafting. Polyploidy in crop plants is most commonly induced by treating seeds with the chemical colchicine.

**Examples of polyploid crops**

- Triploid crops : banana, apple, ginger, watermelon, citrus
- Tetraploid crops : potato, cabbage, leek, tobacco, peanut, kinnow, pelargonium
- Hexaploid crops : chrysanthemum, bread wheat, triticale, oat, kiwifruit
- Octaploid crops : strawberry, dahlia, pansies, sugar cane

Some crops are found in a variety of ploidy. Apples, tulips and lilies are commonly found as both diploid and triploid. Bananas are available as diploid, triploid, tetraploid, and pentaploid. Daylilies ***(Hemerocallis spp*)** cultivars are available as either diploid or tetraploid. Kinnows can be tetraploid, diploid, or triploid.

A survey of the chromosome numbers of the species in a genus or a family shows that these species generally fall into a polyploid series. The species are grouped together under a taxonomic head because of certain morphological resemblances and relationships. They may be crossable or may not hybridize at all with one another. However, the chromosome numbers of the species show a general relationship, i.e., they form multiples of a common basic number. The chromosome numbers of the family *Solanaceae* may be considered as an example.

| Crops | Ploidy level |
|---|---|
| *Capsicum annum nigrum* | 12 |
| *C. annuum* | 24 |
| *Datura fastuosa* | 24 |
| *D. metal* | 24 |
| *D. stramonium* | 24 |
| *Hyocyamus labus* | 36 |
| *H. canadensis* | 72 |
| *Nicotiana sylvestris* | 24 |
| *N. tabacum* | 48 |
| *N. digluta* | 72 |
| *Physalis philadelphica* | 24 |
| *P. peruviana* | 48 |
| *Solanum marginatum* | 24 |
| *S. muricatum* | 24 |
| *S. alatum* | 48 |
| *S. tuberosum* | 48 |
| *S. nigrum* | 72 |
| *S. nigrum var. gigas* | 144 |

## Types

### Autopolyploidy

Autopolyploids are polyploids with multiple chromosome sets derived from a single species. They can result from a spontaneous, naturally occurring genome doubling, like the potato. Others might form following fusion of 2n gametes (unreduced gametes). Bananas and apples can be found as autopolyploids. Autopolyploid plants typically display polysomic inheritance, and are therefore often infertile and propagated clonally.

**Allopolyploidy**

Allopolyploids are polyploids with chromosomes derived from different species. Precisely, it is the result of doubling of chromosome number in an $F_1$ hybrid. *Triticale* is an example of an allopolyploid, having six chromosome sets, allohexaploid, four from wheat (***Triticum turgidum***) and two from rye (*Secale cereale*). *Amphidiploid* is another word for an allopolyploid. Mango and banana are also allopolyploids. Doubled diploids are known as amphidiploids. Some of the best examples of allopolyploids come from the Brassicas, the three diploid Brassicas (*B. oleracea, B. rapa,* and *B. nigra*) and three allotetraploids (*B. napus and B. juncea).*

**Problems due to polyploidy and heterozygosity nature of fruit crops**

Fruit crops such as mango, banana and citrus pose the problem of polyploidy, and crops such as mango, papaya and citrus are highly heterozygous. Choosing of polyploid varieties with desirable qualities may have the hindrance in developing hybrids as sometimes they exhibit sterility and obtaining a good hybrid may be questionable. In banana, when tetraploid is crossed with a diploid or triploid the genome of the segregating population will be unpredictable because of the restitution or unreduced chromosomes arising from the female parent. Heterozgosity on the other hand, create more complexity in breeding of mango, papaya and citrus because of wide segregations in the progenies. Hence, the breeding cycle is extended when compared to self pollinated crops because in every generation careful selection of progenies is required and high level of purity has to be maintained in each generation.

**Questions**

1. Organism having more than two sets of homologous chromosomes is known as a Polyploid.

**Ans: True**

2. Give examples for Octaploid crops

**Ans:**

- Strawberry,
- Dahlia,

- Pansies,
- Sugar Cane

3. Bananas and apples can be found as Autopolyploid.
   **Ans: True**

4. Mango is an example of an Allopolyploid.

   **Ans: True**

5. Heterozygosity is problem in mango, citrus.

   **Ans: True**

## Lecture.4

## Problems in Fruit Breeding – Polyembryony, Parthenocarpy and Seedlessness

### Polyembryony

The phenomenon in which more embryos are present within a single seed is called polyembryony. It may result due to (a) nucellar embryony e.g., Citrus (b) development of more than one nucleus within the embryo sac (in addition to the egg embryo during the early stages of development) leading to multiple embryos (e.g. conifers).

Occurrence of polyembryony is widespread in all citrus species but the number of embryos per seed varies from species to species. In rough lemon, it varies from 3 to 5. In mango certain cultivars are reported to be polyembryonic with the number of embryos ranging from 2 to 10 and the germination per cent from 40 to 87. Polyembryonic seedlings can be identified from its true seedlings by their uniformity and vigorous growth, while the seedling arising from fertilized embryo will be weak. The greater vigor in polyembryonic nucellar seedlings is probably due to the elimination of viruses. In mango polyembryony was determined by single dominant gene (Anon, 1996). In citrus, all the species are polyembryonic in nature except *C.medica* (Citron) and *C.grandis* (Pumelo) which are monoembryonic. Though nucellar embryony in citrus is of great value for producing vigorous, uniform and virus free plants, the phenomenon is an obstacle in hybridization. In polyembryonic cultivars, the vigorous growth of nucellar embryos inhibits the growth of the zygotic embryo and causes its degeneration prior to seed maturation. Such abortive embryos can be rescued by tissue culture.

### Parthenocarpy and Seedlessness

In the recent years, the consumer preference towards seedless fruits is increasing among the consumers. The seedless nature of certain fruits is due to the phenomenon of ‘parthenocapy’ which refers to the development of fruits without fertilization or even without the stimulus that comes from pollination. Parthenocarpic fruits are usually seedless but need not be always.

**Vegetative parthenocarpy**

If a fruit develops even without the stimulus of pollination, then the phenomenon is referred to as vegetative parthenocarpy (automatic) eg. Banana and Japanese persimmon.

**Stimulative parthenocarpy**

If a fruit develops from the mere stimulus of the pollination (but without fertilization), the phenomenon is known as stimulative parthenocarpy. The female flowers of triploid watermelon require the pollen grains of diploid varieties to develop into a seedless fruit. Diploid pollen grain gives a stimulus to the ovary of guava when self pollinated, which result in the development of parthenocarpic fruit due to the stimulation provided by pollen hormones. E.g) Thompson Seedless variety of Grapes and papaya

**Steno-spermocarpy**

In **"**Black Corinth" variety of grapes, pollination and fertilization take place but the embryo gets aborted subsequently resulting in seedlessness. This phenomenon of development of seedless fruits is referred to as 'steno-spermocarpy'.

The seedlessness or parthenocarpic fruits are advantageous since there is a greater preference among the consumers for the seedless fruits of the same kind (e.g. seedless grapes, guava or oranges). Besides the problem of unfruitfulness due to pollination failure, sterility and incompatibility may not arise if a fruit develops parthenocarpically and the grower is assured of good crop (e.g. banana). One drawback with the seedless fruits is that they are usually small in size (e.g. Black Corinth variety of grapes) and irregular in shape (guava).

**Induction of seedlessness in fruits**

The seedlessness can be induced by the following methods.

**1. Use of growth regulators**

Application of GA at 8000 ppm in lanolin paste on the cut end of the style of the emasculated flowers of guava resulted in the development of seedless fruits.

Similarly, seedlessness in loquat was induced by spraying GA 100 to 200 ppm on the emasculated flowers.

**2. Changing the ploidy level**

It was first demonstrated in Japan that by developing a triploid water melon 2n= 33 by crossing tetraploids x diploid varieties, seedlessness could be achieved. Naturally available seedless guava varieties are due to auto polyploidy (triploid) and not due to parthenocarpic fruit development.

**Parthenogenesis**

In some plants, fruits develop parthenocarpically, still they produce viable seeds. (e.g. Mangosteen and Strawberry). This phenomenon is referred to as parthenogenesis. The seedlings of such fruits are genetically uniform. In certain cases, seeds develop partenogentically but they are non-viable (e.g. Apple) When female flowers of jack are pollinated with the pollen grains of bread fruit, seeds do form in jack but they did not germinate as they are non-viable.

**Questions**

1. Give examples for Vegetative Parthenocarpy Banana.
   **Ans: True**
2. More than one embryos present within a single seed is called Polyembryony.
   **Ans: True**
3. Citrus is an example for nucellar embryony.
   **Ans: True**
4. The development of fruits without fertilization is known as Parthenocapy.
   **Ans: True**
5. Give example for Steno-spermocarpy Grapes.
   **Ans: True**
6. Spraying $GA_3$ 100 to 200 ppm on the emasculated flowers induces seedlessness in loquat.
   **Ans: True**

**B. Choose the correct**

**7.** Which one of the following is an example for poly embryony

a) Papaya b) Mango c) Japanese Persimmon d) Apple

**Ans: Mango**

**8.** Which one of the following has Parthenogenesis

a) Loquat b) Grape **c)** Banana d) Mangosteen

**Ans: Mangosteen**

**C. True or False**

9. Stimulative parthenocarpy is noticed in papaya**.**

**Ans: True**

**10.** Parthenocarpic fruits are usually seedless.

**Ans: True**

# Lecture.5
# Incompatibility and Sterility Systems

## Self incompatibility

The barrier between pollination and fertilization in angiosperms is because of the self-incompatibility, a genetically controlled phenomenon. Self incompatibility is the inability of functional male and female gametes of the hermaphrodite flowers to set seeds on self pollination.

## Genetic control of self incompatibility

Incompatibility is generally controlled by a special gene at S-locus represented by multiple allelic series in the population. Each of these alleles control the formation of a specific substance that determines the incompatibility reactions, both in the pistil and pollen. Identical substances specified by identical genes in pollen and pistil favour to prevent fertilization. Based on the timing and mode of S-gene activity, the incompatibility reaction among homomorphic angiosperm is categorized into two groups.

A. Gametophytic control of pollen reaction.

B. Sporophytic control of pollen reaction.

## A. Gametophytic self incompatibility

In this type of incompatibility, pollen is binucleate and pollen behaviour is determined by the S allele present in each pollen and stigma is wet type. It means the incompatibility reaction of pollen is determined by its own genotypes, and not by the genotype of the plant on which it is produced. Generally, incompatibility reaction is determined by a single gene having multiple alleles. Sometimes, polyploidy may lead to the loss of incompatibility due to a competition between the two S alleles present in diploid pollen. Important examples are pineapple, loquat, apple, pear, plum, cherry, almond, apricot, some citrus and members of Solanaceae family.

**B. Sporophytic incompatibility**

The incompatibility reaction of pollen is governed by the genotype of plant on which the pollen is produced and not by the genotype of the pollen. It means the incompatibility is imposed by the maternal genotype, due to that all the pollen grains from a given plant behave similarly. Incompatibility occurs at the stigmatic surface resulting in the inhibition of pollen germination. Pollens are trinucleate and the stigmatic surface is dry e.g. Mangifera indica.

**Mechanism of self incompatibility**

Based on the various phenomenon observed during pollination and fertilization it can be grouped into three:

i) Pollen stigma interaction

ii) Pollen tube style interaction

iii) Pollen tube ovule interaction

**1) Pollen-stigma interaction**

This interaction occurs just after the pollen grains reach the stigma and generally it prevents pollen germination. In the gametophytic system, stigma surface is plumose having elongated receptive cells and is commonly known as wet stigma. Incompatibility reaction occurs at a later stage. There are clear cut serological differences among the pollen grains with different S genotypes and such differences have not been observed in sporophytic system.

In sporophytic system, stigma is papillate and dry covered with a hydrated layer of proteins known as pellicle. There is evidence that the pellicle is involved in incompatibility reaction. There are striking differences in the stigma antigens related to the S allele composition. Within few minutes of reaching the stigmatic surface, the pollen releases exine exudates which are either protein or glycoprotein in nature. This exudate induces immediate callose formation in papillae (which are in direct contact with the pollen) of incompatible stigma. Often callose is also deposited on the young protruding

pollen tubes preventing any further germination of the pollen. Thus, in the sporophytic system, stigma is the site of incompatibility reaction. The incompatibility reaction of pollen is probably due to the deposition of some compounds from anther tapetum on to the pollen exine.

**2) Pollen tube - style interaction**

In most of the gametophytic system, pollen grains germinate and pollen tubes penetrate the stigmatic surface. But, in the incompatible combinations, the growth of pollen tube is retarded within the stigma.

**3) Pollen tube - ovule interaction**

In some cases, pollen tube reaches the ovule and affects fertilization. However, in incompatible combinations, embryo degenerates at early stage of development.

**Methods of overcoming self incompatibility**

One of the following methods can be used for bringing partial fertility by temporarily suppressing the incompatibility reaction:

- **Bud pollination** – Application of mature pollens to immature non-receptive stigma i.e. 1-2 days prior to anthesis.
- **Surgical technique** – Removal of stigmatic surface.
- **High temperature** – Exposure of pistils to temperature up to $60^{o}C$
- **Irradiation** – With x rays or γ rays for single locus gametophytic incompatibility.
- **Double pollination** – Incompatible pollen is applied as mixture with compatible pollen.
- **Pollination at the end of season**

Arora and Singh (1988) observed that in low chilling plum and peach cultivars, methanol killed the mentor pollen and not helpful in overcoming incompatibility barriers, however, frozen and thawed mentor pollen (one which, if alive, would be fully compatible with style receiving it) improved fruit set in both intra and inter specific incompatibility.

In case of sporophytic incompatibility system, the breakdown is comparatively easy because the incompatibility reaction takes place between stigmatic surface and pollen wall in comparison to gametophytic incompatibility in which reaction starts when the pollen tubes have already travelled ⅓ to ½ length of styler tissue (Arora, 1993).

**Advantages of self incompatibility**

1. Where male sterility is non existent, self incompatibility can alternatively facilitate the production of $F_1$ hybrids.
2. Self fertility can be induced temporarily or permanently by mutation of S alleles to $S_1$ through artificial irradiation in clonally propagated orchard species like cherry and apple
3. Seedless varieties, such as in pineapple, grape etc. can be evolved if self incompatibility is present.

**Disadvantages**

- Variations in seed set due to poor fertility.
- Poor preservation of genetic purity of improved varieties since cross pollination is non-restricted.
- Difficulties in development and maintenance of homozygous lines (inbreds) which can be utilized for hybridization.
- Uneven quality of fruits because of mixed planting of different varieties based on their cross compatibility.

**Pollination pattern and incompatibility**

Self-incompatible fruit cultivars/species need cross pollination for seed/fruit set which includes pollen hydration and germination, pollen tube growth into the style to the ovary, entry into the ovule and embryo sac and release of sperms. Pollination failures may, thus, create barrenness in the tress which is otherwise completely normal in health and free from diseases and insect pests. During cross pollination, the sensitive discriminations have to be made between pollen grain of different genotypes for which identity of each pollen is needed. The germination of pollen grain and its penetration into the stylar tissue to reach the embryo sac depends upon acceptability by the pistil which is selective in nature.

**Aonla**

In aonla, male flowers appear in clusters in the axil of leaf all over the branchlet while female flowers are on the upper end of a few of these branches. Bajpai (1968) reported male to female ratio of 307.9:1 and 197:1 in two successive years indicating marked variation in the expression of sex. The maximum number of male flowers opens between 6 and 7 PM and dehiscence of anthers starts soon thereafter. The female flowers open in stages and take 72 hours to open completely and the stigma becomes receptive on the third day of anthesis. Bajpai (1968) reported that aonla pollen are light and thus the pollination occurs through wind. There is no self-incompatibility in aonla. The cause of poor fruit set may be attributed to a high percentage of staminate flowers.

**Apple**

Lal et al., (1972) found 9 apple cultivars completely and 4 partially self-incompatible. For Early Shanburry cultivar, Fanny (54-5%), Winter Banana (60.4%) and Rome Beauty (54.25%) were better pollinizers. In Red Delicious, highest fruit set occurred with Jonathan (87.5%) cultivars Mclntosh, Rymer, Jonathan and Rome Beauty set satisfactory crop with self pollen.

**Ber**

The majority of flowers are borne axillary on current season growth in clusters. The time of flowering varies in different parts of India. Godara (1981) found that cultivars Banarsi, Karaka, Mundia, Murhara, Reshmi, Sandhura, Narnaul, Safeda, Umran, Ilaichi and kakrola were self- incompatible and Umran was found to be the best pollen recipient as well as pollen donor. Being sticky, the pollen is transferred mainly by honey bees. Many flowers do not get pollinated at critical stages of gynoecium receptivity and drop off because of a short receptivity period.

**Citrus**

Pollen development is normal in citrus except in a few cultivars like Navel oranges, Satsuma mandarin and lime which have no viable pollen. In cultivars with abundant pollen, self-pollination occurs but in mixed plantings of different cultivars, cross pollination is not uncommon. The stigma remains receptive for 6-8 days. Honey bees are the known pollinating agents. Self-incompatibility has been reported in pummelo, sweet lime and lemon.

**Fig**

It is a gynodioecious species. The Capri fig is monoecious while common fig is pistillate. The figs commonly grown in India are parthenocarpic and do not require pollination. In other countries, generally Capri figs (wild figs) are planted as pollinizers with the commercial cultivars. The cultivars Pune, Black Ischia and Brown Turkey were reported to be Parthenocarpic from Kodur while Turkish White failed to set fruits without caprification.

**Grape**

Most vinifera cultivars have perfect flowers that have both functional pistil and stamens. Some species of grapes (V.rotundifolia) are dioecious. Berry set results from pollination, fertilization and seed development. Some cultivars like Black Corianth set by stimulative parthenocarpy and in others like Perlette, Beauty Seedless, Pusa Seedless, Delight, and Thompson Seedless stenospermocarpy occurs.

Self pollination is the rule in vinifera grapes. However, cross pollination is also possible and is desirable under certain conditions.

**Guava**

Cross pollination is the rule in guava. However, Singh Sehgal (1968) found that self pollination was also predominant and that the possibility of open pollination cannot be ruled out. Under open pollination, Allahabad Safeda had the highest fruit set of 85.5 per cent in spring and 84.4 per cent in rainy seasons, while cultivar Sardar reorded 83.3 and 82.2 per cent fruit set respectively. Under self pollination, Allahabad Safeda recorded 67.7 per cent fruit set in spring and 66.6 per cent in rainy seasons.

**Jackfruit**

In the tropics, flowering and fruiting are continuous throughout the year in the terminal leaf axil of leader and lateral shoots. There appears to be no regular sequence in the incidence of male and female inflorescences. Although they are similar during early development, the female is later distinguished by a thicker peduncle and a large annular disc at the anthesis, but later emerged males are smaller. Sharma (1964) reported a high degree of sterility with some fruits having 12,000 flowers producing only five fully developed segments surrounded by 448 aborted flowers. They also noted partial seed development, suggesting that some might have occurred after fertilization.

**Mango**

The panicles bear male and perfect flowers and the cross pollination is mainly done by the house fly. The number of perfect flowers per panicle varies between 1000 and 6000. Uniform cross pollination of cultivars Dashehari, Langra and Bombay Green with the pollen of Totapari and of Bombay Green with that of Langra and Chausa, Dashehari and Totapari and of Bombay Green indicated that in nature about 50 per cent of perfect flowers remain unpollinated, stigma remains receptive from one day prior to anthesis with a maximum on the day of anthesis and that fruit set is generally improved by mixed pollination.

**Male sterility**

Male sterility is characterized by non-functional pollen grains, while female gametes are functional. Male sterility can be classified into three groups viz., genetic male sterility, cytoplasmic male sterility, and cytoplasmic genetic male sterility.

**(a) Genetic male sterility**

Like any other morphological traits, particularly mono and oligogenic, this type of male sterility occurs in plant due to mutation of the fertility locus, situated on chromosomes within the nucleus. In this case, cytoplasm is not involved in bringing the sterility. There could be three possible genotypes for this locus and only one of them is male sterile.

Fertile (R-line) = RR

Fertile (B-line) = Rr

Sterile (A-line) = rr

**Sterility maintenance**

By crossing AxB lines, sterile and fertile progenies are produced in equal proportions. For the maintenance of sterile line, the fertile plants need to be quickly removed before the shedding of the pollen grains. The fertile plants can be removed in early stage of plant growth by using marker gene.

**Fertility restoration**

Fertile lines can be obtained by crossing A-line with R-line. It can be used in hybrid seed production and genetical studies or for the preservation of variability.

**(b) Cytoplasmic male sterility**

It occurs due to the mutation of mitochondria or to due to some other cytoplasmic factors outside the nucleus, resulting in the transformation of the fertile cytoplasm into a sterile one. Nuclear genes are not involved. Further, with two types of cytoplasm i.e. sterile and fertile, at the most, only two kinds of genotypes are possible, one of them is sterile and another fertile. The fertile cytoplasm is denoted by (F – B Line) and sterile cytoplasm is denoted by (f – A line).

**Sterility maintenance**

Due to two different types of genotypes, cytoplasmic sterility can be maintained as under:

**Fertility restoration**

Since there is no third type of genotype which can act as R-line, as such restoration of fertility is not feasible. However, this does not exhaust all the possibilities of use of cytoplasmic sterile lines.

**Uses**

As restoration is not possible, this type of sterility is useful only in crops where the seed is not the desired end product. This is important for horticultural crops where vegetative parts are of economic value.

**(c) Cytoplasmic-geneic male sterility**

Such sterility arises from the interaction of nuclear gene(s) and conditioning sterility with sterile cytoplasm. The cytoplasmi-geneic sterility is essentially a cytoplasmic sterility with a provision for restoration of fertility. The fertility is restored by (R) gene present in the nucleus. The combination of both nuclear gene(s) and

cytoplasmic factors determine the fertility or sterility in such plants. Based on these combinations, there can be maximum of six types of genotypes and only one of them is sterile.

**Sterility maintenance**

As visualized by their genetic composition and cytoplasm, only [(rr) f] genotype can maintain the sterility of A-line.

**Fertility restoration**

This is achieved by suitable restorer lines which can give rise to all fertile progenies on crossing with A-line. Among the possible six genotypes, only [(RR) F] and [(RR) r] are such restorer or R-line. They produce all fertile progenies.

**Uses**

Cytoplasmic-genetic male sterile lines are of immense importance in exploitation of hybrid vigour in crops where seed is the desired end product.

## Questions

1. Incompatibility is generally controlled by a special gene is known as S-locus.
   **Ans: True**
2. Gametophytic self incompatibility pollen is binucleate.
   **Ans: True**
3. Pineapple is an example for gametophytic self incompatibility.
   **Ans: True**
4. Stigma is covered with hydrated layer of proteins is known as Pellicle.
   **Ans: True**
5. The incompatibility reaction of pollen is due to deposition of some compounds from anther tapetum on to the pollen exine.
   **Ans: True**

## Lecture.6

## Apomixis – merits and demerits, types

### Apomixis

Apomixis refers to the occurrence of an asexual reproductive process in the place of normal sexual processes involving reduction division and fertilization. In other words, apomixis is a type of reproduction in which sexual organs of related structures take part but seeds are formed without union of gametes. Seeds formed in this way are of vegetative in origin. When apomixis is the only method of reproduction in a plant species, it is known as obligate apomixes. On the other hand, if gameic and apomictic reproductions occur in the same plant, it is known as facultative apomixes. The first discovery of this phenomenon is credited to Leuwenhock as early as in 1719 in Citrus seeds.

Apomixis is widely distributed among higher plants. More than 300 species belonging to 35 families are apomictic. It is most common in Gramineae, Compositae, Rosaceae and Rutaceae.

### Classification of Apomixis

### Recurrent apomixis

The embryo sac (female gametophyte) develops from the megaspore mother cell whether meiosis is disturbed (sporogenesis failed) or from adjoining cell (megaspore mother cell disintegrates). The egg cell is diploid and embryo develops directly from the diploid egg cell without fertilization. Generally, somatic apospory, diploid parthernogenesis and diploid apogamy fall under recurrent apomixis.

Example: *Rubus sp.* (Raspberry), *Malus hupehensis, Malus sikkimensis, Malus sargenti and Malus toringoides* (Mitra (1991), Vashishtha *et al.,* (2004))

**Non-recurrent apomixis**

The development of embryo takes place from haploid egg cell without fertilization. Such type of apomixis rarely occurs. Generative apospory, haploid parthenogenesis, haploid apogamy and androgamy fall under this category.

**Adventive embryony**

This is also known as nucellar embryony or polyembryony. In this case more than one embryo develops in a single seed. In the seed both types of embryo develops i.e. nucellar embryo from nucellar cell and zygotic embryo from egg cell with the result of syngamy.

Example: Mango cvs. Olour, Goa, Kurukkan, Bappakai, Vellaikolamban, Nileswar Dwarf, Salem, Bellary, Goakasargod, Mazagaon, Chandrakaran etc. (Majumder and Sharma,1991) and most of the species of citrus except *Citrus medica* (citron), *Citrus grandis* (Pummelo or Shaddock) and *Citrus latifolia* (Ghosh, 1991, Vashishtha *et al,*2004.)

**Vegetative apomixis**

This is not common in fruit crops. However, in some cases like *Poa bulbosa* and some Allium, Agave and grass species vegetative buds or bulbils are produced instead of flower in the inflorescence.

**Development of apomictic embryo sac**

**Apospory**

It involves the development of embryo sac either from the archesporial cell or from the nucellus, or from other cell. It is of two types:

**(i) Generative or haploid apospory:** If the embryo sac develops from one of the megaspores (n), the process is called generative or haploid apospory. Since it cannot regenerate, as it is haploid and fertilization fails, the process gives rise to non-recurrent apomicts.

**(ii) Somatic or diploid apospory**: When diploid embryo sac is formed from nucellus or other cells, the process is termed as somatic or diploid apospory. Since it regenerates without fertilization, it is recurrent.

**Parthenogenesis**

It can be defined as development of embryo from egg cell with or without pollination but without fertilization. Depending upon the ploidy levels of egg cell, parthenogenesis can be haploid (non-recurrent) or diploid (recurrent type) e.g. Mangosteen (*Garcinia mangostana*).

**Apogamy**

Development of embryo from synergids or antipodal cells within the embryo sac with or without pollination but without fertilization is termed as apogamy. This type of apomixis is also grouped into haploid and diploid apogamy depending upon the ploidy level of cell. Diploid apogamy is recurrent type whereas, haploid aopgamy is non-recurrent type.

**Androgamy**

Development of the embryo from male gametes inside or outside the embryo sac is known as androgamy. Since the cells are haploid in nature they, come under non recurrent type.

**Genetics of apomixis**

Stebbins (1958) stated that as a rule, the apomictic condition is recessive to sexuality, although polyploidy apomicts show tendency towards dominance. However, this recessiveness is not usually due to a monogenic difference. Since there is frequent reversion of apomicts to normal sexuality or sterility or the occurrence of some abnormal genetic behavior in crosses involving an apomictic and an amphimict increases involving or two apomicts of diverse origins, it appears that a successful apomictic cycle is the result of an interaction of many genes which tend to break on hybridization. It is only in the relatively simple type of apomixis like adventive

embryony and vegetative reproduction that simple genetic behavior can be expected. Recently, Vardy *et al.* (1989) recorded three recessive genes with additive effects which are responsible for parthenocarpy.

**Advantages of apomixis in plant breeding**

Apomicts tend to conserve the genetic structure of their carrier and are also capable of maintaining the advantages of heterozygote generation after generation. Therefore, such a mechanism might offer a great advantage in plant breeding where genetic uniformity maintained over generation for homozygosity (in varieties of selfers), and heterozygosity (in hybrids of both selfers and out breeders) is the choicest goal. Additionally, apomixes may also affect an efficient exploitation of maternal influence, if any, reflecting in the resultant progenies, early or delayed because it causes perpetuation of the only maternal properties due to prohibition of fertilization. Maternal effects are most common in horticultural crops, particularly fruit trees and ornamental plants.

**Exploitation of apomixis in crop improvement**

For exploiting the apomixes in sexual crops, the apomictic phenomenon occurring spontaneously in any plant needs to be detected or identified. The artificial incorporation could be perhaps through hybridization between apomixes and amphimicts**.**

**Detection of apomixis**

Positive evidence for the presence or absence of apomixis are obtained only from an intensive screening of a large number of plant varieties / hybrids. The screening involves a careful and systematic tracing of steps for the development of embryosac and embryo, through microtomy of ovule, right from megaspores to embryonic development. Therefore, it is the most tedious job requiring patience and persistence.

It should however, be noted that it is only the recurrent apomixis, namely diploid forms of apospory/parthenogenesis/apogamy/adventitive embryony and the vegetative propagation which are beneficial for plant breeding purposes. The simple reason being that it is these diploid forms, which produce viable diploids without fertilization and thus

can continue to perpetuate truly over generations. Non-recurrent apomixis is of academic importance only.

**Maintenance and transfer of apomixis**

Once an apomict plant is detected, its inheritance pattern may be studied through crossing a few sample flowers with the pollen obtained from normal plants and observing the segregation pattern in $F_2$ and subsequent generations. The remaining flowers may thoroughly be checked and seeds collected on maturity. The true apomictic plant will automatically produce mother apomictic progenies, which can be maintained without difficulty.

In respect of transfer of apomixis, substantial evidence is available for the hybrid origin of many of the apomicts. Nevertheless, there is no evidence at all the hybridization by itself can induce apomixis. Situation is further aggravated by the unstable nature of apomicts since there is every like hood of the breaking down of interacting gene complexes conditioning apomixis. Therefore, possibilities of introducing apomixis in non-apomicts are the least but not totally absent.

**Questions**

**1.** Asexual reproductive process is known as apomixes.

**Ans: True**

2. Rosebery fruit is an example for recurrent apomixes.

**Ans: True**

3. The development of embryo takes place from haploid egg cell without fertilization is known as Non-recurrent apomixes.

**Ans: True**

4. Development of the embryo from male gametes inside or outside of embryo sac is known as Androgamy.

**Ans: True**

5. More than one embryo develops in a single seed is known as Adventive embryony.

**Ans:True**

6. Development of embryo from synergids or antipodal cells within the embryo sac is known as **Apogamy.**

**Ans: True**

7. What are the types of apomixes?

## Lecture.7

## Variability, Germplasm and Its Significances

India is the home for important fruit species *Artocarpus heterophyllus, Citrus indica, c.latipes, Feronia limonia, Garcinia indica, Manilkara hexandra. Mangifera indica, Musa species (AB, AAB group), Syzygium cumini and Zizyphus mauritiana (Arora, 1987).* The Hindustan centre is one of the 8 to 12 regions of genetic diversity (Vavilov, 1949/1950) having linkage/contiguity with Central Asian, Indo-Chinese-Indonesian and Chinese – Japanese regions. As many as 190 species of economic importance are indigenous to the Indian gene centre of which 109 are fruits (Arora and Nayar, 1984).

Considerable genetic material came from the Mediterranean, African, tropical American and temperate regions and quite a few of these have become commercially important. Several of these introductions are useful for improving productivity and quality and for inducing resistance against biotic and abiotic stresses in the indigenous commercial cultivars and for use as rootstocks and pollinizers. Thus, in the past, activities concerning germplasm introduction, collection and utilization occurred as an adjunct to changes in historical and demographic events and were never followed as systematic pursuits. A few efforts to conserve the germplasm resources, e.g. *Lakha Bagh* established by Akbar at Darbhanga and gardens established during the British rule, at Saharanpur, Pune and Howrah in the plains and at Chaubattia in the hills, were also made owing to the fancy of the ex-rulers, nonetheless these proved very rewarding. Genetic resources activities got a boost with the establishment of a Plant Introduction Division in the Indian Agricultural Research. The ICAR Institutes particularly the Indian Agricultural Research Institute, New Delhi, Indian Institute of Horticultural Research, Bangalore and the Central Institute of Horticulture for Northern Plains, Lucknow and the State Agricultural Universities have also contributed greatly

### Variability

### Variability in regions

Although there are nine phytogeographical regions in India, twenty-nine centres of endemism have been recognised. These are: (i) Agasthyamalai hills in

South Kerala and Tamil Nadu, (ii) Idduki-Sulahsiri forests, (iii) Anamalais, (iv) Nilgiris, (v) Agumbe-Phonde, (vi) Mahabaleshwar, (vii) Ratnagiri and Colaba, (viii) Saurashtra- Kutch, (ix) Tirupati-Cuddappa, (x) Nallamalais, (xi)Vizagapatnam hills, (xii) Bastar and Koraput hills, (xiiii) Similipal and Jeypore hill forests, (xiv) Chotangpur plateau, (xv) Panchmarhi-Satpura ranges, (xvi) Marathwada, (xvii) Bundelkhand, (xviiii) Aravalli, (xix) Ladakh, (xx) Valley of Flowers and Kedarnath, (xxi) The Nandaevi, (xxii) Sikkim Himalayas, (xxiiii) Lalichopri, (xxiv) Namdapha, (xxv) Tura-Khasia range, (xxvi) Nagaland-Manipur-Mizoram (Lushai hills), (xxvii)North Andamans, (xxviiii) South Andamans and (xxix) the Great Nicobar Islands. These centres fall into four broad regions of genetic diversity, i.e., North-Eastern region, Western and Eastern Ghats, Western Himalayas, northern and Indo-Gangetic Plains. Rich diversity in the North-Eastern region occurs in citrus, mango and banana (Arora and Nayar, 1984: Ghosh, 1984).

**Variability in Fruits**

Several fruit species of at least 20 genera, such *as Artocarpus, Carissa, Citrus, Diospyros, Emblica, Ficus, Grewia, Juglans, Mangifera, Musa, Morus, Prunus, Punica, Pyrus, Ribes, Rubus, Syzygium, Vitis and Zizyphus* offer great variability in India

**Banana**

Maximum genetic variability of *Musa acuminata* and *M .balbisiana* occur in North-East India. *M. flaviflora* is localized to Manipur and Meghalaya. There are several other species in North Bengal, Sikkim, Khasi hills and on Western Ghats which need systematic collection and conservation.

**Citrus**

Being the home of several Citrus species, rich genetic diversity occurs in the North-Eastern, North-Western and Southern regions, the maximum concentration being in the North-Eastern region. Bhattacharya and Dutta (1956) described 17 Citrus species, their 52 cultivars and a few probable natural hybrids from this region. In rough lemon alone, as many as 32 strains are available. The species, *C.limon, C. medica, C.jambhiri, C.ichangensis, C.latipes, C.macroptera, C.assamensis, C. Indica*

and *C.aurantium* are considered indigenous to this region. The Indian wild orange, *C.indica*, is found in the Naga hills (near Dimapur), Garo hills of Meghalaya and Kaziranga forests in Assam.

**Grape**

There is lot of indigenous germplasm of grape in India. Hooker (1875), in Flora of British India, mentioned as many as 75 species of Vitis in India. Hayes (1975) mentioned four species occurring in the foothills of Himalayas from Kashmir to Burma which give edible fruits. Wild species of grape are also available in the khandala hills near Pune on Western Ghats. Andamans, Chotanagpur Plateau, Jammu and Himachal Pradesh (Kinnaur) are also considered prominent variability centres.

**Mango**

Rich variability in mango is present all over the country. Wild forms of *Mangifera indica* have existed in peninsular tract, evergreen forests, North-East region and in Terai ranges. Tribal areas at the junctions of Madhya Pradesh, Andhra Pradesh and Orissa. Madhya Pradesh, Gujarat and Rajasthan; and South Tamil Nadu and Kerala are some prominent centres. Some *Mangifera* species are native to North-East India, Tripura, Manipur, Mizoram, South Assam, Chotanagpur Plateau, Rajmahal hills and Andamans. Wild forms of *M.indica* and its allied species *M.sylvatica* occur in the forests of North-East region. The fossil leaf impressions of *M. pentandra* have been recovered in Assam. Mukherjee (1985) has reported that at least six out of 41 *Mangifera* speices are native to India.

**Other Fruits**

There is a lot of variability in several other fruits all over the country. Several speices of ber are found in Peninsular tract, Western and Eastern Ghats; *Phoenix* and *Ficus* species in North-Eastern region; Indian gooseberry in Northern subtropical plains; tamarind in Tamil Nadu, Karnataka and Andhra Pradesh; custard apple in Andhra Pradesh; date palm in Kachchh; jackfruit in Eastern and Southern India; and pome and stone fruits in temperate region.

In temperate region, *Amygdalus, Carya, Castanea, Corylus, Cotoneaster, Cydonia, Docynia, Juglans, Malus, Persea, Pistacia, Prunus* and *Pyrus* are available

(Chadha, 1978). In the North-Eastern region also, rich diversity occurs in *Pyrus, Rubus, Ribes and Prunus* (Kaul, 1987). The Shillong plateau of Khasi hills in Meghalaya has many *Prunus* species, such as *P.nepalensis, P.undulata* and *P.cerasoides.*

A rich wealth of 17 wild and less known species of edible fruits exists in India out of a total of 337 species in the world

**Germpalsm collection and its significance**

The plant genetic resources constitute a reservoir of genes and gene complexes and are the raw materials for improvement of horticultural crops. The richness of species and genetic diversity in horticultural crops provided many opportunities, which can be achieved with adoption of more rational, science based and pragmatic approaches. There has been a significant progress in collection, conservation and utilization of genetic resources of horticultural crops. The concerted efforts made in past have yielded results and large number of varieties.

Surveys to collect elite germplasm for genetic improvement of fruit crops by the Institutions is primarily confined to their respective areas of operation. However, these attempts have been mostly sporadic. Surveys to exploit the indigenous diversity has now been realised particularly because of the threat of genetic erosion. In India, it is estimated that 10 per cent of about 5000 endemic flowering plant species, i.e. 1700 species, are so threatened (Nayar, 1987). The National Bureau of Plant Genetic Resources organised crop-specific explorations with inter-institutional collaboration in pre-identified regions known to have rich diversity.

**Banana**

India harbours a great diversity in banana and plantain which can cater to any need, be it for fruit industry, vegetable industry, flower industry or even leaf Industry. They form a market worth several billions across the globe. With systematic efforts on understanding their specific utilities, many of the lesser known varieties, especially the land races can be exploited. The real strength of the country lies not only in exploiting the commercial varieties, but also in thinking differently and exploiting the untapped potential of this crop. Seeded landraces Ladiarit, Ladison, Rigitchi and other

elite types Hatigola, Eboke, Ginde, Egitchi and Essing from Meghalaya landraces mostly belonging to balbisiana (BB group) having resistance to drought cold and frost, *M.cheesmani* and M. v*elutina*, from Arunachal Pradesh, banana varieties Kulprit, Safri, Anatur and Dingamanika from Cachar and Jaintia hills and landraces Palayakodan, Kallur, Nayoodyan, Koombodiayan, Annarkanan and Katu from North Kerala and Betta-bale, Putta – bale, Karibale, Bergi-bale, Sungathi-bale, Rasa-bale, Pachcha-bale, Gujar-bale and Raja-bale from Karnataka have been reported.

**Citrus**

The number of Citrus accessions worldwide is listed to be 6000 inclusive of wild species, old cultivars, advanced cultivars, and breeding lines. Globally a total of 33 genera and 224 species of Citrus and its wild relatives (**Aurantioides subfamily**) are reported which can be used for its improvement. Citrus and its relatives of subfamily Aurantioideae are considered native of South-east Asia, North-east India, South China and North Myanmar have been acclaimed to the primitive centres of origin of contemporary *Citrus* species. The genus *Eremocitrus* and *Microcitrus* are found in Australia, *Clymenia* in New Guinea, *Poncirus* and *Fortunella* distributed in China and genus Citrus distributed in India, China, Myanmar and Malaysia. In India, Citrus types Mimangnarang, Chinora and Sohkwit of *C.macroptera*, Sohsyng of *C.assamensis*, Sohkhyllah (a natural hybrid), Sohmyngor of *C.grandis* and Sohsien, a vermillion coloured *C.reticulata* from Meghalaya (Anon., 1986), wild types resembling pummelo, orange, lemon and limes such as Rebab, Tahi, Tanyum, Sohmiag, Riang, Pinch-Tasing, Pinchipunia, Sikiang-Tasing Sipa-egra from Arunachal Pradesh (Anon., 1987) were found to occur.

**Jackfruit**

Jackfruit types Varikka, Kooza, Navarikka/Pazam Varikka, Rudrakshachakka or Thamarachakkal (Kooza + Varikka) and other wild forms have been collected from Wynaad Plateau in Western Ghats of Kerala. Three types, Rasdar, Khajwa and Sugandhi were identified in the plains of eastern UP.

**Mango**

From Orissa, regular bearing Paushia, scented Haldibas, bunch bearing Seetabhog, flavoured Topisundari, Baunia, Karpurkeli, other elite types Belgaja, Theki, Chanamunda, Mahorajpasand, Manda, Sagarlangra types having bright coloured fruits such as Lal Sundari, Sinduri, Beta Sundari, Goba Sundari, Sundarimath and Ashokgaja; types having good taste, such as Swarnalata, Chandrama and Sasgulla; and Khoja, having fruits with long shelf life , potential commercial cultivars Agna-Kosha, Sunehari Udyan Sundari, Lahsun, Kachhaswadi, Dahipatti and Lungagudi; and rootstock types Thurri and Gurudi have been collected. A dwarf and late maturing mango cultivar, Moreh, collected from Manipur bears very sweet fruits with high pulp content within two years after planting and is free from stone weevil (Anon., 1989-90). Promising types Ladankoo, Heer, Anphus, Meenakshi, Avadh-ki-Shaam, Makhsoos, Jalmorni, Shareefa, Dilpasand, Nashpati, Kakran, Pukhraj, Sharbati, Bagrain, Sahib Pasand and a pickling mango bearing 25-40 fruits in a cluster have been selected from the variability existing in western UP

**Other Fruits**

Some wild edible temperate fruits such as *Sorbus cuspidata, Malus baccata, Pyrus pashia, Prunus cornuta, Punica granatum, Juglans regia and Ribes himalense* from Kumaon hills *walnut, hazel nut, P.cornuta*, apple, pear*, Rosa sp*., *Crataegus*, *Rubus* and *Corylus colurna from Pangi variety* and *Elaegnus, Prunus, Docynia* and *Pyrus* from khasi hills in Meghalaya have been collected.

**Questions**

1. Grape fruits are native to India.

   **Ans:False**
2. Maximum genetic variability of *Musa acuminata* and *M .balbisiana* occur in South-East India.

   **Ans:False**
3. Balbisiana (BB group) having resistance to drought and cold and frost.

   **Ans:True**
4. There are nine regions in phytogas graphical India.

   **Ans: True**

## Lecture.8

## Breeding strategies - clonal selection

### Clone

A clone is a group of plants produced exclusively from a single individual plant through asexual reproduction. Most of the fruit plants are propagated asexually which consist of large number of clones that is why these plants are known as a group of plants derived from a single plant by vegetative means. In other words all the vegetative progenies of a single plant make a clone.

### Characteristics

- Clones are stable- They retain their original traits just like pure line variety
- Theoretically clones are immortal i.e. A clone can be maintained indefinitely by asexual reproduction. However, these are very much susceptible to diseases or insect pests depending upon the species and cultivars.
- Homogeneous-Individual plant of a clone is a mitotic derivative of the same plant and therefore homogeneity in phenotype is the major feature of clones. A group of individual plants derived from the same tissue of the original mother plant carries the same genotype. Phenotypic variation if any in clones is due to environmental impact.
- Continuous inbreeding of clones which are heterozygous might lead to severe loss in vigour
- The phenotype of a clone is due to effect of gene (G), environment (E) and GxE interaction over the population mean (h). Therefore P=h+G+E+GE
- Clones are maintained by asexual reproduction, but pure lines and inbreds are maintained by self-pollination or close inbreeding

**Genetic variation within clones**

Genetic variation within clones may be due to mutation, mechanical mixture and sexual reproduction.

**a. Mutation**

Somatic mutations are also known as bud mutations. The frequency of mutations is generally very low. A mutant allele would be homozygous only when (i) both the alleles in the cell mutate at the same time producing the same mutant allele, or (ii) the mutant allele is already in the heterozygous condition in the original clone. Dominant bud mutations express themselves more frequently than the recessive ones, as recessive mutation get expressed only under homozygous conditions. Bud mutations often produce chimeras, i.e., individuals containing cells of two or more genotypes. However, it is not a great problem because normal plants, i.e., non chimeras, may be produced from chimeras by several techniques.

**b. Mechanical mixture**

Mechanical mixture produces genetic variation within a clone, similar to the manner as seen in pure lines.

**c. Sexual reproduction**

Occasional sexual reproduction leads to segregation and recombination. The seedlings obtained from sexual reproduction are genotypically different from the asexual progeny.

**Clonal degeneration**

The loss in vigour and productivity of clones with the passing of time is known as clonal degeneration and it may be due to mutation and infection of virus and bacteria.

**Clonal selection**

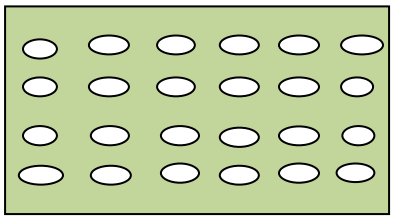
The phenotypic value of a plant or a clone is due to its genotype (G), the environment (E) and the genotype x environment interaction (GE). Of these, only the G

effects are heritable and stable. Therefore, a selection for quantitative characters based on single plant observation may not hold good.

A selection for polygenic characters like yield on the basis of unreplicated clonal plots would also often be misleading and unreliable. The value of clone can be reliably estimated only through replicated yield trials. However, selection for highly heritable characters, such as plant height, days to flowering, colour, disease resistance, etc., is easy and effective even on the basis of single plant or plot.

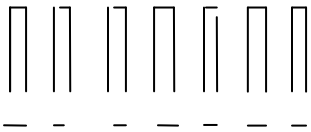
The various steps involved in clonal selection are briefly described below and are depicted.

I year



Select plants of superior clones

II year separately



Evaluate selected clones

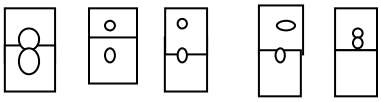
select desirable clones

III year

Preliminary yield trial with

suitable check and selected outstanding clones.

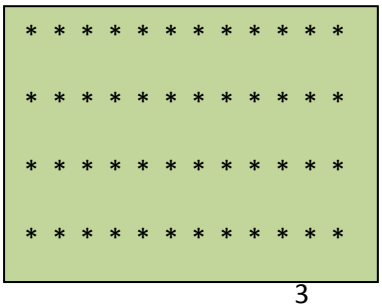
IV year to VIII year



Multilocation trial with Standard checks and

Release of superior clones as new varieties

IX Year



Superior and outstanding clone released as new Variety, Large scale multiplication

**First year**: From a mixed variable population, a few hundred to few thousand desirable plans are selected. A rigid selection can be done for simply inherited characters with high heritability. Plants with obvious weakness are eliminated. In fruit plants, it is difficult to get large number of individual selections. In such case, few plants may be selected.

**Second Year**: Clones from the selected plants are grown separately, generally without replication. This is because of the limitation in propagation material in each clone, and also because of the large number of clones involved. The characteristics of clones will be clear now than in the previous generation when the observations were based on single plant. The inferior clones are eliminated at this stage. The selection is based on visual observation and on the breeder's judgment of the value of clones. Fifty to one hundred clones are selected on the basis of clonal characteristics.

**Third year**: Replicated preliminary yield trial is conducted. A suitable check is included for comparison. Few superior performing clones with desirable characteristics are selected for multi location trials. At this stage, selection for quality is done. If necessary, separate disease nurseries may be planted to evaluate disease resistance of the selected clones.

**Fourth to Seventh years**: Replicated yield trials are conducted at several locations along with a suitable check. The yielding ability, quality and disease resistance etc. of the clones are rigidly evaluated. The best clones that are superior to the check in one or more characteristics are identified for release as varieties.

**Nineteenth year**: The superior clones are multiplied and released as varieties.

## Advantages

i) Clonal selection is an easy and less time consuming method.
ii) Easy maintenance because there is no problem of out crossing and loss of seed viability. Variation occurs due to somatic mutation only which can be managed by removal of undesired plants.
iii) Heterotic clones on selection may be used as permanent hybrids. Heterosis can be exploited for longer time without production of hybrid seed every year (for vegetatively propagated vegetable crops).
iv) Clonal selection is the only method of breeding in vegetatively propagated fruit plants.

## Limitations

- There is limited chance of getting new and useful type of variability
- The multiplication rate is low.
- It is only useful for vegetatively propagated plants.

### Hybridization between clones

Generally, clonal crops are cross-pollinated and they may show self incompatibility. The selected parents may be used to produce single crosses involving two parents or an equivalent of a polycross involving more than two parents (rubber).

**Selection among $F_1$ families**: When the breeding value of parents is not known, and when the relative contribution of general combining ability and specific combining ability is not available, then a large number of crosses have to be made in order to ensure that at least some of the crosses would produce outstanding progenies in $F_1$. This is particularly true in a species where crop improvement has not been done or has been done at a small scale. In such cases, it would be cumbersome to evaluate a large number of $F_1$ progenies generally in detail. To avoid this, small samples of several $F_1$ populations are generally grown. The general value of individual F1 families or populations is estimated noted. Inferior families are eliminated. Promising families with outstanding individuals are then grown at a much larger scale for selection. The procedure is designed to save time, space and labor by planting only small populations of a large number of crosses at the preliminary stage.

**Selection within $F_1$ families**: The selection procedure within $F_1$ families is essentially the same as that in the case of clonal selection.

But in the case of fruit and plantation crops like cashew, it is difficult to follow the above steps. In these perennial crops, the steps given below may be followed:

**Step I:** Select two parents of desirable characters and hybridize them to produce sufficient crossed fruits.

**Step II:** Raise the $F_1$ seedling populations and evaluate the individual progenies for yield and quality.

**Step III**: Select few superior progenies and propagate them vegetatively to produce grafts/budding on standard rootstocks.

**Step IV**: Evaluate the selected clonal seedling progenies (in sufficient number / clone usually minimum of 5-10) along with the parents and standard varieties.

**Step V**: Outstanding clones may be released as new variety.

As step I to V take at least 20-25 years, some breeders avoid step I and IV. Instead, best performing $F_1$ progenies are assessed and the scion collected from them is multiplied as grafts / budlings for further use as next varieties.

**Achievements**

Clone No.51 from Dashehari, MA-1 from Alphanso, Tommy Atkin from Haden. Pusa Surya from Elden in mango, Pusa Seedless from Thompson Seedless of grape etc.

## Questions

1. Clone is a group of plants produced from a single individual plant through asexual reproduction.
   **Ans:True**
2. Clones are maintained by asexual reproduction.
   **Ans:True**
3. Somatic mutations are also known as bud mutations.
   **Ans:True**
4. The loss in vigour and productivity of clones with the passing of time is known as clonal degeneration.
   **Ans:True**
5. The seedlings obtained from sexual reproduction are genotypically uniform from the asexual progeny.
   **Ans:False**
6. Sudden heritable change in the genotype of an organism is termed as mutation.
   **Ans:True**

7. What are the types of mutation?
8. Mutated individual is called as a mutant.

   **Ans:True**
9. What are the different kind of mutations?
10. Micro mutations are more important for direct use in plant breeding.

    **Ans: True**
11. A group of changes at individual loci (point) is called as Point mutation.

    **Ans:True**

## Lecture.9

## Breeding strategies - bud mutations and chimeras

### Bud mutations

If mutation occurs in any one of the actively dividing meristematic tissues, the branch arising from them, expresses the mutant character if it is dominant and this phenomenon is known as *bud mutation* .Though mutation is most frequent at maturation divisions, it may also arise in somatic cells. If mutation occurs in cells from which buds are developed, the later are genetically different from the rest of the plant. These are termed “bud mutation” or “sports”. The frequency of such mutations is very low to be of any economic importance, which is also different in different species. The bud mutation may arise through (1) gene mutation or (2) chromosomal variation. Bud variations have been noted in sugarcane. This was first noted by Lorzier in Mauritius in 1869.

Other instances of sporting are Ribbon canes of Australia, Truna canes of Mauritius and Tip canes of Hawaii which are found to throw bud variations. Barber (1906) noted bud sports in the sugarcane at Samalkota. Striped-Mauritius often sported into green canes and less often into red types. The bud sports not only varied in the colours on rind but also in some of the agricultural characters. Bud sports are frequent in ornamental plants and many new garden varieties have been established by selection of such sports. Economic types from bud sports in the case of field crops are rare. Though bud sports have been noted in crops like potato, they have not been found to be of economic type. Superior varieties in citrus have been evolved by selecting bud mutant. It is reported that in 18 years prior to 1937, about 10 million buds of varieties which originated by bud mutation have been sold in California alone. Robertson Navel orange and Dawn grape fruit are some notable examples of new varieties arising through bud mutation.

**Somatic mutations**

These mutations occur in tissues other than the germ track. Most mutations occur somatically, i.e., after the differentiation has set in, when a group of somatic cells is genotypically different from the other cells in the same individual, a somatic mutation may be suspected. The change occurs in the cells of the growing body. Hence the new types of cells are not only heterozygous but form a patch. In meristematic tissues of axillary buds and others a mutation often leads to a batch with new characters. Such changes occur more frequently in polyploidy and heterozygous plants and in individuals which have been grown for long as clones. If propagated vegetatively the mutated parts give rise to new types of plants. This practice is common in horticulture.

The brown colour of the grain in sorghum in some cases is determined by the persistence of the integument in which, the colour is deposited. Often mutant patches of white occur in individual grains of panicles from homozygous brown grained line. Anatomical studies have shown the suppression of the integument in such places where the white patch appears and genetical studies have shown that this is only affecting the somatic tissue and does not affect the germinal tissues. White grain colour is recessive to brown. In *Cosmos sulphureus,* plants with yellow petals have often been observed to appear suddenly; the usual one has orange-yellow coloured petals. Sometimes the region affected is half the head and, in such cases, in the progeny, plants with all yellow flowers have appeared. These have bred true. Somatic mutations have been recorded in vegetatively propagated plants like apples, dahlias, chrysanthemum, potato, rose, etc.

**Chimeras**

A chimera is an individual with one genotype in some of its parts and another genotype in the others. Somatic mutation may often lead to chimeras. When propagated asexually these chimeras may become perpetual. Certain types of *Pelargoniums* and potatoes are of such chimeras. When growth is encouraged from the concealed tissues the real nature of these chimeras is revealed. Somatic mutations either at the terminal or axillary buds in germinating seeds, seedlings or in mature plants can be produced by irradiation or

chemical treatment. Artificial creations of such somatic mutations open possibilities of production of new horticultural and agricultural plants.

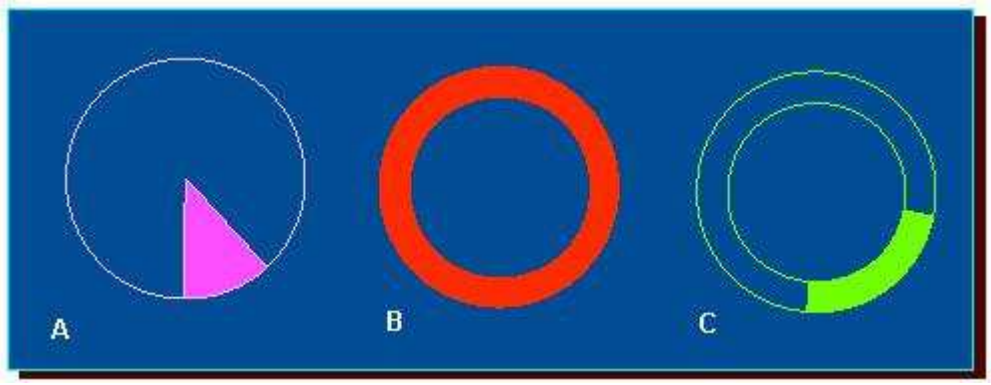
Treatment of seeds and vegetative propagules commonly produces chimeras.. Shoot tip meristem usually has two functional layers; the outer layer, giving rise to epidermis and a part of leaf mesophyll, and the inner layer producing the rest of the plant tissues including reproductive organs.

**Chimeras are of three kinds**

**Periclinal chimera**: When the entire outer or inner layer is affected, the chimera is known as 'periclinal chimera' (inner periclinal or outer periclinal depending upon the layer affected)

**Sectorial chimera**: Only a part of the inner or the outer layer is affected (inner sectorial chimera only a part of the inner or the outer layer is affected (inner sectorial and outer sectorial respectively).

**Mericlinal chimera**: In mericlinal chimeras, the combination is similar to the periclinal except that the cells carrying the mutant genes occupy only a part of the outer cell layer.




A: Sectorial chimera

B: Periclinal chimera

C: Mericlinal chimera

In sexually reproducing species, only the inner chimeras (periclinal or sectorial) will be transmitted to the next generation. Outer chimeras will not be recovered since this layer does not contribute to the production of gametes. In clonal crops, however, both outer and inner chimeras can be utilized either as periclinal chimeras (outer or inner) or by producing homogeneous individuals through sexual reproduction (only if the inner layer is affected), tissue culture or other horticultural manipulations, e.g., wounding etc., which induce production of adventitious shoot buds (utilizing both inner and outer chimeras). Sectorial chimeras are unstable in clonal crops and have to be made periclinal through successive clonal propagation and selection for stability.

Mutant alleles are generally recessive, but some dominant mutations may also occur. In case of sexually reproducing crops, mutation breeding utilizes both recessive and dominant mutations. In dominant mutations, the phenotype can be recognized as a somatic mutation arising from the mutated cell, for example, a colour mutation in an epidermal cell from 'aa' (colourless) to 'Aa'. How ever, recessive mutations are much more numerous than dominant ones. Recessive mutation can occur in the homozygous dominant type as AA – Aa or in the heterozygote as Aa – aa. In the former one, the selfed progeny normally segregate with 25 per cent recessive mutatnt 'aa' types.

Mutation breeding in clonally propagated crops primarily depends on dominant mutation. Recessive mutation may also be utilized provided the clone used for mutagen treatment was heterozygous; for example, if recessive mutant allele is to be useful in a clonal crop, the clone has to have the genotype Aa. Such situations are however, rare. More frequently, the mutants useful in the improvement of clonal crops are dominant mutations.

## Questions

1. Chimera is an individual with one genotype in some of its parts and another genotype in the others.

   **Ans:True**

2. Treatment of seeds and vegetative propagules commonly produces chimeras.

   **Ans: True**

   **Match the following**

3. **Periclinal chimera** - entire outer or inner layer is affected
4. **Sectorial chimera** **-** part of the inner or the outer layer is affected
5. **Mericlinal chimera** **-** only a part of the outer cell layer is affected

## Lecture.10

## Breeding strategies –mutagenesis and its application

### Mutation

Sudden heritable change in the genotype of an organism is termed as mutation. It may be spontaneous (without any treatment by man) or induced (artificially induced by a treatment with certain physical or chemical agents) in plant population. The process through which mutants get induced is called mutation and the mutated individual is called a mutant. Mutants have variously been classified as spontaneous and induced, natural and artificial based on their origin; germinal and somatic based on the tissue involved; chromosomal, genic and cytoplasmic etc.

### Kind of mutations

Macro mutations are large mutations and can be recognized on a single plant basis, e.g., changes in colour, shape, etc., Micro mutations are mutations with small effects and can be recognized only when a group of 30 or more mutant plants are compared with a normal one. Micro mutants differ with normal only quantitatively; for example, mutants with larger or smaller grains or higher yield, etc., Micro mutations are more important for direct use in plant breeding.

Point mutation is another term often used to designate gene mutation but it comprises of group of changes at individual loci (point) including micro structural change, micro-deficiencies and gene mutation.

Somatic mutation refers to mutants appearing in vegetative part in M1 generation. It also refers to 'bud-sport' in the case of vegetatively propagated plants. This may occur either due to dominant mutation (aa $\longrightarrow$Aa), recessive mutation in a heterozygote (Aa $\longrightarrow$ aa), removal of epistatic factor of chromosomal aberrations.

**a. Spontaneous mutations**: These are naturally occurring mutations, which arise somatically. They arise in nature continuously without any human control and create

variability, which forms the basis of conventional crop breeding methods. Their frequency is extremely low (one in a million).

**b. Induced mutations**: Contrary to spontaneous mutations, these are induced by using various agents

Physical or chemical agents, which cause mutation, are known as mutagens or mutagenic agents.

**Procedure of mutation breeding**

When mutations are induced for crop improvement, the entire operation of induction and isolation of mutants is termed as mutation breeding. The various steps involved in mutation breeding are as under:

- Objectives of programme – Objective should be clear cut and well defined
- Selection of variety for mutagen treatment – Locally accepted best variety in which improvement is needed either in polygenic or monogenic trait.
- Part of plant to be treated- Seeds, pollen grains or vegetative propagules (buds and cuttings) may be used for mutagenesis. Selection of plant part for mutagenic treatments are based on mode of multiplication / reproduction. In sexually propagated fruit plants, seed treatment is common. Pollen grains may be used, but it has some limitations. It is difficult to collect large amount of pollen grains and pollen survival life is also short. In case of a sexually propagated fruit plant, buds or cuttings are used for mutagenic treatment.
- Dose of mutagen – An optimum dose is that one which produces the maximum frequency of mutation and causes the minimum killing i.e. LD 50. It is that dose of mutagen which would kill 50% of the treated individual. Dose of mutagen depends upon intensity and time of treatment.
- Mutagen treatment- Selected plant part is exposed to the desired mutagen dose. The plants are immediately planted to raise $M_1$ plant from them. In case of seed treatment they are pre-soaked for a few hours to initiate metabolic activities and then exposed to mutagen. Treated seeds are sown immediately in field to raise $M_1$

generation. The seeds derived from mutated pollen is considered as M1 and subsequent generations can be derived through selfing or clonal propagation.

**Handling of the Mutagen – Treated Population**

The following handling procedure is based on the selection for a recessive mutant allele.

i. ***$M_1$ generation*:** Several hundred (500 or more) seeds are treated with a mutagen and are space-planted. $M_1$ plants will be chimeras for the mutation present in heterozygous state. About 20 seeds from each $M_1$ plant are harvested to raise the $M_2$ progeny rows.

ii. ***$M_2$ generation***: About 2,000 progeny rows are grown. Careful and regular observations are made on the $M_2$ rows. But only distinct mutations are detected in $M_2$ because the observations are based on single plants. All the plants in $M_2$ rows suspected of containing new mutations are harvested separately to raise individual plant progenies in $M_3$. If the mutant is distinct, it is selected for multiplication and testing. However, most of the mutations will be useless for crop improvement. Only 1-3 per cent of $M_2$ rows may be expected to have beneficial mutations.

iii. ***$M_3$ generation***: Progeny rows from individual selected plants are grown in $M_3$. Poor and inferior mutant rows are eliminated. If the mutant progenies are homogeneous, two or more $M_3$ progenies containing the same mutation may be bulked. Mutant $M_3$ rows are harvested in bulk for a preliminary yield trial in $M_4$.

iv. ***$M_4$ generation***: A preliminary yield trial is conducted with a suitable check, and promising mutant lines are selected for replicated multi location trials.

v. ***$M_5$-$M_8$ generation***: Replicated multilocation yield trials are conducted. The outstanding line may be released as a new variety.

It may be noted that above procedure is recommended for all horticultural crops, which are exclusively propagated by sexual means.e.g.Vegetables, *Crossandra*, *Periwinkle etc.*

A detailed method to isolate stable solid mutants in vegetatively propagated horticultural plant is presented.

Mutation breeding scheme for the improvement of horticultural tree plants

| | **1st year** | **Generation** | **Activity** |
|---|---|---|---|
| A. | Initial explant | Shoot meristem (cutting, scion, rooted scion, etc) | Mutagen application x-rays (stabilipan 220V, 15 mA), or gamma rays ($^{90}$ Co), Chronic or acute to establish the suitable treatment dose, grafting, rooting etc. |
| B. | Occurrence of a chimeric situation (mericlinal, sectroial) in auxillary bud meristems. | Shoot growth ($M_1V_1$ generation) | Cutting back of the $M_1V_1$ shoot at the fourth basal node. Vegetative propagation of $M_1V_1$ buds (either from the basal or the median zone) |
| | **2nd Year** | | |
| C. | Occurrence of possible uniform periclinal parts (scion, branch, tree) | Shoot growth ($M_1V_2$) | Isolation of induced somatic mutation, vegetative propagation of the mutated $M_1V_2$ shoots.<br>Cutting back of the unmutated $M_1V_2$ shoots at the fifth basal node |
| | **3rd Year** | | |
| D. | Genetic uniformity achieved within the plants of a mutated clone | Mutant growth ($M_1V_2$) | Further isolation of somatic mutations and preliminary evaluation of the mutants.<br>Vegetative propagation of the mutated $M_1V_3$ shoots, normal pruning of the fruit trees. |
| | **4th – 9th year** | | |
| E. | Verification of the genetic stability of the mutant and the sexual transmission of induced somatic mutations | Vegetative growth and fruit bearing phases of the mutants | Evaluation of mutant's performance, vegetative propagation of the mutants for agronomic traits.<br>Crossing of the mutant, if possible, with other variety, followed by |

| | | | |
|---|---|---|---|
| | | | segregation. |
| **10th year** | | | |
| F. | Final assessment | $M_1$ $V_{10}$ generation of the mutants | Release of improved clones Registration and patenting of new variety,<br>Plant production in a nursery and certification. |

**General characteristics of mutation**

(i) Mutations are generally recessive but dominant mutations also occur.

(ii) Mutations are generally harmful to the organism.

(iii)Mutations are random.

(iv)Mutations are recurrent.

**(v)** Induced mutations commonly show pleiotrophy, often due to mutations in closely linked gene.

**Mutagens**

Agents used for induction of mutations, are known as mutagens. The different mutagens may be grouped as follows:

**A. Physical mutagens**

1. Ionizing radiations
   (a) Particulate radiations – α-rays, fast neutron, thermal neutrons.
   (b) Non-particulate radiations – X-rays, γ-rays.
2. Non ionizing radiation – Ultraviolet radiation.

**B. Chemical mutagens**

1. Alkylating agents – Sulphur mustard, mustard gas, EMS (Ethyl methane sulphonate), Ethylene Imine (EI)
2. Acridine dyes- acriflavin, proflavin, acridine orange, acridine yellow,ethedium bromide.

3. Base analogues – 5-bromouracil, 5-Chlorouracil.
4. Others – Nitric acid, hydroxyl amine.

**Achievements**

Mango – Rosica from Peruvian variety Rosadodelca

Papaya- Pusa Nanha from local type

Grape-Marvel Seedless from Delight

Banana- High gate from Gros Michel, Motta Poovan from Poovan

Orange-Washington Navel

Grapefruits – Marsh and Thompson

**Questions**

1. Sudden heritable change in the genotype of an organism is termed as mutation.
   **Ans:True**
2. The mutated individual is called a mutant.
   **Ans:True**
3. Large mutations which can be recognized on a single plant basis is known as Macro mutation.
   **Ans:True**
4. Agents used for induction of mutations, are known as mutagens.
   **Ans:True**

**Match the following**

5. Somatic mutation - mutants appearing in vegetative part
6. Point mutation - group of changes at individual loci (point)
7. Spontaneous mutations - naturally occurring mutations

## Lecture.11
## Breeding strategies - hybridization and problems associated with hybridization

### Hybridization

Hybridization refers to mating or crossing of two plants or lines of diverse genotypes to obtain a viable hybrid progeny. The seed as well as the progeny resulting from hybridization are known as 'hybrid' or $F_1$.

### Hybridization in self-pollinated crops

By planned hybridization between carefully selected parents, the breeder can create populations with sufficient variability from which plants combining the desirable features of the parents can be selected. Theoretically, all the plants of pure-line or a clone are of one genotype (i.e. they have identical genetic constitution). Therefore, when different pure-lines or clones are crossed, heritable variability is created by recombination. Selection in the segregating generations of a hybrid will therefore be effective.

### Objectives of hybridization

The purpose of hybridization is to combine in a single variety, the desirable characters of two or more lines, varieties or species. Occasionally, the recombination of genetic factors leads to the production of new and desirable characters not found in either of the parents. When two parents are crossed, the resultant $F_1$ is a homogeneous one but is heterozygous in nature, hence all plants look similar phenotypically. When they are selfed to produce $F_2$ the population is heterogeneous and heterozygous. Hence, phenotypically many variations could be seen in this generation. Further, in this generation, a cross may frequently give rise to progenies which are beyond the range of the parents for a particular quantitative character such as height of plant, earliness, fruit size, yield etc. This phenomenon is often referred as "transgressive segregation". For example, the progenies may be taller than the taller parent or earlier than the earlier maturing parent. Such transgresive segregation may enable the breeder to attain his objective quickly.

**Types of hybridization**

**Inter-varietal hybridization**

The parents involved in hybridization belong to the same species. There may be two strains, varieties or races of the same species. It is also known as intraspecific hybridization. The intravarietal crosses may be simple or complex depending upon the number of parents involved.

a. **Simple cross:** In a simple cross, two parents are crossed to produce the $F_1$

A x B

↓

$F_1$

b. **Complex cross:** More than two parents are crossed to produce the hybrid.

Example

Three parent cross (A, B, C)

A x B

↓

(A B) x C

↓

(A B C) (Complete hybrid)

Four parents (A, B, C, D)

A x B C x D

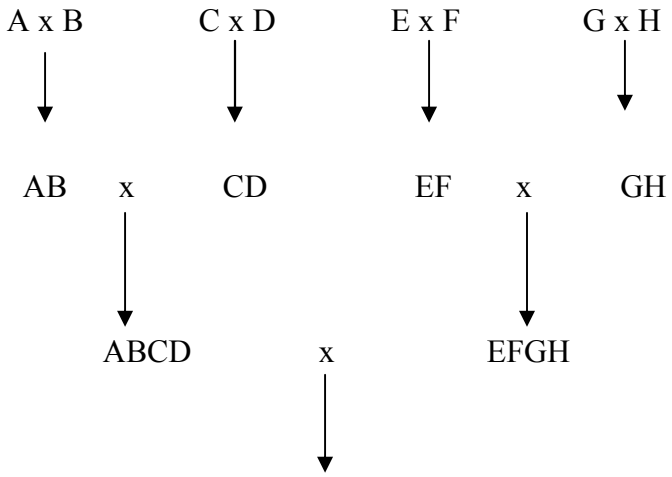
↓ ↓

(A B) x (C D)

↓

(A B C D)

Eight parents (A,B,C,D,E,F,G,H)




**Hybridization technique**

There are seven steps involved in hybridization.

**Choice of parents**

It mainly depends upon the objective of breeding programme. In addition to other objectives, increased yield is always an objective for the breeder.

**Evaluation of parents**

If the performance of parents used for breeding is known, evaluation is not necessary. But if their performance is not known, it should be evaluated, particularly for the characters to which they are expected to contribute.

**Emasculation**

The removal of the stamens or anthers or the killing of pollen grains of a flower without disturbing the female reproductive organs is known as emasculation. The purpose of emasculation is to prevent self fertilization in the flowers of female parent.

**Type of emasculation**

1. Hand emasculation
2. Suction emasculation
3. Hot water emasculation
4. Alcohol treatment
5. Cold treatment
6. Genetic emasculation e.g.male sterility

**Bagging**

Immediately after emasculation, the flowers of the inflorescence are closed in suitable bags of appropriate size to prevent random cross pollination.

**Tagging**

Emasculated flowers are tagged just after bagging. The following information is recorded on the tags with a carbon pencil:

1. Date of emasculation
2. Date of pollination
3. Name of the female and male parents. The name of female parent written first, and then the male parent

**Pollination**

Pollination refers to transferring the mature and fertile pollen from the male parent to the stigma of the female parent. This is done with the help of brush delicately with out disturbing the stigma and female flower.

The pollinated flower is enclosed in a butter –paper bag or muslin cloth bag to avoid contamination from outside pollen and labeled. Few days after pollination, when the fruitset is conspicuous, the bag is removed. The seeds extracted from such crossed fruits are the F0 seeds to raise F1 or hybrid plants.

**Selection procedures with hybridization**

Two selection procedures are commonly followed after hybridization to isolate the desirable genotypes from the segregating progeny.

1. **The pedigree method**: This is widely followed by the plant breeders now, who maintain a detailed record of relationships between the selected plants and their progenies. It consists of the selection of individuals plants with the desired combination of characters in the $F_2$ generation and reselection of the progenies of each selected $F_2$ plant in succeeding generations until genetic purity is reached.

2. **The bulk method**: This method differs from the pedigree method in that the hybrids are grown in bulk till the $F_5$ or $F_6$ generation. Desirable individual plants are selected only in the $F_5$ or $F_6$ generation and these are then carried forward as families, which are evaluated in the same way as in the case of pedigree method.

**Achievements**

| Fruit | Hybrids |
|---|---|
| Mango | Mallika, Amrapalli, Pusa Arunima, Arka Anmol, Arka Puneet, Arka Aruna, Arka Neelkiran, Ratna, Sindhu, PKM-1, PKM-2. |
| Guava | Arka Amulya, Safed Jam, Kohir Safed |
| Papaya | CO-3, CO-2 |
| Sapota | CO-1, DHS-1, DHS-2, Hybrid 214, Hybrid-711 |
| Banana | CO-1 |

**Questions**

1. Crossing of two plants or lines of diverse genotypes to obtain a viable hybrid is known as progeny hybridization.

   **Ans:True**

2. The progeny resulting from hybridization are known as 'hybrid' or $F_1$.

   **Ans:True**

3. The parents involved in hybridization belong to the same species is known as intraspecific hybridization.

   **Ans:True**

4. The removal of anther without disturbing the female reproductive organs is known as emasculation.

   **Ans:True**

5. Pollination is known as transferring the mature and fertile pollen from the male parent to the stigma of the female parent.

   **Ans:True**

6. Maintaining a detailed record of relationships between the selected plants and their progenies is known as pedigree method.

   **Ans:True**

## Lecture.12

## Resistance breeding for biotic abiotic stresses

A plant is said to be healthy or normal when it carries out its physiological functions to the best of its genetic potential. These normal functions include division, differentiation, and development. Absorption of water and minerals from soil and translocation of these throughout the plants, photosynthetic product to areas of utilization or storage, the metabolism of synthesized compounds, reproduction and storage of food supplies.

A plant becomes diseased when it is disturbed by pathogen under certain environmental conditions which interfere with one or more of its essential functions. Diseased plant refers to any disturbance brought about by living organism under environmental factors which interfere with normal function of plant or in other words when any organ and part of plant is not doing their work properly and when either the growth or reproduction is not going forward in natural or regular manner.

Breeding varieties/hybrids resistant to biotic stresses viz., pests, diseases and nematodes and abiotic stresses viz., drought, salinity and adverse climatic conditions like frost, chilling temperature are the primary objectives in any breeding programme.

**Advantages of resistant breeding**

1. Farmers can use resistant varieties without incurring any extra expenditure on plant protection chemicals.
2. It is a safe measure- fungicides and other pesticides leave some residual effect.
3. It is more effective as compared to other measures of disease and pest control.
4. In case of air borne diseases, it is impossible to cover larger area with any other means of
5. disease control.

## Concept of resistance breeding

Insects are usually specialized in their ability to attack the host or part of the host. An insect is capable of damaging or attacking every species of the host. The plant resistance includes those characters which enable a plant to avoid, tolerate or recover from the attack of insect under conditions that would cause greater injury to other plant of the same species.

Resistance is heritable characters possessed by the plant which influence the ultimate degree of damage done by the insect. In other words, plant resistance is defined as being the collective heritable character by which a plant species raise in groups or individually may reduce the probability of successful utilization of that plant or a host by an insect species, race, biotype or individuals. The degree of resistance is a relative term which is measured by using susceptible cultivar of same plant species as check. The degree of resistance among specific host plants may vary between two extremes i.e. immunity and high susceptibility. Any degree of host reaction less than immunity is resistance. In case of abiotic stress, the amino acids or enzymes connected with resistance or tolerance to drought, salinity and other factors will be identified and the plants possessing the desirable traits will be used as donors in breeding programmes.

## Breeding methods for biotic /abiotic stress resistance

### (i) Introduction

An introduced variety resistant to the concerned insect pest and diseases or abiotic stresses may be released for cultivation if it performs well in the new environment and is agronomically desirable. Thus, it is the quickest and perhaps, the earliest method of developing a biotic stress resistant variety. e.g. introduction of *Phylloxera vertifoliae* resistant grape rootstock from USA to France. Sometimes, the introduced variety may not perform well in the new environment and it may be susceptible to the biotypes of the concerned pest prevalent in the area or to a new insect pests and/or diseases of the area.

**(ii) Selection**

Biotic/abiotic stress resistant variants may be found in an existing variety of a crop. In such case, selection for insect and disease resistance is practised to isolate biotic stress resistant variety. Screening large number of germplasm for resistance at field level and further confirmation through artificial testing will help in selection of a resistant line which may be directly used as variety or used as donor for developing a hybrid

**(iii) Hybridization**

When the desired biotic/abiotic stress resistance is present in an agronomically inferior variety of the crop or in a related wild species, hybridization is the only course of action for the breeder e.g. breeding for fruit fly resistant variety in Ber (Vashishtha et al.,1997) However breeding in ber is difficult due to incompatibility, low fruit set etc.

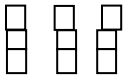
**Backcross Method of Breeding**

The backcross is a form of recurrent hybridization by which one or two desirable characteristics are added on to a superior variety, wherein the hybrids and the progenies in the subsequent generations are repeatedly back crossed to one of their parents. The object of back crossing is to transfer one or two desirable characteristics from an inferior variety to a superior variety, disturbing the genotype of the superior variety as little as possible in the process. Backcrossing is particularly well suited for the transfer of one or two simply inherited and easily recognized characters to a variety that excels in most of its characters.

In a back cross breeding programme, the genetic consequences of repeated back crossing must be understood. Repeated back crossing leads to rapid increase in homozygosity and in the frequency of homozygote's as that of selfing. The steps involved in back cross breeding depend upon the genetic nature of the gene to be transferred.

**The method of transfer of a dominant gene is summarized below:**

| | |
|---|---|
| NONRECURRENT X RECURRENT<br>PARENT A PARENT B | B is the disease resistant parent and A is the disease susceptible parent |
| **F** X RECURRENT PARENT A | Disease resistant plants in $F_1$ is backcrossed with recurrent parent (A) |
| **$BC_1$** X RECURRENT PARENT A | Disease resistant plants with similar characteristics as that of recurrent parent A are selected & again backcrossed with A. |
| **$BC_2$** x RECURRENT PARENT A | |
| **$BC_3$** X RECURRENT PARENT A | As in $BC_1$ generation |
| **$BC_4$** X RECURRENT PARENT A | As in $BC_1$ generation |
| **$BC_5$** X RECURRENT PARENT A | As in $BC_1$ generation |
| **$BC_6$** X RECURRENT PARENT A | |
| **$BC_6F_1$** x SELFED | Disease resistant plants self pollinated and seeds harvested separately. |
| **$BC_6F_2$** **111111111111** | Individual plant progenies grown, selection for disease resistance and plant type similar to parent 'A' |

| | |
|---|---|
| | made.* |
|  | Individual plant progenies grown, homozygous progenies similar to parent 'A' harvested and bulked. |
| \| \| \| \| \| \| \| \| \| | Replicated yield trial with parent 'A' as one of the check. |
| --- --- --- --- ---<br>--- --- --- --- ---<br>--- --- --- --- --- | Seed multiplication for distribution. |

*This resistant material is thus followed to next $F_3$, F4, F5 generation till the desired homozygoisty is obtained.

Normally, in the sixth back cross progeny (BC6F1) more than 98 per cent of plants would have attained the genotypes of recurrent parent and by $10^{th}$ back cross (BC10F1) or with BC6F6 almost 99.95 per cent progenies would have become completely homozygous.

If a recessive gene is to be transferred, the step involved in the backcross breeding programme is different.

Back cross method of breeding has been generally employed for

a. Inter-varietal transfer of simply inherited characters which is controlled by one or two major genes (e.g. disease resistance, seed colour, plant height)

b. Inter-specific transfer of simply inherited characters – especially to transfer the disease resistance gene from a wild species (e.g. Yellow Vein mosaic resistance in okra).

c. To transfer cytoplasm from one variety or species to another (e.g. Onion)

**(iv) Mutation**

Generally, it has not been used to produce a successful biotic stress resistant crop. The reason for this is difficulty in screening of suitable mutations, the failure of such mutagenesis to generate positive changes to the genome and large number of progeny that must be handled.

Production of disease resistant plant by non-conventional breeding

**Basic technique in plant cell culture**

a. Callus and suspension culture

b. Haploid culture from pollen

c. Protoplast isolation and culture

d. Embryogenesis in cell culture

e. Selection of mutation from pathotoxin resistant cells and clones

f. Regeneration within heterogeneous materials

g. Regeneration of plants from somaclonal/protoclonal variation

h. Resistant plant through fusion of protoplast

i. Disease resistance through uptake of foreign genetic material

**Genetic engineering or Recombinant DNA technology**

There is scope of genetic engineering in fruit crops for the development of transgenic varieties resistant to biotic/abiotic stresses. This technology involves the isolation of gene of desired character. Insertion of this isolated gene in a suitable vector (making it a recombinant vector). Insertion of the recombinant vector into a suitable host (organism/cell) known as transformation. Selection of the transformed host and multiplication followed by expression of the introduced gene into the host is the normal procedure adopted.

**Questions**

1. Resistant breeding is more effective measure of disease and pest control as compared to other measures.

   **Ans: True**

2. Taking a crop species in to a new area where it being grown so far is known as Plant introduction.

   **Ans: True**

3. Repeated back crossing leads to rapid increase in heterozygosity.

   **Ans: False (Homozygosity)**

4. The degree of resistance is measured by using susceptible cultivar of same plant species as check.

   **Ans: True**

5. The objective of back crossing is to transfer one or two desirable characteristics from an inferior variety to a superior variety.

   **Ans: True**

6. Fifth back cross ($BC_5F_1$) or with $BC_3F_1$ almost 99.95 per cent progenies would have become completely homozygous.

   **Ans: False ($10^{th}$ back cross or $BC_6F_1$)**

## Lecture.13

## Role of genetic engineering and biotechnology in improvement of fruit crops

Biotechnological tools are appropriate for accelerating the productivity. Application of biotechnological tool in plant improvement has been found effective in three ways (i) rapid multiplication of existing allied clones and varieties (ii) speeding up the process of conventional breeding and (iii) conservation of germplasm and evolving novel genotypes through genetic engineering technology. Realizing the importance of biotechnology in National development, the Government of India set up a full-fledged Department of Biotechnology (DBT) in 1986 to coordinate and oversee priority areas. DBT has initiated a number of programmes to promote fruit industries. As a result of this, biotechnological revolution has taken place in horticulture.

### Biotechnological application

### a. Micro propagation

Superior selections and hybrids developed at various research centers failed to reach the orchardists due to lack of sufficient planting material. It leads to non-realization of the potential of improved cultivars, thus making the efforts of fruit improvement programme unfruitful. In this case, micropropogation can be a powerful tool for large scale propagation of fruit crops. This is also an ideal system for production of disease free plants. Among the fruits, micro propagation has been most successful in banana, papaya and date palm multiplication. Long term micro propagation of passion fruit by formation of multiple shoot primordial initiated from leaf explants has been reported (*Kawate et al*., 1995). *In vitro* propagation of grape vine is also possible (Heloir et al., 1997. Gray and Fisher, 1985)

### b. Conservation of germplasm

The potential importance of natural gene pool to meet the future need of crop improvement by introducing specific characters such as abiotic stress resistance can not be under estimated. However, the number of wild species and their natural habitats are disappearing rapidly, as a result of introduction of highly bred modern varieties, growing

urbanization and an increased pressure on land for cultivation. This leads to the erosion of the natural germplasm to such extent that there is a general fear that potentially valuable germplasm is being lost irretrievable. In plant improvement, it is necessary to facilitate the assimilation of germplasm collection in working for the use of the breeders. The process of genetic erosion necessitates measure that germplasm must be conserved in such a manner that there should be minimal losses of genetic variability of a population. The conventional methods of germplasm conservation may be vulnerable to losses due to (i) Attack by pest and pathogens (ii) Climatic disorders (iii) Natural disasters and (iv) Political and economic causes. Besides this, the seeds of many important fruit plants such as mango, litchi etc, may loose their viability in a short time under conventional storage system.

National Bureau of Plant Genetic Resources, New Delhi is maintaining large *in-vitro* germplasm collection of banana, phalsa, bael, jackfruit, pomegranate etc. There are two basic approaches followed to maintain the germplasm *in-vitro.*

Conservation of germplasm through biotechnology is a more efficient tool for short and medium term storage. It can be achieved by reduced temperature and light, incorporation of sub lethal levels of growth retardants, induction of osmotic stress and maintenance of culture of a reduced nutritional status particularly reduced carbon and reduction of gas pressure over the culture. Advantage of this approach is that culture can be readily brought back to normal culture conditions to produce plants on demand. But the disadvantage is that culture may be subjected to contamination and somaclonal variation.

Cryopreservation at ultra low temperature of liquid nitrogen at -190$^{o}$C offers the possibility for long term storage with maximum phenotypic and genotypic stability.

**c. Anther culture**

*In-vitro* androgenesis holds a myriad of possibilities for improvement of horticultural crops. This technology has been extended for a number of horticultural crops. The purpose of anther and pollen culture is to produce haploid plants by the

induction of embryogenesis from repeated divisions of monoploid spores, either microspore or immature pollen grains.

The major interest in haploids is based upon the production of homozygous plants as an alternative for repeated cycles of inbreeding in self pollinated crops. In cross pollinated species, double haploids are more to be used as parents in the production of single or double cross hybrids which are as follows.

- As a result of haploid induction, chromosome homozygosity is attained in a very short time. This is particularly useful in heterozygous and self incompatible crops like mango, etc.
- With the use of homozygous parents in crossing programme, the production of pure $F_1$ hybrids become possible.
- Haploid cell lines have great advantages in studies on mutant selection *in-vitro*.

**d. Overcoming crossing barriers (embryo culture)**

This technique pertains to the cultivation of excised plant embryo in artificial medium. Embryo culture technique has found its application both in the applied and basic research. In the conventional plant breeding programme, breeder often faces problem in transferring resistance from wild species to the cultivated species and getting the desirable interspecific hybrids (Yeung *et al.,* 1981). Application of embryo rescue can overcome some of the pre and post-fertilization barriers in fruit crops. Further, most useful and popular application of zygotic embryo culture has been used in raising hybrids. Embryo culture technique has important role in haploid production, shortening of breeding cycle (Lammerts, 1942) rapid seed viability test and propagation of rare plants.

**e. Somaclonal variation**

Somaclonal variation explores the naturally occurring or *in-vitro* induced variability of somatic cells following plant regeneration. Somaclonal variation is an excellent method for shortening breeding programmes. Somaclonal variation may be due

to variation in chromosome number, structural variation of chromosomes due to deletions, duplication, translocation, genetic and cytoplasmic mutation etc.

Hwang and Ko (1987) identified Somaclonal variation in the cultivars Giant Cavendish with putative field resistance to Fusarium wilt (race 4) but inferior in agronomic characters. A somaclonal variant of Cavendish banana expressing resistance to Yellow Sigatoka Leaf Spot disease with satisfactory yield has been reported (Chandha and Sahiram, 2000).

**f. Somatic hybridization**

It is an approach of immense value in the area of fruit breeding. Somatic hybridization provides a method where sexual incompatibility in the plants can be by-passed. Protoplast culture includes a series of operation such as isolation of the protoplasts from cells, culturing them in a suitable medium, inducing them to divide and then regenerating plantlets from them. Fusion of protoplasts may occur spontaneously or they may be induced to fuse in the presence of fusigenic agents. The polyethylene glycol (PEG) is the most widely used fusigenic agent (Chandha *et al*., 2000)

Important fruit plants in which protoplast fusion is practised are as under:

| **Name** | **Method of fusion** |
|---|---|
| Citrus (Tangelo)+*Murrya paniculata* | Electrofusion |
| (*Citrus reticulate x Citrus paradisi)*+ *Citrus jambhiri* | Electrofusion |
| *Citrus sinensis*+*Citrus reticulata* | Peg mediated |

**g. Molecular approaches**

Morphological characters, chemical composition and cytological information have been used over the years for the classification of plants. However, these techniques have certain limitation as they could be influenced by environmental and developmental

effects. The molecular markers are now being increasingly used in the areas of plant classification and breeding. Polygenic characters which are very difficult to analyse using traditional plant breeding methods can be easily analysed using molecular markers.

**h. Genetic engineering**

The advent of recombinant DNA technology has opened tremendous possibilities for transforming almost any plant by transferring any gene from any organism across, taxonomic barriers. The recombinant DNA technology involves the following major steps.

- Isolation of gene of desired characters.
- Insertion of the isolated gene in a suitable vector (making it a recombinant vector).
- Transformation – Insertion of the recombinant vector into a suitable host (organism /cell).
- Selection of the transformed host.
- Multiplication followed by expression of the introduced gene into the host.

**Gene transfer technology**

Important gene transfer methods used for production of transgenic plants are as under:

- Agrobacterium-mediated transformation (Hohn et al., 1989)
- Microprojectile bombardment-mediated transformation (Sanford, 1990)
- Propoplast-mediated transformation (Paszkowski et al., 1989)
- In-planta electroporation (Chowrira et al., 1996)
- Intact tissue electroporation (D'Halluin et al., 1992)
- Silicon carbide fibres (Songstad et al.,1995)
- Electrophoresis (Songstad et al.,1995)
- Microinjection (Neuhaus and Spangenburg,1990)
- Sonication (Joerbo and Brunstedi,1992)
- Laser-mediated gene transfer (Guo et al.,1995)

**i. Biotechnology for biotic/abiotic stress management**

Fruit crops suffer from a variety of insect pests. It is possible to implement biotechnological approaches to manage insect pests in a rational, durable and eco friendly manner. Therefore, novel insecticidal proteins and their respective genes need to be identified and used in conjunction with Bt to prevent development of resistant insect. In addition, Integrated Pest Management will have to play a central role in sustainable horticulture. Disease resistance, herbicides resistance, abiotic resistance etc. are the areas where genetic engineering can play an important role in imparting resistance in fruit crops.

**Eg:** In apple gene attacin (from *Hyalophora cecropia*) *lysozyme* (farm chicken) and cercropin B (from *H.cecropia*) can be used for disease resistance against *Eriwinia amylovora*.

**Questions**

1. Micro propagation is a powerful tool for large scale propagation of fruit crops.

   **Ans:True**

2. Expand-NBPGR

   **Ans:** National Beaureau of Plant Breeding and Genetic Resources

3. The objective of anther culture is to produce haploid plants

   **Ans:True**

4. A popular application of zygotic embryo culture has been used in raising hybrids.

   **Ans:True**

5. Give an example for most widely used fusigenic agent

   **Ans:** polyethylene glycol (PEG)

6. Widely practiced gene transfer method is Agrobacterium-mediated transformation (Biological method)

   **Ans:True**

7. Conservation of germplasm through biotechnology is more efficient tool for short and medium term storage.

   **Ans: True**

8. Liquid nitrogen at temperature of -140ºC is used for cryopreservation.

   **Ans: False (-190 ºC)**

## Lecture.15

## Crop improvement in mango

**Botanical name :** *Mangifera indica* L.

**Family:** *Anacardiaceae*

**Chromosome number:** 2n = 2x = 40

Mango is one of the choicest fruits of India, grown over an area of 1.23 million hectares in the country. Mango occupies the prime position in India as apple in temperate and grape in subtropical areas. In India, mango is acclaimed as 'King of fruits'. The name *Mangifera* was given for the first time by Bontius in 1658, when he referred to this plant as arbor *Mangifera* (the tree producing mango). Linnaeus also referred it as *Mangifera arbor* in 1747, prior to changing the name to its present form (*Mangifera indica*) in 1753. Mango is a good source of vitamin A and C apart from the usual content of minerals and other vitamins. Mango is also considered to have some medicinal properties. Ripe fruits of mango are fattening, diuretic and laxative. The kernel is effective against diarrhoea and asthma. Besides table purpose, fruits of mango can be used for the preparation of pickles, preserves, jam, amchur (mango powder) and mango leather (ampapad) (Singh, 1992).

### Germplasm resources

India is the home of mango germplasm where more than thousand varieties are existing, which are widely distributed in different agroecological zones. Central Institute for Subtropical Horticulture, (CISH) Lucknow has the largest collection of mango (633 accessions in the national repository) and they have greater genetic variability with respect to fruit shape, skin colour, stone size, period and time of maturity, pulp thickness, colour, bearing habit, yield and quality parameters (Anon., 2002). Further, IIHR, Bangalore, IARI, Pusa, New Delhi, Sabour (Bihar), Fruit Research station Sangareddy (Andhra Pradesh) etc. are also maintaining the germplasm of mango. In India, majority of varieties are monoembryonic whereas in most tropical region polyembryonic types are predominant.

Almost all the commercial cultivars of mango are related to a single species *Mangifera indica*. However, a few commercial cultivars of South East Asia belong to other edible species such as *M. altissima. M. caesia, M. cochinchinensis, M. foetida, M. griffithi, M. langinifera, M. longipes, M. macrocarpa, M. odorata, M. pajang, M. pentandra, M. sylvatica* and *M. zeylanica*. There are different reports regarding the number of species in Genus *Mangifera*. Singh (1969) reported 62 species whereas Mukherjee (1949) reported 41 species but later on he reported that only 39 species are existing (Mukherjee, 1985). There are five species of *Mangifera* reported from India e.g. *M. andamanica, M. indica, M. khasiana, M. sylvatica* and *M. comptosperma* (Mukherjee, 1985).

**Objectives**

Qualities of an ideal mango variety have been outlined as follows

- Dwarf tree growth habit
- Precocity and regularity in bearing
- Attractive and good quality fruits
- High productivity and resistance to major diseases and pests
- Good transport and processing qualities

**Breeding methods and achievements**

**Introduction**

For incorporation of good colour to boost export of fresh fruits, a number of mango varieties were introduced from different countries for use as donor parent. Tommy, Ziulete, Haden, Sensation and Julie are the coloured varieties of mango which were introduced from Miami, Florida (USA). Other varieties, Pl 24927, M 4336 (Carabao) from USA and EC 201556 (Carabao) from Phillippines were introduced as regular bearing varieties, Cultivar Amolie and Sweet were introduced from Belgium and Thailand respectively.

**Selection**

Almost all the present commercial varieties of mango in the world were developed from open pollinated seedling selection e.g. Dashehari, Langra, S.B.Chausa, Rataul, Swarnarekha etc.

**Langra**

The evolution of Florida varieties which are the leading mango cultivars of the world is interesting. In 1889, introductions were made from India of which Mulgoa became popular. Cultivar Haden was a seedling of Mulgoa. Subsequently, many promising seedlings were selected which became popular. Tommy Atkins from Haden, Keitt from Mulgoa, Dyke and Palmer from unknown origin, Irwin from Lippins, Golden Nuggets and Brooks from Sandersha, Sensation from unknown origin etc. are promising seedling selections.

**Tommy Atkins**

**Clonal selection**

Alphonso

Exploitation of natural variability for selection of superior clones of commercial mango cultivars has been undertaken. Clonal selection has also resulted in identification of few elite clones. Dashehari-51 from Dashehari, a regular bearer (CISH, Lucknow), ‘ Subash’, a chance seedling from Zardalu (BAC, Sabour), Red blush, a strain of Alphonso (Vengurla), heavy yielding strains of Langra and Himsagar (Kalyani, W.B.), bacterial black spot resistant clones of Kensington, superior clones of Rumani and Neelum (Tamil Nadu) and a regular bearing cultivar ‘Cardoz Mankhurad’ in Maharashtra which is selected from Goa Mankurad. In Maharashtra, one off-season selection ‘Niranjan” has been made at Parbhani, which comes to flowering during June to July and matures the fruits in October. In TNAU (Regional Research Station, Paiyur), a clonal selection from Neelum was identified as dwarf variety and released as Paiyur-1. This is suitable for high density planting (400 plants/ha).


Himsagar

## Hybridization


Dashehari

In mango hybridization, work taken up in post independence period laid emphasis on regular and precocious bearing, dwarfness, high percentage of pulp, fibreless flesh, large fruits with red blush, good keeping quality and freedom from spongy tissue. In recent years, emphasis has also been laid on evolving varieties tolerant to mango malformation. A variety Bhadauran, tolerant to this disorder, was developed through hybridization between Neelum and Dashehari (Singh *et al*., 1985). The work at Sabour yielded two promising hybrids namely Mahmud Bahar and Prabha Shankar from the parental combinations of Bombai x Kalapady. Hybrid Mahmud Bahar was found to be a regular bearer for four years whereas Prabha Shankar, was not a regular bearer. Further, the work on improvement of mango was initiated at Saharanpur in 1951 and also in Punjab in 1950 to develop regular bearing varieties. Later on, in India, nearly 20 inter-varietal hybrids of mango have been released for cultivation from IARI, New Delhi, CISH, Lucknow, IIHR, Bangalore, FRS, Sangareddy, HC & RI, Periyakulam, AES, Paria (Gujarat), FRS, Vengurla etc. Of the hybrids developed in India, Mallika and Ratna have received commercial recognition. The cultivar 'Sindhu' evolved through intensive back crossing between Ratna and Alphonso develops fruits parthenocarpically under natural temperature conditions.

## Interspecific hybridization

Interspecific hybridization did not receive more attention but it can be a useful tool to transfer some useful genes in cultivated varieties. This is possible because all the *Mangifera* species have the same chromosome number (2n = 40). Therefore, they can inter cross easily (Mukherjee, 1963).

**Improved Hybridization technique**

a. Single day pollination of limited number of flowers in a panicle is the ideal practice. Here, the main emphasis was given on utilizing large number of panicles and crossing whatever few flowers opened on the panicle during that single day. Bagging with perforated polythene bags of 24" x 12"size of 100 gauges was preferred. Crossing of a few flowers in a given panicle at one time is advocated than taking up crossing in more number of flowers in a given panicle in batches over a number of days. (Mukherjee *et al*., 1961).

b. **Caging technique:** The discovery of self incompatibility in some of the popular cultivars at IARI, New Delhi led to further improvement in the technique of hybridization. It is known as caging technique (Sharma and Singh, 1970, Singh *et al*., 1962). In this technique, grafted plants of parent varieties are enclosed in an insect proof cage and pollination is effected through freshly reared houseflies.

c. **Marker gene:** The purple colour of new leaves and panicle and beak characters of fruit helps in identifying the hybrid seedlings in the nursery (Sharma and Majumder *et al*., 1985).

d. A new off- season crossing technique was suggested by kulkarni (1986). It involves induction of flowering in the desired parents in off season by veneer grafting, their defoliated shoots on to leafy shoots off season flowering cv Royal special and allowing open pollination between the desired parents. As no other cultivar flowers during this season, this is a safe technique.

**Promising hybrids of mango**

| | |
|---|---|
| IARI, New Delhi | Mallika, Amrapalli, Pusa Arunima. |
| IIHR, Bangalore | Arka Anmol, Arka Puneet, Arka Aruna, Arka Nilkiran |

| | |
|---|---|
| RFRS, Vengurla | Ratna, Sindhu, Konkan Ruchi. |
| CISH, Lucknow | CISH-M1, Ambika |
| FRS, Sangareddy | Au Rumani, Manjeera. |
| HC & RI, Periyakulam | PKM-1, PKM-2 |
| BAC, Sabour | Safari, Jawahar |
| AES, Paria | Neeleshan, Neeleswari, Neelphanso |

In Israel, a new cultivar, Naomi, has been released which has smooth skin and red pigmentation. In Australia, a hybrid of Sensation x Kensington has shown promising results. In Israel, rootstock breeding is also in progress and a polyembryonic rootstock 13/1 has been released that is tolerant to salinity.

**Mutation breeding**

Naturally occurring useful mutants like Rosica has been isolated from the Peruvian variety 'Rasado de lca'. Similarly, Davis Haden is a mutant of Haden. However, no induced mutant is known to have been released.

**Polyploidy breeding**

Much scope exists for polyploidy breeding. However, till date there is no report on this line. Vellai Columban cultivar of mango is tetraploid in nature (2n = 4x = 80) which is a polyembryonic type.

**Heterosis**

Iyer and Subramanyam (1984) observed large fruits in some progenies of Alphonso x Banganapalli. Transgressive segregation for this character was also observed.

The population with bigger fruits was large among hybrid progenies obtained with Banganapalli as one of the parents. This effect may be due to an accumulation of dominant allele each having additive effects and masking the effect of deleterious recessive allele.

## Questions

1. The name *Mangifera* was given for the first time by Bontius.

   **Ans:True**

2. All the *Mangifera* species have the same chromosome number 2n = 40.

   **Ans: True**

3. India is the home of mango germplasm.

   **Ans:True**

4. Most of the mango cultivars were developed through selection from open pollinated seedling population**.**

   **Ans: True**

5. Expand- CISH

   **Ans: Central Institute for Subtropical Horticulture**

6. Tommy Atkins variety is introduced from Philippines.

   **Ans: False (**Miami, Florida (USA)

7. In India, Mallika and Ratna varieties have received commercial recognition.

   **Ans:True**

8. Caging technique is adopted overcome self incompatibility in some of the popular cultivars.

**Ans:True**

9. A Polyploidy mango cultivar is Vellai Columban.

**Ans:True**

10. Bhadauran hybrid is tolerant to mango malformation.

**Ans: True**

## Lecture.16

## Crop improvement in banana

**Botanical name:** *Musa sp.*

**Family** : Musaceae

**Chromosome number**: n=11

2n = 22, 33 or 44 also exists

**History of banana breeding**

Banana breeding was started in Trinidad, West Indies in 1922 and in Jamaica in 1924 (Shepherd, 1994). The driving force for this breeding programme was to develop improved *Fusarium* wilt (*Fusarium oxsyorum* F.sp. Cubense) resistant banana for export trade. In 1960, both the programmes were combined under the Jamaica Banana Board. United Fruit Company also started a small breeding programme in Panama in 1920s. In India hybridization work was started at Central Banana Research Station, Adhuthurai, Tamil Nadu in 1949. Important banana growing states are Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa,Bihar, West Bengal and Assam . In recent days, in some districts of Uttar Pradesh, Harichal banana is cultivated on a commercial scale. In South India, other than its edible use, banana is extensively used in all auspicious occasions such as wedding, festivals and worshipping God. Banana is a good table fruit, besides, the cultivar Nendran is used for cooking. It is also used for preparation of chips.

**Centre of diversity**

Edible banana is native to old world especially South East Asia (Simmonds, 1962). Malayan area seems to be the primary centre of origin of cultivated banana (*M.acuminata*). *M.acuminata,* was probably introduced into India and Burma where *M.balbisiana* is a native species. Natural hybridization between these two species might have resulted in many hybrid progenies (AAB, ABB etc).

**Genetic resources**

*Musa* has about 50 species and this genus is divided into five sections:

a) **Eumusa:** Includes about 13-15 species of edible and wild banana. The chromosome number is 2n=22 in wild species and most of the cultivated varieties are having 2n=33 (2n=44 rarely) e.g. *M.acuminata*, *M.balbisiana*, *M.basjoo* etc.
b) **Rhodochlamys:** Mostly diploid, spread from India to Indonesia. Five to seven species are kept in this group. Parthenocarpy is absent in this group e.g. *M.ornata*, *M.velutina*.
c) **Callimusa:** This is of ornamental value and x=10 and 2n =20. It is found in Indo-China, Malaya and Borneo. Parthenocarpy is absent in this type. It includes about 5-6 species e.g. *M.coccinea*.
d) **Australimusa:** Like Callimusa it has x = 10 and 2n=20 chromosome. Species of this group is common in Queensland and Philippines. Important species of this group are *M. textilis* or manilahemp, *M.maclavi* etc.
e) **Incertae sedis:** It includes *M.ingens* (x=7, 2n=14) of New Guinea which grows to a height of over 10 m. This is the largest known herb. Another species in this group is *M.beccarii* (x=9, 2n=18) from North Borneo.

*Ensete* is another genera of this family probably originated in Asia. Genus *Ensete* has 6-7 species of which *E.ventricosa* is reported to be grown in Ethiopia as a food crop. The most important *Musa* cultivars are almost sterile triploids (2n=3x=33) and also tetraploid and diploid banana cultivars have also local importance in Asia. All banana and plantain land races are farmers selection from intra and inter specific hybridization of two different species, *M.acuminata* Colta, donor of the A genome and *M.balbisiana* Colta, donor of the B genome. Simmonds and Shepherd (1955) reported scoring technique to indicate the relative contribution of the two wild species for the constitution of a given cultivar. Fifteen distinguishing characters between *Musa acuminata* and *Musa balbisiana* were identified by them. Score one was given for each character in which a cultivar agreed with *Musa acuminata* and score five was given for each character to which agreed

with *Musa balbisiana*. Intermediate expressions of the characters were assigned score of 2, 3, or 4 depending on their intensity.

**Taxonomic Scoring of banana based on distinguishing features**

| **Characters** | ***Musa acuminata*** | ***Musa balbisiana*** |
|---|---|---|
| Pseudostem colour | More or less heavily marked with black or brown blotches | Blotches slight or absent |
| Petiolar canal | Margin erect or spreading with scarious wings below, not clasping pseudostem | Margins not winged below, clasping pseudostem |
| Peduncle | Usually downy or hairy | Glabrous |
| Pedicel | Short | Long |
| Ovules | Two regular rows in each locule | Four irregular rows in each locule |
| Bract shoulder ratio | Usually high (ratio:0.28) | Usually low (ratio:0.30) |
| Bract curling | Bracts roll | Bracts lift but do not roll |
| Bract shape | Lanceolate or narrowly ovate tapering sharply from the shoulder Acute | Broadly ovate, not tapering sharply |
| Bract apex | Red dull purple or yellow Inside pink, dull purple | Obtuse |
| Bract color | Inside bract colour fades to yellow towards base | Inside bract colour continues to base |
| Bract scars | Prominent | Scarcely prominent |
| Free tepal of male flower | Variably corrugated below tip | Rarely corrugated |
| Male flower colour | Creamy white | Variably flushed with pink |
| Stigma colour | Orange or rich yellow | Cream, pale yellow or pale pink. |

At the botanical garden, Howrah, seeds of few banana species were collected from Chittagong and Madras (Roxburg, 1832). More number of genotypes of banana was also maintained at Central Banana Research Station, Aduthurai (Nayer, 1957). After that it was shifted to Horticulture college and research Institute, Tamil Nadu Agricultural University, Coimbatore. After the formation of National Research Centre on Banana (NRCB) in 1995, a wide germplasm collection including wild types are being maintained at this centre and intensive research programmes are being taken up on various problems

related with banana. Presently, Tamil Nadu Agricultural University also maintaining 186 collections of germplasm.

**Objectives of breeding**

- To develop dwarf statured banana suitable for high density planting and to prevent damage from high wind velocity.
- Production of good quality fruits.
- Resistant to biotic and biotic stresses i.e. nematodes, panama wilt, bunchy top, sigatoka leaf spot, moko disease and pseudostem weevil etc.
- To develop varieties with wider agro-ecological adaptability.
- Development of male fertile parthenocarpic diploids with resistance to major diseases and pests.
- Developing longer finger size.
- Suitability for export.
- Good keeping quality.

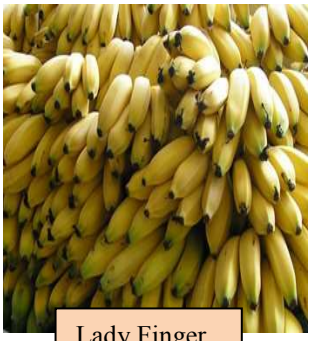
**Taxonomic classification of edible banana (Simmonds and Shepherd, 1955)**

| **Genome** | **Ploidy level** | **Score and nomenclature** |
|---|---|---|
| **Constitution** | | |
| AA | 2x | 16-23 Matti,Anai komban |
| AAA | 3x | 15-21 i)Gros Michel ii) Cavendish |
| AAAA | 4x | 15-20 Bodles Altafort (Synthetic hybrid of West Indies) |
| AB | 2x | 46-49 Ney Poovan, Kunnan |
| AAB | 3x | 26-46 Champa, Rsathali |
| ABB | 3x | 59-63 Kanchkela, Monthan |
| ABBB | 4x | 63-69 Klue Teparod |

## Breeding methods and achievements

### Introduction

Introduction of some cultivators of banana was made with resistance to biotic stresses e.g. Lady Finger (EC 160160) resistant to bunchy top virus introduced from Australia and is being evaluated at IIHR, Bangalore and TNAU, Coimbatore. Further, cultivars Naine MS (EC 27237) from France and Valery from West Indies were introduced for utilization in improvement programme (Singh and Rana, 1993).



Lady Finger

### Hybridization

In India, breeding work was started at Central Banana Research Station, Aduthurai (Tamil Nadu) in 1949 (Sathiamoorthy and Balamohan, 1993). Afterwards breeding programme was also initiated at TNAU, Coimbatore and Kerala Agricultural University, Trichur. Technique of hybridization in banana is different from other crops. Pollination is best carried out in the morning. The bunches of female parent are bagged at shooting and each successive hand is pollinated as it is exposed. At maturity and ripening the bunch is cut and seeds are extracted. Seeds are sown at once in the green house.

Evaluation of hybrid progenies from seedlings to harvest may not be the correct phase instead, evaluation of the same under next vegetative phase i.e., sucker to harvest stage will be ideal as full expression of yield potential could be observed only in the second crop of the $F_1$ progeny. The first crop (seedling to harvest) takes more than 15-19 months, where most of the energy of the plants is needed for corm formation.

Three main approaches in breeding dessert bananas of the Cavendish types are:

1. 3n x 2 n superior diploid; there is no chromosome reduction in the egg cells thus yielding tetraploids
2. 4 n bred tetraploids hybrids x 2n superior diploids producing ‘Natural triploids’
3. 2 n meiotic restituting clones x 2n superior diploids producing ‘Natural triploids’.

**Developing new diploid male parent**

In many banana growing countries, initially wild diploid bananas (AA) were utilized as male parent and as a result, the resultant tetraploids had inherited many undesirable traits. Hence, it has been felt by banana breeders that the primary objective is to synthesize a good male parent. An ideal male parent must be highly resistant to Panama and Sigatoka diseases, must have vertical and compact bunch and fruits as large as the diploidy can allow and must be parthenocarpic having sufficient pollen to permit its use as a male parent. *Musa acuminata* subsp. *burmannica* and its hybrids offer a good source of resistance to black Sigatoka. One such diploid developed in Honduras is SH 2989. Other male diploids worthy to be mentioned are SH 3142 for nematode resistance and SH 3176 evolved through multiple crosses for resistance to Black Sigatoka with desirable horticultural traits.

**Breeding work at TNAU**

Since 1971, extensive inter-diploid crosses were made to synthesize new diploid forms at the Tamil Nadu Agricultural University, Coimbatore using the following parents:

**Matti**

Matti (AA) is a diploid cultivar commercially grown in the southern most part of India. It exhibits a strong resistance to Sigatoka disease but is highly susceptible to nematodes. Its bunches weigh 12 to 19kg with 9 to 10 hands containing fairly long fingers. It sets seeds when pollinated, though it is highly male sterile. This cultivar is extensively used as female parent in the diploid breeding programmes. *M.acuminata* subsp. *burmannica* has been shown to have resistance to fusarium wilt Races 1 and 2, sigatoka diseases and nematodes.

Other diploid clones involved in the diploid male parents synthesis at Coimbatore are the indigenous cultivars Anaikomban (AA) and Namarai (AA). Anaikomban is resistant to nematodes and fusarium wilt but susceptible to yellow sigatoka. It has long fingers (15

to 18 cm) and usually produces a smaller bunch weighing 6 to 8 kg. Namarai is a small slender plant, grown in Pulney and Sirumalai hills of Tamil Nadu. With small fruits having piquant flavor and pleasant acid sweet taste. It has very short pedicel. It is susceptible to both Sigatoka disease and nematodes but no incidence of Panama disease is known so far.

The introduced diploids are Pisang lilin (AA) and Tongat (AA), known for their resistance to Panama disease and nematodes.

Many synthetic hybrids (diploids) have been developed which have good horticultural characters including resistance to Sigatoka, Panama wilt and burrowing nematodes. These hybrids are now used as the male parents to cross with local triploid varieties or inter crossed to synthesise new triploid hybrids.

3n x 2n breeding programme taken up at TNAU has resulted in the development of $CO_1$ banana.

Kallar Laden x *M balbisiana cv. Sawai*

(AAB) ↓ (BB)

AB x Kadali (AA)

↓

CO 1 (AAB)

It is a Pome group of banana of the genome AAB and closely resembles Virupakshi (AAB), a pome type banana popular in the hills of Tamil Nadu. Presently three pre-release cultures viz., H.96/7 ( akin to Karpooravalli)

At Kerala Agricultural University, two hybrids viz., BRS-1 (Agniswar x Pisang lilin) and BRS -2 (Vannan x Pisang lillin) have been developed. BRS -1 (AAB) is 100 days earlier than Rasthali with significant differences in bunch weight. It has been released for homestead cultivation in Kerala, as it is resistant to sigatoka leaf spot. BRS-2 (AAB) is a medium statured hybrid, tolerant to leaf spot and panama disease, rhizome

weevil and nematodes. The average bunch weight is 14 kg with 8 hands and 118 fruits in crop duration of 314 days.

**Breeding work in other Countries**

PITA-9: A Black Sigatoka Resistant (BSR) hybrid from the "False Horn" plantain, a tetraploid hybrid having black Sigatoka resistance has been developed at International Institute of Tropical Agriculture (IITA), Nigeria.'BITA-3' is a tetraploid starchy banana hybrid with low partial resistance to black Sigatoka disease developed at IITA High Rainfall Station in Onne (Southeastern Nigeria), where both (Banana streak virus) and cucumber mosaic virus (CMV) have been observed. 'BITA-3' is a hybrid from the interspecific cross 'Laknau' x 'Taju Lagada', 'Laknau' is a female –fertile AAB starchy banana that closely resembles plantains. 'Taju Lagada' is an AA diploid Banana having a long bunch with many hands. BITA-3' produces heavy bunches.

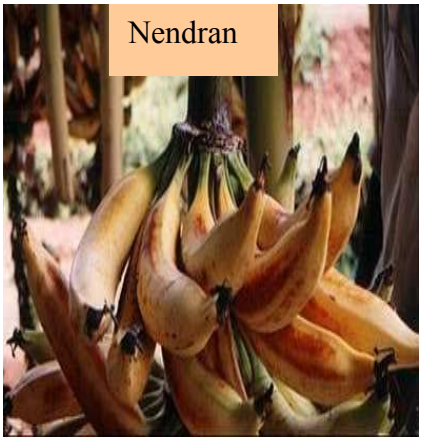
Banana breeding programme has been taken up in Honduras by the Fundacion Hondurena De Investigation Agricola (FHIA) with the aim of developing superior diploid plantations combining desirable agronomic traits with resistance, which is then used for production of primary tetraploids. This organization has developed many FHIA hybrids, which possess resistance to nematodes, Fusarium wilt etc. Introduction and testing of these hybrids in India in various centers revealed superior performance of FHIA-1, FHIA-3, FHIA-21 and FHIA-25.

**Mutation breeding**

Bud mutation in Indian banana is very common perhaps due to spontaneous rearrangement of chromosomes in somatic meristem and structural re-assortment. A great majority of edible bananas are triploids, a condition that interferes with normal equilibrium of plants and may provide the requisite stimulus to structural rearrangement of chromosomes, leading ultimately to the evolution of a new gene complex. Several natural sports of well established commercial clones have been recognized e.g) High gate (AAA) is a semi-dwarf mutant of Gros Michel (AAA), Motta Poovan (AAB) is a sport of Poovan (AAB), Ayiranka Rasthali a sport of Rasthali (or Silk), Barhari Malbhog is a

sport of Malbhog, Krishna Vazhai is a natural mutant of Virupakshi (or Pome), and Sambrani Monthan (ABB), a mutant of Monthan (ABB).






In Nendran, more than six mutants have been recognized. One of these, Moongil, has undergone such a radical change that there is no male phase and a bunch has only one or two hands with biggest size fruits. Attu Nendran, Nana Nendran, Myndoli, Velathan and Nenu Nendran are a few mutants which have been selected for one or the other desirable character. Similarly, Ambalakadali and Erachi vazhai are mutants of Red Banana. The Kunnan variety of Malabar has provided a few mutants known as Thattilla Kunnan (male phase absent), Veneetu Kunnan,

Adakka Kunnan and Thaen Kunnan. From cv.Monthan, Sambal Monthan, Nalla Bontha Batheesa, Sambrani Monthan, Pidi Monthan and Thellatti Bontha have been recognized as sports. At INIVIT, Cuba induced mutations of ABB cooking banana, Burrow Cemsa, was obtained (Rodriguez Nodals *et.al*., 1992). At TBRI, Taiwan, Tai Chiao 1 and GCTV, triploid bananas with Fusarium wilt resistance are obtained as a result of clonal variation of AAA Cavendish banana (Hawang 1991, Hwang and KO, 1988, 1989). The early flowering FATOM 1 was developed as a result of *in vitro* gamma irradiated meristem culture of cv.Grand Naine has been released in Malaysia.

**Biotechnology**

Plant tissue culture and molecular biology techniques are applied to enhance the handling and improvement of banana. Important application of a cell biology are micro propagation for rapid multiplication and germplasm exchange, embryo culture/rescue for in-vitro seed germination, cryopreservation of germplasm and genome manipulation through genetic engineering using cell suspensions or protoplast culture. Although, Vylsteke et al. (1996) reported that somaclonal variation through micropropagation is of limited use in plantain breeding, it has been successfully applied in Taiwan for the development of improved Cavendish banana cultivars with resistance to Fusarium wilt and acceptable fruit quality (Hwang 1991, Hwang and Ko, 1989). In gene transfer methods, Sagi *et al*. (1995), from Katholieke University, Leuven. Belgium reported that the transgenic triploid cooking banana showing transient expression of GUS marker gene in pot growing in the green house from DNA particle bombardment on ABB cooking banana. The molecular markers are providing tools for phylogenetic investigations and cultivar identification, basic genetic research, marker assisted selection and diagnostics in pathogen identification.

**Source of resistance**

| **Name of the clone/cultivars** | **Name of the biotic and abiotic stress** |
|---|---|
| *Musa balbisiana* | Drought |
| Calcutta-4 | Black sigatoka |
| Pisang Lilin | Panama wilt (Race1) |
| SH3142 (Diploid hybrid) | Race 1 of *Fusarium* |
| *Musa acuminata sp malaccensis* | Race 1 and Race 2 of *Fusarium* |
| *Musa acuminata sp burmannica* | Bacterial wilt race 2, Moko disease |
| Pisang Jari Buaya (PJB) | Burrowing nematode |
| Tongat and Anaikomban | Nematodes |

## Questions

1. In India hybridization work was started at Central Banana Research Station, Adhuthurai, Tamil Nadu. as early as 1949.

   **Ans:True**

2. Parthenocarpy is absent in Rhodochlamys group banana.

   **Ans:True**

3. Callimusa is an ornamental banana.

   **Ans:True**

4. **I**ncertae sedis group of banana grows up to 10 m height.

   **Ans:True**

**Match the following**

5. AA - Rasthali
6. AB - Bodles Altafort
7. AAA - Matti
8. AAB - Gros Michel and Cavendish
9. AAAA - Klue Teparod
10. ABBB - Ney Poovan

**Ans**

1. AA - Matti
2. AB - Ney Poovan
3. AAA - Gros Michel and Cavendish
4. AAB - Rasthali
5. AAAA - Bodles Altafort
6. ABBB - Klue Teparod

**Lecture.17**

**Crop improvement in citrus**

**Botanical Name** **:** *Citrus sp.*

**Family** **:** Rutaceae

**Chromosome number** **:** 2n= 2x = 18

Citrus constitutes a major group of fruits comprising of mandarins, oranges, lemon, pummelo, grape fruit, tangelo, trifoliate orange, citron, citranges etc. Despite of inter-specific and inter-generic hybrids, *Poncirus* and *Fortunella* also belong to genus Citrus. During its long history, citrus has given the world numerous varieties both by open pollination, bud sports and of recently by controlled pollination and artificial induction of bud variation. Citrus fruit cultivation lies between latitude 40°N also 40°S where conditions are neither cold nor moist and dry. India is considered to be the home of several citrus species and they are found growing wild in some parts of the country. Many types of citrus still remain unexploited by man and such types are considered as semi-wild.

**Centre of diversity**

There are three major centers of diversity in India. The first in the North-East including Assam and adjoining areas. It includes Papedas, pummelos and their hybrids, citron, lemons and mandarins and other interesting types like jenera-tenga, soh synteng, a sour fruit similar to the sweet lime and soh siem, a mandarin type. The second diversity in south India, indigenous types include Gajanima, kichili and some wild mandarin types. The third in North-West region at the foot of Himalayas where the hill lemon (galgal) is common. The various types of mandarins, hybrids of pummelo, citron,lemons,karna-khatta and rough lemon are found all over the country. In general, the wild types are more common in the foot hills. Many of the progenitors of citrus fruits are believed to have originated in India. These include *C. latipes*, *C. limonia*, *C.kama*, *C.pennevesiculata*, *C.maderaspatana*, many of these are wild types. Presence of Sah-Niangriang, a wild sweet orange and a wild mandarin (*C.indica*) furnishes strong

evidence that Eastern India might be the centre of orgin for many citrus fruits, (Tanaka, 1981).

**Germplasm resources**

Exotic collection of citrus germplasm was started in 1940. Kinnow mandarin was one of the collections which is now a leading cultivar in North – Western India. Besides, other exotic collections were Valencia Late, Washington Navel, Jaffa, Malta Blood Red, Pineapple, Ruby orange, Satsuma, Dancy Tangerine, Climentime, and Cleoptera wilking ,Temple, Duncan, Marsh seedless, Lisbon lemon, Trifoliate orange, Dancy, Lisbon lemon, Trifoliate orange, (Dutta,1958), More than 650 accessions are being maintained at CHES, Chethali, Bangalore, CHES, Ranchi, RFRS, Abhor, NRC on citrus, Nagpur, Horticultural Experiment Station, Bathinda, IARI, New Delhi, MPKV, Rahuri, Citrus Improvement Project, Tirupati, Citrus Experiment station, Nagpur, HC&RI, Periyakulam, and Citrus Experiment Station, Tinsukia, Assam. During 1988 as a result of systematic exploration by NBPGR in North-Eastern region, *C. Indica* and many endangered species were collected for conservation.

North-Eastern region is a hunting ground of biodiversity of Citrus species. Chakrawar et.al (1988) identified two promising clones of acid lime Vikram and Pramalini in Maharashtra. At Nagpur, seedless Santra has been selected which gives high yield and quality fruits (Anon., 1989.)

Attempt has been made during 1978 by NBPGR to preserve the *C. indica* which is progenitor of *C.reticulata* (Singh, 1981). For establishment of gene sanctuary, National Park, the natural genetic diversity of *C .indica* was observed in the forest of Garo hills in Megalaya which exhibited plant characters varying from bush to climber with high frequency of distribution in dense forest and showing resistance to biotic stresses. Therefore, a gene sanctuary for *C. indica* was established in Tanga Range in Garo hills. Genetic material of citrus is conserved in field gene bank or repository.

**Problems in citrus breeding**

There are three major problems which hinder the success of citrus breeding.

**Time**

Citrus being perennial in nature takes more time for bearing .However this period can be reduced to a maximum of half by top working the seedling on an old tree.

**Polyembryony**

It is peculiar feature found in citrus in which seed consist of more than one embryo. In addition to the zygotic embryo, one or more sometimes as many as fifteen additional embryos are developed from the nucellar tissue called nucellar embryos and found in the embryo sac. Most often, the zygotic seedling is crowded out by the vigorous nucellar seedlings. Forgetting large number of hybrids, citrus breeder should select a seed parent known to be either monoembryonic citrus species or polyembryonic except (*C.medica*, *C.latifolia* and *C.grandis)* which are monoembryonic restricts the choice of breeder and complicate the procedure required to attain the desirable objectives.

**Sterility**

Sterility is inability of gametic or sexual reproduction. Prevalence of high generative sterility is obviously a serious hindrance in the use of a particular parent for hybridization. Complete pollen sterility is problematic, where proportion of nucellar embryos are very high. High level of sterility often leads to production of seedless fruits which is serious hindrance to develop varieties**.**

**Self incompatibility**

Self incompatibility and cross incompatibility is a common phenomenon which occurs widely in citrus. Most of the varieties of grape fruit (*C.grandis*) are found to be self incompatible besides, some varieties of lemon, sweet orange and mandarins exhibit self incompatibility of gametophytic type goverened by oppositional alleles. Hybrid cultivars including Clementine, Orlando, Minneola, Sukega, Nova, Robinson are cross incompatible. Nova and Robinson is also suspected to be cross incompatible. Sweet orange varieties like Washington Navel and Satsuma mandarin are having sterile pollen,

thereby they produce parthenocarpic fruits if cross pollination is not done through viable pollens.

**Long juvenility**

It is a major barrier in the progress of citrus breeding in India. General treatments to shorten the period or induce early flowering have not been generally effective. It was reported that neither chemical treatments nor incorporation by genetic transfers has been effective in combating long juvenility in citrus.

**Breeding objectives**

- Producing early maturing citrus fruits with high yield and fruit quality.
- Developing rootstocks having disease and nematodes resistance, wider adaptability, etc.

In rootstock breeding, the main emphasis has been given on the development of root stock resistant to tristeza virus, *Phytophthora*, nematodes, etc. Most of the breeding programmes make use of *Poncirus*, which is a carrier of resistance to tristeza, *Phytophthora* and nematodes besides cold hardiness. Salt tolerant rootstocks have also been found possible in some progenies involving Cleopatra and Sunki mandarin and Rangpur lime.

**Floral biology**

Flowering in citrus takes place during February –April. In North India, sweet orange and mandarins bloom only once in March. However, it is reported that sweet oranges bloom twice in a year under Bihar conditions i.e.February –March and June – July. Inflorescense in citrus species is of cymose type. Generally anthesis takes place in the morning between 9.00 am to 12.00 noon. Flowers on shaded side of the tree have been observed to open later than those exposed to sunshine.

## Breeding Methods

### Introduction

Introduction of germplasm either from other countries or from one agro climatic region to the other within the country has been one of the most potent improvement methods. The mandarin variety 'Santra' is known to have been grown in India for many centuries. It was introduced into the Central Provinces (now Maharashtra) by Ranghojee Bhonsal II from Aurangabad in eighteenth century. Tangerines, St.Michael Blood Orange and Large White Orange were imported and cultivated at Goojranwallah in Punjab during 1880. The present century has seen the introduction of a number of sweet orange varieties including Washington Navel, Valencia, Jaffa, Blood Red Malta and tangerines. The first two were introduced from America and the others from the respective countries of their origin. Grapefruits were introduced from California and Florida, lemons from China and Malta from USA and Italy. 'Mosambi' seems to have been introduced in Nagpur during the beginning of the $20^{th}$ century.

The introduction of 'Kinnow' mandarin (King x Willow leaf) in 1947 showed great promise in North India. It was introduced in South India in 1958 and Punjab in 1959 and has performed extremely well in Punjab.

### Clonal selection

Exploitation of natural variability existing in a variety has resulted in the isolation of some promising clones in Citrus.

1. 'PKM 1 lime is a clonal selection from seedling progenies of kadayam Type of Tirunelveli district of Tamil Nadu.
2. 'Yuvaraj Blood Red' is a seedless and early maturing clonal selection from 'Blood Red' orange.
3. 'Pramalini' and 'Vikaram', the two kagzi lime varieties were developed through clonal selection at Marathwada University.
4. 'Chakradha' is a thornless and seedless selection from Kagzi lime.

**Hybridization**

Hybridization is confronted with real problems in citrus improvement, both on scion as well as rootstocks because the long juvenile phase delays the assessment of the hybrids.

Most of the cultivated varieties are highly polyembryonic, hence the crosses made using these as females result in very few weak hybrids, which are difficult to identify from nucellar seedlings. Electrophoretic techniques separating the isozymes of parents and hybrids may be of great value in scion breeding programme, as no morphological markers are available at present.

The heterozygous nature of the crop further leads to wide segregation. The problems are little less complicated of rootstock breeding where the commonly used disease resistant male parent *'Poncirus trifoliata'* has trifoliate leaves which is dominant over the monofoliate character (in other citrus varieties and all the hybrids), by which distinction of unifoliate nucellar seedlings could be easily made.

**Hybridization Technique**

The mature flower buds on the female parent are emasculated early in the morning on the day of opening and are bagged. The flowers to be used as male parent are bagged the previous evening. The next morning as the day warms up, the anthers dehisce releasing the pollen grains when these flowers can be plucked to pollinate the receptive stigmas of emasculated flowers. The pollinated flowers are bagged, opened after about a week and allowed to mature into ripe fruits. In some cases, especially when the trifoliate orange is used as male parent, difficulties are encountered as its flowering is over before other citrus varieties flower. Therefore, pollen has to be stored at low humidity and temperature.

Seeds from mature fruits are extracted and sown immediately in sterilized sand and soil mixture. When seedlings are about 15 cm high, hybrid seedlings are identified. Particularly those showing some morphological characters of male parent are marked while others are rejected. Electrophoresis methods can also be employed for identification of zygotic seedlings. Identification of hybrid seedlings having *P.trifoliata* as male parent is easily done by looking for trifoliate character. The hybrid seedlings are grown to mature trees in the field and the seedlings raised from the fruits are evaluated

for resistance to various diseases, insect pests, nematodes and for suitability as scion or rootstock.

**Evaluation for rootstock purpose**

Rootstock hybrids should have desirable attributes like high percentage of nucellar embryony, resistance to different diseases and nematodes. The selected hybrids are then tested with different scion varieties and compared with the commercial rootstock. Various plant and fruit characters, yield and yield contributing characters are recorded.

**Evaluation of scion hybrids**

In the first round of evaluation, the zygotic seedlings are raised on suitable rootstock and observations on different vegetative and fruit characters are recorded. Meanwhile, the resistance to different diseases is also confirmed. Selected hybrids are tested on different rootstocks at different locations and compared with the commercial varieties.

**Intergeneric and intrageneric hybrids**

**Intergeneric**

Though intergeneric hybrids are rare in fruit plants, much success has been obtained in Citrus.

**1. Hybrids of Poncirus**

**Citrange** –A group having the parentage of trifoliate orange (*Poncirus trifoliata*) and sweet orange (*C.sinensis*), the hybrids showed intermediate characters of the parents. The leaves are mainly trifoliate but unifoliate evergreen leaves are also observed in some plants. The fruits are juicy and flavoured. Some of the cultivars are Troyer, Carrizo, Morton, Etonia, Rusk, Coleman, etc.

Citrangequat - This is a tri-generic hybrid of three different genera *(Poncirus, Citrus and Fortunella).*

Citrangor - This hybrid was developed by back crossing Citrange with *C.sinensis.*

Cicitrange - Another back cross hybrid between Citrange and *Poncirus trifoliata* x *C.paradisi.*

| | | |
|---|---|---|
| Citrandarin | - | A hybrid between *Poncirus trifoliata* and *C .reticulata.* |
| Citremon | - | A hybrid between *Poncirus* trifoliate and *C.limon* |
| Citradia | - | Very similar to citrange. A hybrid between *Poncirus trifoliata* and *C.aurantium*. |
| Citumquat | - | This is the hybrid between *Poncirus trifoliate* and *Fortunella japonica* or *F.margarita*, a very difficult hybrid to breed. |

**II.Hybrids of Fortunella**

| | | |
|---|---|---|
| *Procimequat* | - | (*F.japonica* x *C.aurantifolia* cv. Mexican) x *F. hindisii* |
| *Limequat* | - | *C.aurantifolia* x *F.japonica* |
| *Orangequat* | - | *C.reticulata cv*.Satsuma x *F.japonica* x *F.margarita cv*. Meiwa. |
| *Intrageneric Tangor* hybrids | - | Mandarin x sweet orange *(C.sinensis x C.reticulata)* e.g.cv.Temple, Clementine, and Monreal are some important cultivars, mostly monoembryonic. |
| Tangelo *e.g.cv*.Orlando, | - | Mandarin x grapefruit, *(C.reticulata x C.paradisi)* Sampson, Minneola, Seminole, etc. |
| Lemon Lemonnage | - | Lemon x lime, *(C.limon xC.aurantifolia)* e.g.*cv*.Parrine *(C.limon x C.sinensis)* Lemandarin *(C.Limon x C.reticulata)* |

In India, very little work has been done on citrus improvement through hybridization. At the PKV, Akola, hybridization work has been undertaken to evolve hybrids of kagzi lime. As a result, Hybrid 2, Hyrbid 4 and N52 were found resistant to canker.

Breeding for improvement of citrus rootstock was initiated in 1972 at the Central Horticultural Experiment Station, Chethali, and IIHR, Bangalore. Trifoliate orange was

used as a donor source for *Phytophthora* and citrus nematode resistance. Hybridization programme resulted in the production of 1183 hybrids from 16 different cross combinations. Of these, CRH.3, CRH.5 and CRH.41 resistant to citrus nematode have been evolved. A hybrid between Rangpur lime and trifoliate orange (Australia) having high resistance to nematodes and *Phytophthora*, and highly polyembryonic in nature is being evaluated for its suitability as rootstock for mandarin and sweet orange.

**Mutation Breeding**

Somatic mutations are common in citrus and through selection of the natural mutants, quite a few number of desirable clones have been obtained. The frequent occurrence of chimera may lead to clonal impurity and thus bud selection work in propagation becomes important for ensuring clonal purity. Selections of natural mutants have been successfully employed for seedlessness (lyo tangor), season of ripening (Satsuma, Navel), improvement of colour (Ray Ruby grapefruit) etc. in Citrus.

Besides natural mutations, many induced mutants have been developed in Citrus. For instance, 'Star Ruby' and 'Rio Red' varieties of grapefruit were developed in Texas, USA through x ray and thermal neutron treatments of seeds of *cv.* 'Ruby red' whose red flesh colour faded at harvest. In Japan, a few closely related clones of Satsuma mandarin with varied fruit colour and fruit ripening times were obtained through mutation. In USA also mutations had produced Satsuma seedling lines differing in productivity, fruit shape and the ripening time. The grapefruit clones like Thompson and Foster Pink arose as limb sports on white grapefruit. Gamma irradiation of seeds and bud woods performed in Orlando, Florida, resulted in Seedless fruits on certain trees of seeded cultivars like Pineapple orange as well as Duncan and Foster grapefruit. In Israel, Shamouti trees of compact habit and early fruiting types and seedlessness have been developed in Eureka lemon through irradiation of bud wood with gamma rays.

**Polyploidy breeding**

Most of the species and varieties of *Citrus* are diploids but occurrence of polyploidy has been reported in many cultivars. The Hongkong wild kumquats,

*Fortunella hindsii* may have been the first reported tetraploid. Polyploidy breeding seems to offer prospects to obtain large sized fruit with dwarf plant types. Production of triploids by crossing tetraploid with diploids may be useful in obtaining seedless varieties. The seedless lime (*C. latifolia*) a triploid. Triploids have favorable characteristics and yield well but they are sterile. The development of triploid through breeding is very limited. Production of 3x is normally achieved by crossing of 4x with 2x which is often not feasible for want of sexual parents. The reciprocal cross ((2x) x (4x)) produces many tetraploid individuals. Polyploidy manipulation by crossing of tetraploids with diploids yielded some valuable triploid varieties like 'Oroblanco' and 'Melogold'. A large diversity of autotetraploid parents with desirable characters expressed in the progeny will be of high value to any citrus cultivar breeding program. Spontaneous autotetraploids occur among many polyembroyonic citrus varieties. Tetraploid trees of monoembryonic cultivars can be obtained by colchicine treatment. Triploids also, occasionally occur spontaneously as sexual seedlings. In most cases the egg provides the double chromosome number.

**Biotechnology in improvement of citrus**

Transformation of fruit species by biotechnological tools is a potential approach to develop disease resistant cultivars. Woody plants are known to be difficult to work *in-vitro* than herbaceous plants but citrus is exceptional. Though nucellar embryony in citrus is of great value for producing vigorous, uniform and virus free plants, it appears to be an obstacle in hybridization. In polyembryonic cultivars, the vigorous growth of nucellar embryos inhibits the growth of the zygotic embryo and causes its degeneration prior to seed maturation. Such abortive embryos can be rescued by tissue culture. Tissue culture has effectively been used in obtaining hybrid *Poncirus* plantlets from polyembryonic citrus cultivars. *Poncirus trifoliata* not only carries a genetic marker, but also possess resistance to tristeza, *Phytophthora,* nematode and cold stress. Inter – generic hybridization with the aid of cell/tissue culture offers possibility of incorporation of multiple desirable characters found in different genera for improvement of citrus root stocks and scion cultivars.

Cell and tissue culture and specially protoplast manipulations have effectively been explored in citrus improvement by regeneration of citrus trees from protoplast, somatic hybridization (cybridization) and organelle transfer. In an attempt to develop protoplast derived plants in the last one decade, Israel and Florida have shown protoplast system in a dozen genera and interestingly citrus is the only woody plants among them. Efficient protocols have been developed to obtain protoplasts with cell diversion capability from all major citrus cultivars and some of their wild relatives.

**Important species and cultivars**

**Mandarin group**

***Citrus reticulata***

Loose skinned orange, though mandarin and tangerine are names used more or less interchangeably to designate the whole group, tangerine is applied more strictly to those varieties which produce deep orange or scarlet fruits.

**Calamondin** (*C. madurensis*)

Tanaka has recognized it as loose skinned orange group. It is very cold resistant for a true citrus fruit as hardy as Satsuma. Fruit colour is orange to deep orange, smooth and glossy surface, pitted shape, oblate, deep orange, and size small with flattened base having 7-10 segments.

**Clementine (Algerian Tangerine)**

It is a tangerine and is probably an accidental hybrid of the mandarin and sour orange which is considered to be originated in Algeria. Fruit colour deep orange, shape globose to elliptical, size-medium with depressed apex, rind thick, segments 8-12 adhered slightly. It is an early variety.

**Cleopatra** (*C. reshni*)

It is originated in China. Plant is thornless with dense top. Fruits are produced singly or in clusters, fruit colour dark orange red, shape oblate flattened at both ends, size small and segments 12-15.

**Coorg orange**

It is an important variety of South India particularly in Coorg and Wynad tracts. Fruits are medium to large, bright orange colour, oblate to globose in shape, finely papillate and winkled,
glossy, segments 9 – 11.

**Dancy tangerine**

In USA, the Dancy is the best known and highly prized of all the mandarin oranges. Tree large, nearly thornless and has upright growth. Fruit colour is deep orange red to scarlet, rind thin, loose, easily separable, segments 10-14. It is a late variety.

**Deshi mandarin (Pathankot)**

This variety is mainly grown in Punjab hills. The tree is large with semi – upright growth habit and compact foliage and are spineless. Fruit are ovoid to sub globose. Colour uniformly cadmium, surface pitted, semi glossy and finely wrinkled, rind medium, adherence slight, segments 7-10.

**Khasi mandarin**

Swingle believed the king mandarin as a tangor, a hybrid between mandarin and sweet orange. King mandarin was first introduced from Cochin China to California in 1882. King mandarin is cultivated in Assam. This is a prolific bearer, frost resistant and produces high quality fruit.

**King mandarin (*C.nobilis*)**

This is believed to be a hybrid between mandarin and sweet orange, and cultivated in Assam. It is a prolific bearer, frost resistant and produces high quality fruit.

**Willow leaf mandarin (*C. deliciosa*)**

The tree is willowy in growth, almost thornless, and fruits usually borne singly at the tip of slender branches. Fruit colour orange, surface smooth, glossy frequently slightly lobed, necked base, apex depressed, wrinkled, rind thin with 10-12 segments. It is an early variety.

**(King x Willow leaf mandarin)**

**Kinnow mandarin**

It is a first generation hybrid between the king and willow leaf mandarin and developed by H.B. Frost at the California Citrus Experiment station in 1915. It was introduced into Punjab from USA. Tree is vigorous, large, top erect, dense symmetrical with few scattered thorns. Fruit colour resembles of king, deep yellowish orange, surface, smooth, glossy, very shallow pitted, shape slightly oblate, size medium with flattened base, rind thin, peel tough and leathery, segment 9-10 easily separable, seed 12-24. It is a late variety.

**Nagpur Santra**

This variety occupies prime position in Indian market and is one of the finest mandarins grown in the world. It is also known as Ponkan. Tree is large, vigorous, and spineless with compact foliage. Fruit size is medium, cadmium colour, smooth surface, and glossy, rind thin, soft, and slightly adhered with 10-12 segments.

**Satsuma Orange**

It is a Japanese variety introduced into Florida in 1876. It is a frost resistant and useful breeding material. It is also resistant to canker, gummosis and scaly bark. Plant is thornless having spreading growth habit, orange fruit colour, rough surface, oblate to

spherical shape, medium to large in size ,thin and easily separable rind, flavor rich and seedless.

**Temple mandarin**

It is a hybrid between tangerine and sweet orange. Temple mandarin is most beautiful and highly flavored fruit of the citrus group. Tree is medium, thorny, spreading with deep orange to reddish fruit colour, rugose glossy surface, medium to large in size, depressed or nearly flat apex, loose rind, solid axis with 10-12 segments, orange pulp. It is late in maturity.

**Lemon (*C.limon*)**

**Varieties of lemon**

**Eureka**

It is a seedling selection of Sicilian lemons. Tree is medium, spreading and thornless. Its fruit colour is lemon yellow, surface rugose, pitted, shape obovate, size medium, apex round, rind medium thin axis small, solid, segments 8-10, juice acidic with excellent flavor and quality. Eureka is a heavy yielder and begins bearing at early age. It has tendency of bearing in the terminal end of the shoot.

**Lisbon**

Its appearance and yield is superior to Eureka. It is resistant to frost, heat and high wind velocity. Tree is large and vigorous with spreading shoots. It has upright thorn growth, lemon yellow fruit colour, smooth surface, medium size, pitted rind, small axis, solid, 6-10 segments with 0-8 seeds.

**Pant Lemon**

Fruit size medium, juicy, heavy fruiting, tolerant to pests and diseases.

**Villi Franca**

It belongs to Eureka group and was introduced into Florida from Europe in 1875. Tree is vigorous, thorny, spreading, erect, fruit oval to oblong, size medium to large, colour bright lemon yellow, apex pointed, base rounded, rind thin, smooth, segments 8-12, flesh fine grained, juice colourless, seed 25-30.

**Meyer lemon**

Tree semi-dwarf, thornless, spreading, cold resistant, fruit colour light orange, surface smooth, finally pitted, shape oblate or oblong base rounded, rind thin, axis small, segments 8-10, seeds 8-12.

**Acid lime** (*C. aurantifolia*)

It is native of India and widely cultivated in the tropics. Tree medium sized, hardy, semi vigorous, upright growth, thorny, fruit round to oblong, yellow apex rounded and slightly nippled, base round, rind thin, papery segments 8-10, seeds 8-10.

**Varieties of acid lime**

**Vikram**

It was developed at MAU, Parbhani, fruit medium size, heavy fruiting, fruit colour golden**.**

**Pramalini**

It was developed at MAU, Parbhani, high yielder, golden fruit colour, tolerant to canker.

**Sai Sarbati**

Kagzi lime selection developed at Mahatma Phule Krishi Vidhyapeeth (MPKV), Rahuri, Maharashtra. Fruit surface smooth, fruits more uniform, good size, thin skin, high juice, TSS and acidity. High yield potential and tolerant to canker and tristeza.

**Tahiti lime Persian lime** (*C.latifolia)*

It is large fruited acid lime. The plants are large, spreading, cold resistant, thornless, fruit large in size, seedless triploid, and produce non-viable pollen. It is considered as hybrid between lime and lemon. Fruit colour orange yellow, smooth surface, segments 8-10. It is a late variety.

**Rangpur lime** (*C. limonica*)

It is indigenous to India and is commonly used as root stock. Rangpur lime is mainly grown for home consumption and ornamental purpose. It is also known as Marmalade orange. It has loose rind, easily separable segments and pulp is light orange yellow.

**Sweet lime (***C.limetoides***)**

Generally, sweet lime is grown as a root stock for its non acidic fruits.

**Pummelo (***C.grandis***)**

It is native of Polnasia and Malaysia and commonly grown in South China. Fruit is pyriform, largest fruit size among citrus fruits, rind thick, juice is acid bitter, juice sacs easily separable. Seeds are monoembryonic. Fruits are of two types (a) elongated pear shaped with neck (b) Oblate or globose, flattened and neckless. In India there is no improved cultivar except Nagpur Chakotra.

**Varieties of Grape fruit (***C.paradisi***)**

**Duncan**

It was developed as chance seedling in Florida. It is the hardiest variety, fruit colour yellow, surface smooth, shape oblate to globose, size large, basal area depressed, apex round, rind medium thick, firm, axis medium in size, segments 12-14, seeds 25-50.

**Foster**

It belongs to pink or red pulp group and originated as bud sport of Walters grape fruit by R.B. Foster in 1906-07. Fruit colour is light yellow, surface smooth, oblate or globose shape, size medium large, base rounded, apex round, rind medium thick, segments 12-14, seeds 2-5. It is a late cultivar.

**Thompson**

It is a bud sport of Marsh. Fruit colour light yellow, surface smooth, segments 10-12, seeds 2-5.

**Ruby**

It belongs to pink or red pulp group. It is originated as bud sport from Thompson. Deep red colour which uniformly distributed throughout pulp.

**Questions**

1. Seed consists more than one embryo is known as Polyembryony.

**Ans:True**

**2.** Cross between King x Willow leaf is 'Kinnow' mandarin.

**Ans:True**

3. **Satsuma Orange** is resistant to canker, gummosis and scaly bark.

**Ans: True**

4. Citrangor is a tri-generic hybrid of three different genera.

**Ans: False (Citrangequat)**

5**.** ***Citrus reticulata*** is loose skinned orange.

**Ans: True**

## Lecture.18

## Crop improvement in grapes

**Botanical name**: *Vitis vinifera L.*

**Family:** Vitaceae

**Chromosome number**: 2n=2x=38.

**Centre of diversity**

European grape *(Vitis vinifera L.)* is considered to have originated primarily between Caspian and Black sea region (Vavilov, 1951). American grapes belonging to a large number *Euvitis* and *Muscadinia* species have originated in North America, referred to as 'Vine land' by Zielinski (1955).

**Germplasm resources**

Field gene banks of grapes are maintained at Division of Fruits and Horticultural Technology, IARI, New Delhi, Indian Institute of Horticulture Research, Bangalore, Ganesh Khind Botanical Garden, Pune etc. Further, 616 genotypes of grapes are maintained at IIHR, Bangalore

**Objectives**

Objectives of breeding for grapes are:

- To develop early maturing, seedless and sweet cultivars for table purpose.
- To induce resistance to anthracnose, Phylloxera and chaffer beetle.
- To develop varieties with medium vigour and productive basal bud, which can be trained on head or pandal system of training

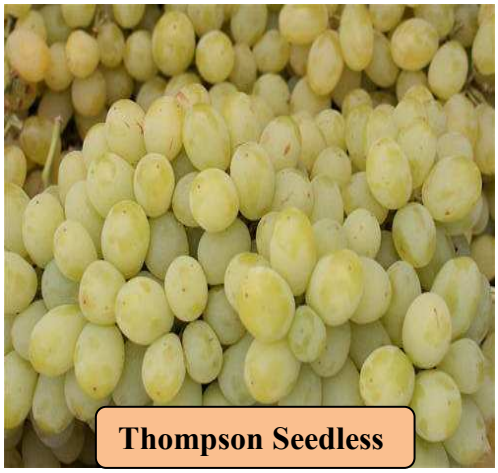
For the tropics the objectives of breeding should be:

- To develop high yielding and high quality varieties with increased fruitfulness of basal buds, less degree of apical dominance, suitability for different purpose such as table, raisin, wine and juice and resistance to diseases.
- To develop root stocks resistant to salinity, nematodes and drought

## Introduction

Grapes are reported to have been introduced in Tropical India about 2600 years ago in 620 BC (Olmo, 1976). Commercial cultivation did not start until the beginning of 20th Century. During 1930, Shree R.S.Pillay, identified Anab-e-Shahi from the collections of Nawab Baquer Ali Khan and subsequently its commercial cultivation picked up in South India. Bhokri and Cheema Sahebi in Maharashtra, Bhokri and Muscat Hamberg in Tamil Nadu and Bangalore Blue in Karnataka are the introductions

The commercial varieties of grapes were introduced into India mostly by invaders of Iran and Afghanistan (Thaper, 1960). Muhammed Bin Tughlaq introduced, Bhokri,Fakhri and Sahebi cultivars in Aurangabad (Daulatabad) in 1338 (Pillay,1968). Large scale introduction in a planned manner were initiated at Lyallpur as early as 1928, when S.B.S.Lal Singh, was Head of Department of Horticulture, introduced as many as



**Thompson Seedless**

116 graps varieties from different grape growing countries (Singh and Singh, 1940, 1942). The earlier promising introduction include, Thompson Seedless, Perlette, Beauty Seedless, from USA,Kishmish Beli and Kishmish Charni from USSR (Singh and Singh,1972). The cultivars like Ruby Seedless,Gordo Blano,(Reisling, MS 18-55,MS 19-77,MS 16-2,Wortly Hall hybrids from Australia,Totlocha from Brazil Flame Seedling 1281,Dogridge,Pride,Dixie,Wedor and Black Cornith-2 from USA,Surnak Kitabiskij, Pozdrijwir and Shirajx-6 from USSR, Malvasiafina (Douro), Boal De Alicante, Tinta Deira Preta, Jampal, Tinta Roriz,from Portugal and 0912 Horizon (SW) , 0913 Leon Millet, Foch and 0912 Swanson Red from Canada for wine, raisin and table purposes have been introduced and are under evaluation. Further, number of *Vitis* sp.have been introduced for resistance to biotic and abiotic stresses e.g. *V.gigas*, *V.caribea*, *V.munsoniana*, *V.smalliana,V.cineraria, V.shuttleworthi, V.arizonica* and *V.monocola* from USA (Singh and Pana,1993)

**Selection**

Open pollinated seedling segregates for a large number of characters and hence the population of seedlings from open pollinated seeds is a potential source for selection of desirable type e.g. Cheema Sahebi (Sel-7), Selection-49. Some promising seedlings from open pollinated population of Pandhari Sahebi and Kabul Monukka were also selected.

Clonal selection is also one of the methods of fruit improvement. Due to natural mutation in existing cultivars considerable variation occurs between individuals that help in varietal improvement through clonal selection. The promising clonal selections of grapes are as follows:

| Cultivars | Clonal Parent | Characteristics |
|---|---|---|
| Tas-A-Ganesh | Thompson Seedless | Developed by Mr.Arue of Borgoan in Sangli district of Maharashtra. Its berries are quite elongated and respond to $GA_3$treatment. |
| Rao sahebi | Cheema Sahebi (Sel-7) | Isolated by Rao Saheb Kadlag of Sangamner in Nasik district of Maharashtra. Fruits have longer berries with stronger attachment to rachis which is a major problem in Cheema Sahebi. |
| Sonaka and Manik Champa | Thompson Seedless | Sonaka has much elongated berries as compared to Tas-A-Ganesh. It gives better response to $GA_3$. |
| Dilkhus | Anab-e-Shahi | Selection was made at Hyderabad. It produces golden yellow elongated seeded berries in attractive bunches. The yield potential is almost same as in parent. |

**Selection made by Institutes**

a. **Pusa Seedless from Thompson Seedless:** Developed at IARI, New Delhi. It differs from the parent in respect of having more elongated berries. Vine vigorous and heavy

yielding. TSS 22-24%, acidity 0.77% and juice content 65%. It ripens in the middle of June.

b. **HS 37-6 from Perlette:** Developed at HAU, Hissar. This cultivar is 15 days earlier in maturity than the parent

**Hybridization**

Grapes are highly heterozygous and are propagated asexually at commercial scale. Inbreeding results in rapid loss of vigour and fertility of vine, even in first generation. The crossing of unrelated parents with good combining ability followed by raising a large number of hybrid seedlings in each combination and rigorous selection may result in good ideotype of commercial use.

In India, hybridization work was started in 1958 at IARI, New Delhi. The purpose of hybridization at IARI, New Delhi was to develop early maturing, high yielding, better quality seedless varieties with resistant to biotic stresses. However, IIHR, Bangalore, started breeding programme in 1968, with objective to develop superior varieties for table, raisins, wine and juice, On the basis of types of parent used, it can be grouped into two (a) Interspecific / Intergeneric hybridization and (b) Interspecific or intervarietal hybridization.

**Interspecific / Intergeneric hybridization**

*Muscadinia* is a rich source of resistance to diseases and pests and also possesses a unique and delightful flavor and aroma. The crosses between *Vitis* and *Muscadinia* which differ in chromosome number are made with difficulty, but most of the resulting hybrids remain sterile. The pollen of *M.rotundifolia* will fertilize the egg cell of *V.vinifera* but the reciprocal cross is less successful. Partly fertile $F_1$ hybrids (2x=39) can cross reciprocally between themselves or with *V.vinifera x M.rotundifolia* which have been further improved by back crossing with *V.vinifera*, resulting in some fertile vines that produce acceptable quality table grapes (Olmo 1971).Crossing within *Muscadinia* has given outstanding self fertile cultivars like Tarheel (*M.rotundifolia x M.munsoniana*), South Land, Magron, Regale (Cold hardy) Sterling (cold hardy) and Triumph (bronze cloured berry weighing 7.9g). Telki 5A (*V.berlendieri* x *V.riparia*) highly resistant to *Phylloxera*, tolerant to lime soils and moderately resistant to nematodes, Harmony (1613

x *V.champini* planchon cv.Dogridge) has been developed as a result of interspecific hybridization.

**Intervarietal hybridization**

A few promising hybrids identified through inter varietal hybridization at IARI were, Hybrid 62-37 (Hur x Pusa Seedless), H62-65 (Hur xPusa Seedless),H-62-20 (hur x Black Hamburg) H-62-67(Hur x Bharat Early),H-63-10 (Bhokri x Pearl of Casaba), H-63-32 (Bhokri x Pearl of Casaba). In 1996, cultivars Pusa Navrang (Madeleine Angevine x Rubi Red and in 1997 Pusa Urvashi (Hur x Beauty Seedless) were released from IARI, New Delhi. The promising hybrids developed at IIHR, Bangalore were Arkawati (Black Champa x Thomson Seedless),Arka Kanchan (Anab-e-Shahi x Queen of the Vine Yards), Arka Shyam (Bangalore Blue x Black Champa), Arka Hans (Bangalore Blue x Anab-e-Shahi),Arka Chitra (Angur Kalan x Anab-Shahi), Arka Krishna (Black Champa x Thompson Seedless),Arka Majestic (Angur Kalan x Black Champa),Arka Neelmani (Black champa x Thompson Seedless),Arka Soma (Anab –e-Shahi x Queen of the Vine Yards),Arka Thrishna (Bangalore Blue x Convert Large Black ),Arka Shweta Syn,Shweta Seedless (Anab-e-Shahi x Thompson Seedless).

**Hybridization technique**

It includes the choices of parents, emasculation, pollination, shortening of breeding cycle for early assessment, growing of hybrid seeds and planting in the field for assessment and selection.

**(i) Choice of parents**

In order to incorporate the desirable characters of one cultivar into other through hybridization, the knowledge of inheritance pattern and general and specific combining ability of the cultivars is very essential for making choice of parents in restricting the cross-combination and more seedlings population for better selection. The viability and germination ability of the hybrid seeds are also important factors in deciding the parents to be used in hybridization. It has been found that in some cultivars when used as female parents or selfed, the seed germination is poor and some time do not germinate e.g. Cordinal. If such cultivars are required in hybridization, they should be used as male parents in order to induce seedlessness in the progeny. It would be better to select a

variety having high seed index as female parents. Cultivar Angoor Kalan can also be used as female parent for earliness, seedlessness and good quality, but for the same purpose cultivars Beauty Seedless, Perlette and Pusa Seedless should be used as male parents

**(ii) Emasculation and pollination**

Emasculation of small flowers of grapes is a tedious job. Since the grape is self fertile emasculation is most essential for making desired crosses. Use of reflexed stamens and functionally female cultivars like Hur, Angoor Kalan, Banquiabyad, Katta, Kurgan as female parents can help in eliminating the tedious task of emasculation. Iyer and Randhawa (1966) reported that aqueous solutions of maletic hydrazide (MH) at 400 to 750 ppm, 2,3,4 Tri iodo – benzoic acid (TIBA) at 400 to 500 ppm and 1,2 dichloro-iso-butyrate (FW-450) at 0.30% applied twice to 13 to 15 days old inflorescence induced pollen sterility. When emasculation is completed the emasculated bunches are bagged and pollinated with desired male parents very next day.

**Mutation breeding**

Mutation breeding may be attempted as a complementary tool in grape breeding for one or more important characters, without altering the whole genetic setup. The important mutagens used in grape breeding are physical mutagens (χ ray and γ rays ) and chemical mutagens (Ethyl Methane Sulphonate (EMS),N-Nitroso-N-Methyl Urethane (NMUT) and N-Nitrose-N-Methyl-Urea (NMU).

Further, induced mutations have resulted in a few improved varieties, New Perlette (Loose Perlette) with comparatively loose bunch has been evolved with χ rays (2.5 KR) treatment on Perlette Self thinning property of New Perlette is a result of meiotic irregularities caused by chromosomal translocation. Red

**Loose Perlette**

Niagara having red fruit from Niagara and Robin Cardinal an early maturing variety from Cardinal are other important induced mutants in grapes.

**Polyploidy breeding**

Polyploidy breeding has immense importance in the improvement of table grapes. The chief benefit from polyploidy is the increase in berry size. However, autotetraploids are found to be considerably sterile and are less productive than the parents. The crossing of diploid with induced tetraploids may help in evolving new triploid seedless grapes. The triploids are highly sterile. Allo tetraploids even between infertile species have been more desirable as commercial varieties. Colchicine is generally used as an aqueous solution of 0.25-5.0% with 5-10% glycerine to induce polyploidy. Marvel Seedless from Delight, Early Niable (Campbell x Niagra), Lonetto, Early Giant from Campbell, Muscat Common Hall from Muscat Alexandria, Black King from Campbell, Wallis Giant from Concord, Case from Sultana etc. are important examples of polyploidy

**Biotechnological tools**

**Embryo rescue technique**

Seedlessness is a desirable character for table and raisin grapes. Inheritance of seedlessness is postulated to depend on two complementary recessive genes and only about 7.5% of the total progeny from crosses between Seeded x Seedless grapes produced fruits without noticeable seed traces. The embryo rescues theoretically increases the proportion of seedless progeny as it makes possible to cross two seedless varieties. Ovules are excised before abortion and are cultured on either filter paper in liquid medium or solid medium

**Genetic engineering / Plant transformation**

Some encouraging preliminary results have been obtained on *Agro bacterium*-mediated transformation of grape vines. But the production of genetically transformed grape vines which express a marker gene is yet to be reported.

**Protoplast culture**

Protoplasts are of great importance as tool for genetic amelioration and somatic hybridization. But regeneration of grape vines from protoplasts has not yet been successful.

**Anther culture**

Anther culture can result into haploid grape vines which can then be developed into homozygous diploids by doubling chromosomes. These homozygous diploids will be very useful for producing $F_1$ hybrids and for making genetic studies. But there is low success rate of regeneration of grape vines from anther and only one case of haploid has been reported in grape.

**New cultivars of grape**

**Arkawati** (Black Champa x Thompson Seedless)

Bunch is medium in size, yellowish green berry, sweet, TSS 22-25%, seedless berry, suitable for raisin making, fresh table use and making good quality dry and white table and dessert wine. Released in 1980.

**Arka Chitra** (Angur Kalan x Anab-e-Shahi)

Released in 1994, this is tolerant to powdery mildew, moderately vigorous vine, good yield potential (34kg/vine), Bunch is well filled, medium to large (310g), berry very attractive; golden yellow with pink blush, slightly elongated, large (3.18g), sweet, TSS 20-21°B, acidity 0.4-0.6%, suitable for table purpose, all the buds are fruitful, suitable for head system of training and gives two crops in a year.

**Arka Hans** (Bangalore Blue x Anab-e-Shahi)

Released in 1980, bunch is medium in size, berry yellowish green, sweet, TSS 18-21°B, having foxy flavor seeded cultivar, suitable for making quality wine, resistant to anthracnose.

**Arka Kanchan** (Anab-e-Shahi x Queen of the Vineyards)

Bunch is large, golden yellow colour berry, ellipsoidal to ovoid, sweet, TSS 17-20°B, having muscat flaovur, seeded cultivar, suitable for fresh table use and dry white table and dessert wines, released in 1980.

**Arka Krishna** (Black Champa x Thompson Seedless)

Vigorous vine, good yield potential (30kg/vine), Bunch well filled berry, dark colored, seedless, sweet TSS 20-21°B, acidity 0.6-0.7%, suitable for head system of training and gives two crops in a year, suitable for juice making, released in 1980.

**Arka Majestic** (Angur Kalan x Black Champa)

Released in 1994, vine is vigorous, high yield potential (34kg/vine), Bunch is well filled, medium to large (370g) berry deep tan colour, sweet, TSS 18-20°B, acidity 0.4-6% all the buds are fruitful, suitable for head system of training, it gives two crops in a year. Tolerant to anthracnose.

**Arka Neelamani** (Black Champa x Thompson Seedless)

Vigorous vine with high yield potential (25kg/vine), bunch well filled, sweet, TSS 20-22°B,suitable for head system of training, it is good for table purpose and making red desert wine, tolerant to anthracnose, released in 1980.

**Arka Shyam** (Bangalore Blue x Black Champa):

It was released in 1980, bunch is medium in size, berry bluish black, spherical to obovoid, sweet, TSS 20-25°B,having mild foxy flavour and seeded, it is good for fresh table use and making dry table, dessert wines and juice, resistant to anthracnose disease.

**Arka Soma** (Anab-e-Shahi x Queen of the Vineyards)

This variety was released in 1994, vine is vigorous with heavy yield potential (36kg/vine), bunch is well filled large (410g) berry greenish yellow, round to ovoid large

(3.8g),sweet, TSS 20-21°B,acidity 0.5% having muscat flavor, gives two crops in a year, suitable for good white dessert wine.

**Arka Trishna** (Bangalore Blue x Convent Large Black)

It was released in 1994, it is an improvement over variety Bangalore Blue, vine is vigorous, having high yield potential medium bunch, well filled, very sweet, TSS 22-23°B, acidity 0.3- 0.4% it is male sterile hybrid, good for wine making suitable for head system of training, resistant to anthracnose and tolerant to downy mildew.

**Arka Sheweta or Shweta Seedless** (Anab-e-Shahi x Thompson Seedless)

It was released in 1994, moderately vigorous vine, yield potential is about 28kg/vine, bunch is medium, it responds to GA3 application for berry thinning and enlargement, berry seedless, sweet, TSS 18-19°B, acidity 0.5-0.6%, berry greenish yellow.

**Digrasset**

This variety was collected at ARI (MACS), Pune from the grape germplasm collection maintained at Ganesh Khind Botanical Garden, Pune in 1976. It is a clone of *Vitis champini*, Vine shows vigorous, spreading and prostrate growth having deep root system. It remains dormant during winter season after October pruning and again grows in February-March under climatic conditions of Maharashtra. This is a potential root stock for growing grape under saline and drought conditions.

**Pusa Navrang** (Madeleine Angevine x Rubired)

It was released in 1996, it is basal bearing, tenturier (peel and pulp both coloured), seeded cultivar, it is early maturing, suitable for making coloured juice and wine, bunch is loose and medium TSS 19°B, resistant to anthracnose.

**Pusa Urvashi** (Hur x Beauty Seedless)

It was released in 1997, it comes in early group, bunch is medium, berry is greenish yellow, TSS 20-22°B.

## Questions

1. Variety suitable for wine production Arka Hans.

   **Ans:True**

2. Give an example for a grape variety developed through mutation

   **Ans: Cardinal**

3. Anthracnose is a major fungal disease in grapes.

   **Ans:True**

4. Embryo rescue technique is one of the biotechnological tools used for development of seedless grapes.

   **Ans:True**

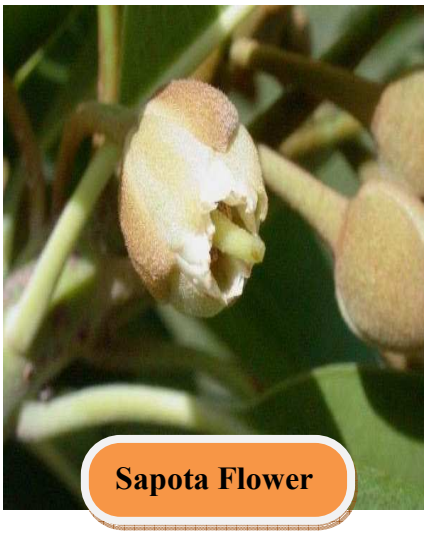
**Lecture.20**

**Crop improvement in sapota and pomegranate**

## SAPOTA

**Sapota :** *Achras zapota*.,
**Family :** Sapotaceae
**Chromosome number** is 2n=2x=26.

It is a wind pollinated crop. Flowers are protogyny and the stigma grows out of the bud about two days before anthesis. Flowers open between 4-4.30 a.m. Anthers dehisce between 8-10 p.m. The flowers keep fresh for nearly two days. The stigma is found to be receptive two days before opening and continues to be like that up to 12 hours after opening. Peak receptivity is between 8-10 a.m. The total time taken from fruit set to maturity is 10-12 months under North Indian Conditions but in Tamil Nadu it takes only 4-5 months.


Sapota Flower

Flowers are emasculated and bagged before 4-5 p.m and well before the stigma protrudes out of the bud. The actual procedure consists of making a circular incision around the flower bud with sharp knife or blade, so that 2/3 of the upper floral cup is removed including the portions of calyx, corolla and epipetalous stamens. The style is left in position in remaining1/3rd of the floral cup. Stamens from male parent, which should shed their pollen in the early hours of next day, are collected in the previous day evening and kept over night in a petridish. These are used to pollinate the receptive stigma of the emasculated flower between 8-10 a.m in the next day.

### Breeding objectives

The main emphasis on breeding of sapota are to develop dwarf stature trees with precocity in bearing, high yield and high keeping quality of less seeded fruits with less latex

**Breeding methods**

**Clonal selection**

Number of varieties like Cricket Ball, Kirthi Barthi, oval, Thagarampudi, Badami, Baramasi and Guthi exhibit natural variability. Exploration of this natural variability by clonal selection is an accepted method of breeding in sapota.


**CO.2**: developed at TamilNadu Agricultural university, Coimbatore is a clonal selection from Baramasi. It is a high yielder; seeds are less in number and small sized (2-3)

**PKM.1**: developed at Horticultural College & Research institute, Periykulam (TNAU) is also a clonal selection from Guthi. It is a dwarf, high yielding (3600 fruits/tree/year), almost bearing throughout year.


**PKM – 4:** a clonal selection from open pollinated seed of PKM – 1. It has spindle shaped fruits suitable for dry flakes production. Pulp is attractive with light pinkish honey brown colour, crisp and sweet flesh (TSS 24˚brix).

**Hybridization**

Tamil Nadu Agricultural Univerity, Coimbatore has developed four hybrids so far.

**1. Co.1**: It is a hybrid between Cricket Ball and Oval. This variety is superior to either of the parents. The fruits are long oval (egg shaped), medium in size with a mean fruit weight of 125g. The flesh is granular in texture and reddish brown in colour, taste being very sweet with a TSS of 18˚Brix.

**2. Co.3**: It is hybrid between Cricket Ball and Vavivalasa. Fruits are oblong – ovate in shape. Pleasantly flavored, very sweet with a T.S.S of 24.2. The average yield of the tree is 157 kg as compared to only 101.32 kg and 109.5 kg in CO-1 and CO-2 respectively. The stature of the tree is more upright and compact, suitable for high density planting at a spacing of 5-6 m either way instead of the conventional spacing of 8mx8m.

**3. PKM.2**: It is a hybrid between Guthi and Kirthi Barthi developed at 'Horticultural College & Research institute, Periyakulam (TNAU). A high yielder with a performance of 1500 to 2000 fruits per tree per year weighing 80 to 100 kg. Fruits are bigger in size and oblong to oval shaped. The average fruit weight is 95g. TSS ranges from 25 to 27˚Brix.

**4. PKM. 3**: It is a hybrid between Guthi and Cricket Ball. It has vertical growth habit and hence lends itself for high density planting. Trees bear big sized fruits with oval shape and have cluster-bearing habit. The fruit yield is 14 tonnes per hectare.

**5. DHS:1**: A hybrid between Kalipatti and Criket Ball developed at UAS, Dharwad. Tree is vigorous, bearing round to slightly oblong fruits with high yield. The fruits are very sweet having a soft, granular and mellowing flesh with

a TSS of 26˚brix. The colour of the pulp is light orange. The mean fruit weight is 150g.

**6. DHS.2:** It is also a hybrid between Kalipatti and Cricket Ball. Tree is vigorous and bearing round fruits. It is a high yielder. The fruits are sweet with a TSS of 23˚ brix having a light orange brown pulp, which is soft, granular and mellowing. The mean fruit weight is 180g.

## Pomegranate

**Botanical name:** *Punica granatum* L.

**Family:** Punicaceae

**Chromosome number :** 2n = 2x =18

**Centre of diversity**

Pomegranate is native of Iran and cultivated extensively in the Mediterranean countries like Spain, Morocco, Egypt, Iran, Afghanistan and Baluchistan. It is also grown to some extent in Burma, China, Japan, USA, USSR and India.

**Germplasm resources**

Being cross pollinated crop, a lot of variability exists in seedling populations, which can be utilized in further improvement programme. At present 150 genotypes of pomegranate have been maintained at Central Institute of Arid Horticulture, Bikaner (Anon., 2002). Out of these genotypes, 55 are deciduous and rest 95 are of evergreen in nature. Field gene banks of pomegranate are maintained at Abohar, Rahuri, Bikaner, Bangalore, Allahabad, Jodhpur and Ludhiana.

**Objectives**

- To develop suitable types which produce small soft seeds with attractive red (pink) aril.
- To develop easily manageable upright growth habit of the tree.
- To develop thornlessness in the twigs, a desirable character as it helps in cultural management of the tree.

- To develop varieties resistant to fruit borer (*Virachola isocrates*) and fruit rot (*Phomopsis sp.)*
- To develop varieties free from fruit cracking, aril blackening.
- Identification and development of suitable varieties for cold arid region.
- Varieties with longer steerage life.

**Breeding methods and achievements**

**Introduction**

Some important cultivars including soft seeded , dark red grained types, viz. Wonderful from the USA, A.Males, Be Hastah, A Alah, A Agha,Mohammed Ali, A Post Sephid Sirin from Iran and Ranninj G-1-8-23,Rannyij G-1-3-34, Chereny,Gulsha Red, JG-1-8-7 from USSR and few cultivars from Tunisia have been introduced. At Hissar, cultivar Shirin Anar and Russian Seedling were found resistant to bacterial leaf spot. A pomegranate line of Iranian origin has been indentified at Rahuri which has dark pink arils, soft seeds and high TSS (Singh and Rana, 1993).

**Selection**

Many pomegranate types cultivated in India are of seedling origin. They offer a wide range of variability with respect to shape and size of fruits, mellowness of seeds, aril colour, rind colour, sweetness and acidity. On the basis of yield and physico-chemical characters of fruits, number of cultivars have been recommended for commercial cultivation in different states of India,viz. Ganesh, G-137,P-23,P-26 and Muscat in Maharashtra, Bassein Seedless, Jyothi and Madhugiri in Karnataka, Dholka in Gujarat, Jalore Seedless, Jodhpur Red , and Jodhpuri White in Rajasthan and Kabul Red, Vellodu, Yercaud 1, and Co-1 in Tamil Nadu. Two ornamental types (Japanese Dwarf and Double flower giving red, yellow and white flowers) are planted in the omamental gardens (Nath and Randhawa,1959). Due to considerable variability and their adaptability to existing agro-climatic conditions, selection of superior genotypes will be the best approach to get desirable ideotypes. The cultivar GBG-1 is a selection from open pollinated population of Alandi in 1932. The name Ganesh was given in 1970. Five Muskat types, namely P-13, P-16, P-23, P-26 and SK-1 were identified by Naik (1975). Further, P-23 and P-26 were released in 1986 for commercial cultivation by MPKV, Rahuri. At the University of

Agricultural Sciences, Bangalore as a result of evaluation of seedling populations raised from Bassein Seedless and Dholka Varieties, GKVK-1 now named as Jyothi was released. At Coimbatore self seeded selection Co-1 was identified (Khader *et al.*, 1982).

**Clonal Selection**

G-137 is a superior clonal selection over Ganesh, other clones are also superior i.e.G-107,G-132,G-133. Sayed *et al*.(1985) reported a clone Acc.No.455 which has been renamed as Yercaud-1 and released for commercial cultivation in Tamil Nadu.

**Hybridization**

In order to incorporate blood red colour of Russian types into Ganesh, several crosses were made at Rahuri in 1976.Out of 122 $F_1$ hybrids, seven had deep red aril colour but the seeds were hard and inferior in taste than Ganesh. A promosing line from the $F_2$ population (No.61) combining desirable quality attributes has been released by the name Mridula (Ganesh x Gulsha Rose Pink).


**Mutation**

Use of physical (x rays) and chemical mutagens (N, N-dimethyl N.nitrosourea) may help in the development of the superior cultivar of soft seeded types (Levin, 1990).

**Biotechnological tools**

Attempts have been made to regenerate the plant by using leaf (Omura *et al.,* 1987) and shoot tip explants (Mahinshni *et al.,* 1991). Enzyme based marker was also used to identify the genetic variability among the existing genotypes. Somatic embryogenesis was also practiced by using petal as explant (Nataraja and Neelambika, 1996).

Important characteristics of some promising selections raised from open pollinated fruit of $F_1$ hybrids of pomegranate (Keskar *et al.,* 1993).

| Characteristics | Sel-5 (Ganesh x Shirin Anar) | Sel-130 (Ganesh x Gulsha Rose Pink) | Sel-303 (Ganesh x Gulsha Red) |
|---|---|---|---|
| **Fruit colour** | Apple red | Greenish brown | Yellowish brown |
| **Fruit weight (g)** | 130 | 107 | 140.0 |
| **Fruit size LxB (cm)** | 6.9x6.5 | 6.1x6.5 | 5.5x6.8 |
| **Aril colour** | Blood red | Dark red | Blood red |
| **Mellowness of seeds** | Soft | Soft | Soft |
| **Taste** | Sweet | Sweet | Sweet |
| **No. of grains/100g** | 58 | 94 | 45 |
| **Grain Peel ratio** | 1.17 | 1.17 | 1.80 |
| **Juice colour** | Dark red | Blood red | Blood red |
| **Juice (%)** | 80 | 80 | 80 |
| **TSS (%)** | 18.4 | 15.8 | 19.0 |
| **Acidity (%)** | 0.64 | 0.80 | 0.64 |

**Cultivars of pomegranate grown in different states**

| Name of the states | Cultivars |
|---|---|
| Rajasthan | Jalore Seedless, Jodhpur Red,Jodhpuri White. |
| Haryana | Ganesh,Muskat Red,Paper Shell. |
| Gujarat | Dholka,Muskat Red,Paper Shell. |
| Maharashtra | Ganesh,G137,P23,P26,Muskat Mridula |
| Karnataka | Bassein Seedless,Jyothi, Paper Shell,Madhugiri |
| Tamil Nadu | Co-1, Yercaud, Vellodu, Kabul Red. |

**Description of important cultivars**

**Alandi**

Also known as Vidaki, medium fruit size, fleshy testa, blood red or deep pink with sweet, slightly acidic juice with hard seeds.

**Dholka**

Large fruit size, greenish white rind, fleshy testa, pinkish white or whitish with sweet juice, soft seeds and acidic juice.

**Kabul**

Large fruit size, rind deep red mixed with pale yellow, thick, fleshy testa dark red, slightly bitter juice.

**Kandhari**

Fruit large in size, rind deep red, fleshy testa, blood red or deep pink with sweet, slightly acidic juice, hard seeds.

**Muskat red**

Fruit small to medium in size, rind somewhat thick, fleshy testa with moderately sweet juice, seeds are semi hard.

**Paper Shell**

Fruit medium in size,rind thick,fleshy testa, reddish pink with sweet juice and soft seed.

**Spanish Ruby**

Fruit small to medium in size, rind thin, fleshy testa rose coloured, soft seed.

**Ganesh**

Prolific bearer, medium fruit size, soft seeds, sweet in taste.

**Jyothi**

Also known as GKVK-1, attractive yellowish red fruit colour, medium fruit size, red aril colour and soft seeds.

**Vellodu**

Fruit medium to large in size, rind moderately thick, fleshy testa, juicy, seed moderately hard.

**Poona**

Fruit large in size, fleshy testa, deep scarlet or pink and red.

**Bedana**

Fruit medium to large in size, rind brownish or whitish, fleshy testa, pinkish white with sweet juice and soft seeds.

**Bhagwa**

It is developed by MPKV, Rahuri. It is tolerant to thrips and mites, it is free from blackening of arils and there is no incidence of fruit cracking. Fruits have cherry red bold aril.

**Phule Arakta**

It is also developed by MPKV, Rahuri. Plant is heavy yielder with bigger fruits and sweet soft seed. It is less susceptible to fruit spots and thrips.

**Questions**

1. In Sapota, anthesis occurs between 4-4.30 a.m.
   **Ans:True**
2. Pomegranate is native crop of Iran.
   **Ans:True**
3. Pomegranate variety with blood red color is Alandi.
   **Ans:True**
4. Paper Shell is soft seeded variety of pomegranate.
   **Ans:True**
5. Sapota flowers are protogyny in nature.
   **Ans:True**
6. The main emphasis on breeding of sapota is to develop dwarf stature trees with precocity in bearing.
   **Ans: True**

**Match the following**

7. **CO.2** - clonal selection from Guthi
8. **PKM.1** - hybrid between Kalipatti and Cricket Ball
9. **PKM .4** - clonal selection form Baramasi
10. **DHS:1** - clonal selection from PKM.1

**Ans**

11. **CO.2** - clonal selection form Baramasi
12. **PKM.1** - clonal selection from Guthi
13. **PKM .4** - clonal selection from PKM.1
14. **DHS.1** - hybrid between Kalipatti and Cricket Ball

**Lecture.21**

**Crop improvement in pineapple and guava Pineapple**

**Botanical name :** *Ananas comosus* L.

**Family:** Bromeliaceae

**Chromosome number:** 2n = 2x = 50

**Centre of diversity**

Pineapple is believed to be originated in Brazil. The wild Brazilian pineapple (*Ananas microstachys* Lindle) is considered as ancestor of cultivated pineapple. It reached India during 1548. The geneic name "Ananas" is derived from the Indian "Nana".

**Germplasm resources**

In India, much attention has not been given in the development of field gene banks. However, commercial cultivars are maintained at BCKV, Kalyani, Agriculture Research Station, Kovvur (APAU), Department of Horticulture, College of Agriculture, Jorhat, Regional Research Station: Diphu (Assam Agricultural University), Department of Horticulture, College of Horticulture, Navsari (GAU), College of Horticulture at Vellanikara and Trichur. A list of 135 varieties was published as early as in 1935 by Johnson, although some of them were found synonymous.

**Objectives**

- To develop high yielding, early maturing varieties with wider geographical adaptability.
- Plant should be hardy, vigorous, capacity to produce good ratoon crop, leaves should be spineless.
- Fruit stalk should be short and strong.
- There should be flat eyes and small cones.
- Development of varieties resistant to biotic and abiotic stresses (e.g. multiple crown, fasciation, wilt, heart rot, root rot and nematode).

**Inheritance Pattern**

According to Collins, 1960 spineless form in which spines are restricted to top few inches of the leaf and dominanat to spiny wild type. Further many wild cultivars possess spiny leaves. *Ananas ananosoies* is also a source of disease resisteance. The cultivar pernambuco is donor for good flavor and aroma, tender non fibrous juicy fruits, early fruiting, resistant to heart and root rot. Queen can be for crisp, non fibrous deep yellow flesh fruits, early Repening.

Red Spanish is good source of vigour, resistance to wilt, heart and root rot. Singapore Spanish can be good donor for square. Shouldered fruits with golden yellow flesh and wild species are good source of vigour, resisteance to various disease and pests, spiny tip and spiny characters are the phenotypic expression of single pair of alleles, with spiny tp being dominant (Collins and kerns,1946). Homozygous 55 and heterozygous 5 and produce spiny tips, recessive and may give rise to spiny plants progeny (Collins and kerns, 1946). The piping and non piping characters are controlled by another non- linked pair of alleles with the gene P (piping) being epistatic to 5 and s. The homozygous pp genotype produce pronounced piping than Pp genotypes. Frequent mutations of 5 and s occur (scn. 1996*)*. *Ananas erectifolius* is having $S^e$ gene of smooth tip leaves. (Collins, 1960).

**Breeding methods and achievements**

**Selection**

Most of the cultivars/varieties of pine apple were developed by simple selection of mutant clones within cultivars and by hybridization between cultivars followed by selection from the highly heterozygous progeny. Selection from the Singapore Spanish population in Malaysia had led to a new cultivar, “Masmerah”. It is more vigorous, possessing more leaves, stand more erect and bears heavier fruit than the parent cultivar (Wee, 1974). Several such selections have been made in different pineapple growing areas.

## Hybridization

A cross between Red Spanish and Cayenne has led to the development of a new hybrid PR-1-67 in Puerto Rico (Remirez, 1970). This hybrid shows better plant vigour and resistance to wilt disease. However, self fertile somatic mutants obtained from cultivar Cayenne show a loss of vigour on selfing and heterosis on crossing. A hybrid (H-7) has been produced by crossing Valera Monendi x Kew. This hybrid produces large fruits, individually weighing on an average 3.0-3.5 kg.

## Mutation


Induction of mutation in this crop seems to be quite feasible. However, due to wide natural variation, limited attempts have been made for induced mutations. In Kerala, irradiation of plants of cultivar Kew and Mauritius led to growth retardation and premature suckers. Merz (1964) reported the induction of self fertile mutants by X- ray irradiation of pollen during meiosis. Several morphological mutations were found when 1.0 to 1.5 month old detached slips were treated with chemical mutagens like Ethyl imine-(El), N-Nitroso-N-Methyl Urethane (NMU) and Diethyl Sulphate (DES). One mutant produced spineless plants from cultivar Queen and was economically significant (Singh and Iyer, 1977).

## Biotechnological tools

Attempts have been made for rapid multiplication of the plants through micro propagation by using different kinds of explants i.e. leaf base, shoot base, excised lateral buds, meristem tips from crown etc. In the crosses where fertilization fails due to incompatibility, embryo culture technique can help to rescue the hybrid. The genetic

transformation of pineapple clones has been attempted with the objective to acquire ability to introduce desirable genes

**Major group and varieties of pineapple**

| | Cultivars | Important Characteristics |
|---|---|---|
| **Abacaxi (Brazilian)** | Abakka, Amarella, Papelon, PinaValera, Sugar Loaf, Venezolana,Vermelho,Yupi | Fruit conical in shape, weighing about 1.2 to 1.5kg, yellow rind, pale yellow or white flesh, sweet, tender, and juicy, leaves spiny, disease resistant, grown for fresh domestic consumption. |
| **Cayenne** | Boron, Baraonne de Rothschild, Champaka, Cayenne Lisse, Emeralda,Gautemalan,Giant Kew,Hilo Cayenne, Kew, Rothschild, Smooth,St.Micheal Smooth Cayenne,Typhone. | Fruit shape is cylindrical with a slight upward tapering and flat eyes, most suitable for canning fruit weight is about 1.8 to 3.0 kg. Colour of rind is dark orange and flesh is pale yellow, sweet, mildly acid with low fiber and a tender juicy texture, leaves smooth with few spines near the tip, highly susceptible to mealy bug and wilt, suitable for export. |
| **Vaipure** | Bumanguesa,Legrija,Maipure,Marquita, Monte Lirio, Perolera, Plamba de, Rondon | It is sweeter than the Cayenne, aromatic, fibrous but tender and very juicy, leaves completely smooth, grown for fresh consumption, fruit ovoid to cylindrical in shape, fruit weight is about 0.8-2.9 kg, rind colour is yellow to dark orange or red, flesh is white or deep yellow. |
| **Queen** | Alexandria, Bakhat, James, Jhaldhup, MacGregor,Mauritius, Netal,Queen,Ripley,Victoria,Z.Queen | Fruit shape is conical, weighing about 0.5 to 1.12 kg rind is yellow, flesh is deep yellow, less acidic than Cayenne, sweet, low in fiber, spiny leaves, highly resistant to diseases than the Cayenne. |
| **Spanish** | Betek, Cabezona, Castilla, Espanola Roja, Gandol, Green Selangor, Masmerah, Nangka,PRI-67,PRI-56,Red Spanish,Singapore Spanish. | Fruit shape is globose, fruit weight is 0.9-1.8 kg rind deep reddish, flesh pale yellow to white with spicy acid taste, fibrous texture, leaves spiny, resistant to mealy bug and wilt, susceptible to gummosis, suitable for export and fresh consumption. |

# GUAVA

**Botanical name: *Psidium guajava* L.**
**Family: Myrtaceae**
**Chromosome number 2n-2x-22**

Guava is also known as the 'Apple of the Tropics. It is a very rich and cheap source of vitamin C and also contains a fair amount of calcium. Important guava growing states in the country are Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra. Allahabad district of Uttar Pradesh has the reputation of growing the best quality of guava fruits in the world (Mitra and Bose, 1990). The importance of guava is due to the fact that it is the hardy fruit which can be grown in alkaline and poorly drained soil.

## Center of diversity

Tropical America is supposed to be the center of origin of guava where it is found in wild as well as cultivated forms. Guava came to India at a very early time before 17$^{th}$ century.

## Germplasm resources

Guava is mainly a self pollinated crop but occurrence of cross pollination results in great variation in the seedling population. About 103 genotypes are available in the Indian collections (iyer and Subramanian, 1987) while Yadav (1990) has listed 153 genotypes including *Psidium* species, cultivars and hybrids mainly at CISH, Lucknow, IIHR, Bangalore, NDUAT, Faizabad, and HAU, Hisar. Guava germplasm is being maintained at several centers in the country in field banks which are often not systematically maintained (Pathak and Ojha,1993).

## Breeding objectives

1. Devlopment of seedless variety
2. Less pectin content for edible purpose
3. More peetin content for processing
4. Uniform ripening

5. High keeping quality
6. Resistance to tea mosquito bug and wilt.

**Botany**

Most of the Cultivars of Indian guava belongs to the genus *Psidium* and species *gujava.* Based on the shape of common guava fruits, they are classified into two groups (De Candolle 1904) i.e. *Psidium pyriferum*, *Psidium pomiferum*. Genus *Psidium* contains about 150 species (Hayes, 1970). All cultivated varieties of guava are either diploid 2n-2x-22 or triploid 2n-3x-33 (Atchinson, 1947).

**Floral biology and pollination**


Guava Flower

Guava bears flower solitary or in cyme of two to three flowers, on the current season growth in the axil of the leaves. About one month is required from flower bud differentiation to complete development upto calyx cracking stage. Peak time of anthesis is between 5.00-6.30 AM in most of the varieties of guava. The dehiscence of anthers starts 15-30 minutes after anthesis and continues for two hours. The pollen fertility is high in almost all the cultivars. The pollen fertility is 78% and 91% in Allahabad Round and Lucknow Safeda, respectiviely.

**Inheritance pattern**

- Bold seed is found to be dominant over soft seed and governed monogenically.
- Red flesh colour is dominant to white pulp colour and also goverened monogenically.
- Red fleshed cultivars are supposed to be heterozygous

- There is linkage between red flesh colour and bold seed size.
- Triploidy and some other genetic factors are responsible for female sterility.

**Breeding methods and achievements**

**Clonal Selection**

Propagation by seeds during early days gave rise to considerable variation in the form and size of fruit, the nature and flavour of pulp, seediness and other morphological characters such as spreading or erect growth habit of the tree. Improvement work in guava was started for the first time in the country in 1907 at Ganesh khand fruit Research Station, Pune primarily with the collection of seeds of varieties, grown in different places to isolate superior strains. About 600 seedlings were raised and evaluated for fruit and yield characters. One strain from open pollinated seedlings of Allahabad Safeda collected from Lucknow was selected and released as Lucknow -49 which is a popular variety throughout India.

At Horticultural Research Station, Saharanpur, evaluation of seedling types resulted in a superior selection, S-1, having good fruit shape, few seeds, sweet taste and high yield.

At Narendara Deva University of Agriculture and Technology, Faizabad, out of the 23 strains collected as a result of survey in guava growing region, 3 seedlings of Allahabad Safeda (AS1,AS2,AS) and 2 of Faizabad Selections (FS1and FS2) were found to be promising with respect to fruit quality and yield. At IIHR, Bangalore, from 200 open pollinated seedlings of variety Allahabad Safeda collected from Uttar Pradesh, one seedling selection, selection-8, was found to be promising. These plants are dwarf and give higher yield. The fruits are of medium size with white pulp and few soft seeds and excellent. This selection has been named as Arka Mridula.

**Achievements**

| Sl.No | Varieties | Important characters |
|---|---|---|
| 1. | L.49 | Developed at GFES, Pune, Seedling selection of Allahabad Safeda, Semidwarf tree, high yielding |

| | | |
|---|---|---|
| | | and white flesh. |
| 2. | Banarsi Surkha | It is a selection from local red fleshed type, heavy bearer, large fruits, flesh soft and pink. |
| 3. | CISHG-1 | Developed at CISH, Lucknow. Fruit skin colour is deep red, TSS 15°Brix, soft seeds. |
| 4. | Bangalore Local | It is a local selection, with white flesh and soft seeds, fruit is large. |
| 5. | Arka Mridula (Sel -8) | Develoed at CISH, Lucknow, it is a selection from apple colour seedling, skin and flesh colour is pink with good acid sugar blend. |
| 6. | Plant prabhat | Seedling selection from GBPUAT, Pantnagar, Prolific bearer, soft seed with good quality |

**Hybridization**

At IIHR, Bangalore, as a result of hybridization among Allahabad Safeda, Red Flesh Chittidar, Apple colour, Lucknow-49 and Bananas, 600 $F_1$ hybrids were raised. One hybrid Arka Amulya has been released recently. It is a progeny from the cross Allahabad Safeda x Triploid. Plants are medium in vigour and are spreading type. Fruits are round in shape. Skin is smooth and yellow in colour. Fruits on an average weigh about 180-200 g, Flesh is white in colour and firm. TSS is around 12˚Brix, soft seeded, keeping quality is good.

Hybrid 16-1 (Apple color x Allahabad safeda) has been developed. Plants are semi vigorous, moderate yielding, fruit skin bright red with few seeds high Tss and good keeping quality (Subramanyam and I year, 1993).

At Fruit Research Station, Sangareddy (Andhra Pradesh), inter-varietal hybridization resulted in the isolation of two superior hybrids.

***Safed Jam***: This is a hybrid between Allahabad Safeda and Kohir (a local collection from Hyderabad –karnataka region). It is similar to Allahabad Safeda in growth habit and fuit quality. The fruits are bigger in size with good quality and few soft seeds.

***Kohir Safeda*:** It is a hybrid between Kohir x Allahabad Safeda, Tree is vigorous, fruits are larger with few soft seeds and white flesh.

Haryana Agricultural University, Hissar has released two hybrid varieties.

***Hisar Safeda***: It is a cross between"Allahabad Safeda" x 'Seedless', which has upright growth with a compact crown. Its fruits are round, weighing about 92g each, pulp is creamy – white with less seeds, which are soft, TSS is 13.4% and ascorbic acid 185 mg/100g.

***Hisar Surkha****:* It is a cross between'Apple Colour' x 'Banarasi Surka'. Tree is medium in height with broad to compact crown, fruit is round weighing 86g each. Pulp is pink having 13.6% TSS.0.48% acidity and 169 mg/100g ascorbic acid. Yield is 94 kg/tree/year.

CISH, Lucknow isolated two hybrids H-136 for red pulp and soft seeler with high Tss.

**Breeding for wilt resistance**

Work at CISH, Lucknow has shown that Chittidar, Portugal, Seedless and Spear Acid are tolerant to wilt.

Resistance species of guava can be utilized for imparting the wilt resistant character. It was observed that *psidium guajava* and *psidium chinensis* are compatible. However, cross between *psidium guajava* and *psidium molle* was incompatible but reciprocal combination was a compatible combination (subramanyam and I year, 1982).

**Polyploidy Breeding**

Producing triploids will be futile since the fruit shape in triploid is highly irregular and misshapen because of differential seed size. However, in order to evolve varieties with less seeds and increased productivity, crosses were made at IARI, New Delhi, between seedless triploid and seeded diploid variety Allahabad Safeda. Of the 73 $F_1$ hybrids raised 26 were diploids, 9 trisomics 5 double trisomics and 13 tetrasomics. Distinct variation in tree growth habit and leaf and fruit characters was observed. Three trisomic plants had dwarf growth habit and normal shape and size of fruits with few

seeds. The imbalance in chromosome numbers in aneuploids imparted sterility resulting in seed reduction in fruits.

**Characteristics of important species and cultivars**

**Description of some important species are as under**

***Psidium guineense***

This is also known as the Guinea guava or Brazilian guava. The plants are like shrub or small tree. The leaves are green in colour, broad, oblong-oval, acute or obtuse, 8-12 cm long with lower surface pubescent. Red hairs are found on the mid veins.

***Psidium guineense***

***Psidium montanum***

Plants are just like shrub, attain a height of about 1.5m, flat round branches. It is found in mountains of Jamaica. Fruits are round with very poor quality

***Psidium montanum***

***Psidium fredrichsthalianum***

It is known as Chinese guava. Plants are tall (7-11 m height), fruits are small and globose in shape with high acid content. It can be used for jelly making. Plants are tolerant to guava wilt.

***Psidium Cattleanum***

It is known as the Cattely guava or Strawberry guava. It is a shrub or small tree (3-6 m in height), fruits are small, deep scarlet in colour, and globose in shape. This species is more tolerant to low temperature than *Psidium guajava.*

***Psidium cattleianum var. lucidum***

Tree height is more than Cattley guava in Hawai Island. Height of plant is noticed up to 12m. Generally, it is propagated through seeds. Fruits are yellow in colour and used for jelly making.

***Psidium molle***

Tree is medium in height; leaves are green and oval in shape. Apex of leaf is pointed; lower part of leaves is velvety in appearance. Red hairs are found on the central veins. In one leaf 6-8 pairs of primary veins are found. Petals are 5-11, stamens are 196-239, and stigma is long with big ovary of 3-5 chambers. Fruits are small in size, average fruit weight is 13g. It contains vitamin C about 70 mg/100 g of pulp

***Psidium pumilum***

It is also known as Chinese guava. Tree is like pyramidal in shape, leaves are light in colour, small in size, non-pubescent, having 13-17 pairs of primary veins. Petals 7 smooth and creamy colour which drop immediately after anthesis, Stamens are 252-327 in number, small stigma with medium size of ovary having 4-5 chambers. It flowers twice in a year. It takes about 130 days for attaining the maturity of fruits. Average fruit weight is about 19g and an average vitamin C content is 171mg/100g pulp.

***Psidium cujavilis***

Growth characters and flowering habit of the plants is just like *Psidium guineense*. The size of fruit is small to medium, average weight is 30-50 g, and sour in taste.

***Psidium policarpum***

The growth characters are similar to *Psidium guajava* except the shape of the fruits is periform. Average fruit weight is about 200-250g. Flavonoid patterns show close affinity between *P.guajava and P.molle* (Dass and Prakash, 1981). However, inspite of the morphological similarities in *P.molle* and *P.guineense*, they showed minute differences in flavonoid pattern.

**Questions**

1. Pineapple hybrid PR-1-67 is resistance to wilt disease.
   **Ans:True**
2. Spanish variety of pineapple is resistant to mealy bug.
   **Ans:True**
3. Guava is also known as the ‘Apple of the Tropics.
   **Ans:True**
4. Pineapple is rich and cheap source of vitamin C and also contains a fair amount of calcium.
   **Ans: False (guava)**
5. Most common breeding objective of guava fruit is development of seedless variety.
   **Ans:True**
6. Give an example for pink fleshed variety of guava Arka Mridula.
   **Ans:True**
7. Spear Acid guava variety is tolerant to wilt.
   **Ans:True**
8. *Psidium fredrichsthalianum* is tolerant to Guava wilt.
   **Ans:True**

9. *Psidium Cattleanum* is known as Strawberry guava.

   **Ans:True**

**Lecture.22**

**Crop Improvement In Apple and Other Rosaceae Crops**

## APPLE

Cultivated apple has been classified as *pumila group*. Majority of the cultivated apples are diploids (2n=34) and few are triploids (2n=51). Delicious group of apples are very popular and occupy 50-70 per cent area in the states of Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh and North- East hills.

### Breeding objectives

Apple is grown as a composite tree consisting of rootstock, scion and occasionally interstem. Thus genetic improvement must involve both rootstock and scion. The scion breeding objectives are to evolve varieties, red in colour with early maturity, high yield, superior dessert and storage quality and resistance to scab. Besides, a new wave of clonal rootstocks capable of surviving under wide range of environmental conditions, inducing precocity, enhancing productivity and fruit quality in scion are required to be bred.

### Genetics of apple

Malus has 25 to 30 species and several sub-species, many of which are cultivated as ornamental trees for their profuse blossoms and attractive fruits. Many of the species intercross freely and semi self incompatibility is common. Trees grown from collection of *Malus* are frequently inter-specific or inter-varietal hybrids. The cultivated apple is botanically *Malus domestica* Borkh.

***Malus domestica***

The majority of cultivated apples are diploids (2n=34). There has been a belief that they are complex polyploids, being partly tetraploids and partly hexaploid with the basic number of x=7 which is common in Rosaceae. The hypothesis is based on the associations and behavior of chromosomes and six sets of three chromosomes. So, they are functionally diploids. Among the cultivars, there are also triploids (2n=51). Triploids appear to be more common in cultivated apples, accounting for about 10 per cent of the commonly grown cultivars. Some triploid varieties are Baldwin, Gravenstein, Rhode Island Greening, Blenheim Orange and Mutsu. These are more vigorous and tend to have larger fruits but produce poor pollen and require diploids to pollinate them. These are useless as parents for breeding as they produce few seeds and give rise to weak seedlings.

**Sterility and Incompatibility**

Sterility and incompatibility are two main causes of unfruitfulness in apple. The generational sterility is caused by the failure of any of the processes concerned with the development of pollen, embryo sac, embryo and endosperm. This is common in triploids and some diploids. Gagnieu (1951) concluded that the segregation suggests a simple disomic inheritance of four different and possibly allelomorphic genes $P^1$ $P^2$ $P^3$ and $P^4$.

Sexual incompatibility which is due to the failure of the pollen, although functional, to grow down the style and bring about fertilization is widespread in the apple. Self incompatibility is particularly common, although cases of cross incompatibility are also known.

**Apomixis**

Facultative apomixes is characteristic of a number of *Malus* species which are probably of hybrid origin but does not appear to occur among the cultivated apples. The apomictic species which have been investigated are polyploids. *Malus sikkimensis* (Hook). Koehne is a triploid, *M.coronaria* (L.) Mill., *M.hupenhensis* (Pamp.) Rehd, *M.lancefolia* Rehd. *M.platycarpa* Rehd., *M.toringoides* (Rehd.,) Hugs are known in triploid and tetraploid forms. *M.sergenti* Rehd is known in diploid, triploid, tetraploid and pentaploid forms. Under normal circumstances, these species reproduce themselves freely by apomictic seeds but most of them can produce sexual hybrids if crossed with

sexual diploids. Seedlings from these apomictic species are not necessarily identical and a certain amount of variation can be found. The importance of this character in *Malus* species is that seedlings of some are sufficiently uniform to enable their use as rootstocks which are virus – free.

**IMRPOVEMENT**
**Introduction and Selection**
**Spur type cultivars**

At Regional Fruit Research Station, Mashobra, spur varieties introduced through the National Bureau of Plant Genetic Resources, New Delhi during the eighties are under evaluation. These varieties include Red Spur Delicious, Golden Spur Delicious, Miller's Sturdeespur, Oregon Spur and Red Chief of which Red Spur Delicious has been found to be promising.

**Golden Spur Delicious**

In UP, cultivars Red Spur and Oregon Spur were introduced from Italy and are being multiplied for evaluation.

**Colour Sports**

Colour sports like Royal Red, Vance Delicious, Top Red, Skyline Superme Red Delicious were introduced in HP. The cultivars Royal Red, Vance Delicious and Top Red and Skyline Supreme Red Delicious were found to be promising.

**Early varieties**

Among the early varieties introduced at NBPGR Regional Station, Phagli, Shimla, EC 32221, EC 38683. Yandik-Ovskoe and Papisovka Canniaga are promising

**Low Chilling Varieties**

Work at NBPGR Regional Station, Phagli, Shimla indicated that the cultivars Vered, Michal, Maayan, Shilomit, Hybrid-1 and Tropical Beauty were found to be promising for cultivation under mid and low hill conditions. In the mid hills of HP, the

cultivars Tropical Beauty and Parlins Beauty were found to be the best in respect of yield and fruit quality.

**Scab resistant varieties**

Scab is a serious disease of apple and none of the commercial varieties are resistant to it. Although some resistant varieties have been evolved in other countries, none of these compares favourably with the popular Delicious and its commercial sports. The scab resistant varieties Prima, Priscilla, Sir Prize, Jonafree, Liberty and Coop.12 introduced from USA are under evaluation at Regional Fruit Research Station, Mashobra and Bajaura in HP.

**Hybridization**

**Selection of Parents**

Most of the quality traits like size, shape, cropping, etc., are under polygenic control. Thus, when two cultivars are crossed, there will be a continuous range of expression of these characters in the seedlings and will not segregate into discrete categories.

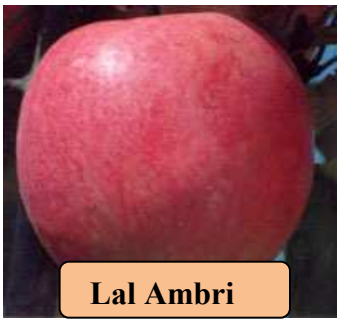
Williams (1959) calculated that the percentage of desirable seedlings that can be expected as the main product of an apple breeding programme for polygenically controlled characters is seldom more than 40 per cent and for every additional character, the figure rapidly decreases. Thus, for a programme in which the main objective is polygenically controlled mildew resistances, size of fruit, season of maturity, flavor and colour of skin, a reasonable estimate would be 40,20,20,10 per cent respectively.

**New Varieties**

The modern breeding, objectives are breeding of varieties with high yield, superior dessert and storage quality, disease and pest resistance. Breeding work on apple has been in progress at Regional Fruit Research Station, Mashobra in Himachal Pradesh, Fruit Reseach Station, Shalimar in Kashmir and Horticultural Experiments and Training

Centre, Chaubattia in UP. The major objectives were better shelf-life, early maturity, high dessert quality and scab resistance.

**Shelf-life and dessert quality**


Lal Ambri

All the popular Delicious group of cultivars ripen at the same time and thus cause glut in the market. With a view to combine high dessert quality with good keeping quality, work was initiated in Kashmir in 1956. Two hybrids, Lal Ambri (Red Delicious x Ambri) and agold (Ambri x Golden Delicious) were released. Work on similar lines was started in HP in 1960 (Chand, 1962). As a result three promising hybrids, namely, Ambred, Ambstarking, and Ambrich were selected. Subsequently, hybrid Ambroyal was also selected Salient characters of these hybrids are enumerated below.

**a) Ambred** (Red Delicious x Ambri 157) : Tree is tall, maturity in second week of September; fruits medium in size, conical, symmetrical, bright red stripes over barium yellow ground; dots obscure; skin medium in thickness, smooth and glossy; flesh whitish, crisp, firm aromatic and juicy, keeping quality is good up to three months in air cooled storage. It has low incidence of powdery mildew, sooty blotch and apple scab.

**b) Ambstarking** (Starking Delicious x Ambri 81): Tree is vigorous, tall and open, maturity in second week of September; fruits medium in size, round, conical symmetrical and uniform in shape, currant red streaks over chrome yellow ground; dots numerous and conspicuous; skin rough, smooth, flesh whitish firm, crisp, tough and juicy; keeping quality comparable with Starking Delicious. It is tolerant to apple scab.

**c) Ambroyal** (Starking Delicious x Ambri 84): Tree is semi-dwarf and spreading. Fruit maturity is in third week of September; fruits medium in size, conical in shape; skin thin. smooth, red streaks on yellow ground; flesh white, soft, sweet, juicy with good dessert quality. Storage quality is comparable with Starking Delicious.

**d) Ambrich** (Richard x Ambri 15): Tree is semi-dwarf, semi-spur type; spreading drooping fruit maturity in second week of September, fruit medium size, round , conical

in shape, symmetrical sides equal and uniform, skin thick, smooth with chrysanthemum crimsonwash; flesh whitish, firm crisp, sub acid aromatic and juicy with good dessert quality. Tree is moderately susceptible to powdery mildew and tolerant to apple scab.

**Early and dessert quality:** Work was started at Chaubattia in 1970 and two promising hybrids Chaubattia Princess and Chaubattia Anupam were evolved. Both these are from crosses of Red Delicious x Early Shanburry.

Chaubattia Princess ripens during last week of June to the 1st week of July. The tree is of medium vigour with upright growth habit. Fruits are medium in size, regular and conical in shape. Fruit skin is thin and smooth with deep red streaks on pale background. Flesh is creamy white, crisp in texture, firm juicy and very sweet. TSS is 14 per cent and acidity 0.22 per cent. The fruit pressure at maturity is 14 to 15 1b/sq. inch. Keeping quality is quite good.

**Scab resistance**: During 1983, crosses Gala x 58553, Liberty x Delicious, Gala x 6356-22 Gala x 6143-1, Freedom x delicious, Gala x Prima and Freedom (open pollinated) were made at Mashobra and the hybrid seedlings are being evaluated.

**Out breeding and Backcrossing**

Dominant single gene resistance in a *Malus* species can be transferred to the cultivated apple by a modified backcross procedure to avoid inbreeding. The method involves crossing the wild species with a large fruited cultivar. The resistance $F_1$s is heterozygous and the best ones are selected and backcrossed to a good cultivar and their progeny yields 50 per cent resistant seedlings. The best of these are again backcrossed to a good cultivar until all the good qualities of the cultivated apple are recovered and the resistance from the wild species retained. This avoids inbreeding by alternating different cultivars for the recurrent quality parent and eliminates loss of vigour and incompatibility problems.

## Mutation Breeding

Work on induction and selection of desirable bud mutants was taken up at Horticulture Experiment and Training Centre, Chaubattia in 1973. As a result, four mutants with distinctly compact habit and better keeping quality of fruits were selected and are being evaluated under different agroclimatic conditions.

# PEACH

## Breeding objectives

The main objective of peach (*Prunus persica*) improvement for low chilling areas would be to develop cultivars with low chilling requirement, tolerance to high summer temperature, maturity between 60 and 70 days after full bloom, firm flesh, freedom from loose fibre, attractive colour, non- browning of flesh, resistance to root-knot nematode, iron chlorosis and water logging. For processing peaches, firmness of flesh, freedom from loose fibre, attractive colour and non-browning of flesh are the important characters to be improved.

## Introduction and selection

**Sun Red**

A large number of low chilling peach varieties, e.g. Floridasun, Sun Red and Sun Gold and some other selections, Floridared and Floradabelle were introduced at the PAU, Ludhiana, during late sixties from Florida and California states in USA. Of these introductions, Floridasun, Floridared, Sun Red and 16-33 (named-I-Shan– Punjab) became very popular. Of the later introductions from USA, TA 170, known as 'Partap', has been identified as early (7 days earlier than Flordasun). Its flesh is yellow, firm, with red coloration and better keeping quality. Another two introductions from Florida, Flordaprice and Earligrande, have been recommended for commercial cultivation for the plains of Punjab and adjoining areas. Flordaprice is early ripening, whereas Earligrande is an mid-season variety.

**Clonal selection**

'Sharbati' is a chance seedling selected at Saharanpur

**Hybridization**

Redhar is a cross between "Halehaven and Kalhaven bred at USA. Inter-specific hybridization has also been attempted in peaches especially in the development of rootstock resistant to nematodes. Nemagcrad, a hybrid between *P.persica x P. davididasa* is a widely used root-knot nematode resistant rootstock, which is immune to *Meloidogyne incognita.*

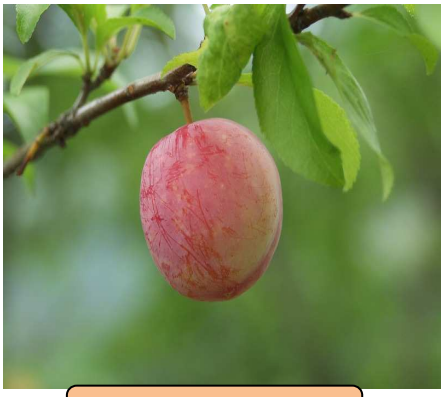
Planned hybridization work on peach was started in 1957 at Saharanpur. Peach Saharanpur Prabhat (Sharbati x Flordasun) was released. Fruits of this variety are attractive, sweet, maturing at least 4 days earlier than Flordasun.

## PLUM

**Breeding objectives**

In European plum (*Prunus domestica*), improvement for cold hardiness, productivity, large sized fruits, colour (red, purple or blue), free stone and dessert quality are important criteria. For Japanese plums (*P. salicina)*, self fertile, late blooming plums, with high quality (particularly yellow skin) are important characteristics.

***Prunus domestica***



***Prunus salicina***

The main objectives of plum improvement programme for subtropical regions are to develop an early maturing cultivar with low chilling requirement, tolerant to high temperature and dwarfing rootstocks, tolerant to saline and stagnant soils, large fruited, free stone, juicy with proper TSS/ acid ratio, suitable for processing and resistant / tolerant to insect, pests and diseases.

**Breeding methods**

**Introduction**

A large number of plum varieties have been introduced from different countries. Of these, Santa Rosa and Sutlej Purple are important commercial cultivars found suitable for midhills of North Western Himalayas. Other methods of breeding are not yet followed in this crop in India.

## PEAR

Pear, *Pyrus communis*, has a chromosome number of 2n=34. Breeding objectives are to develop dwarf scion and dwarf rootstocks tolerant to wet and saline soils and resistant to diseases like *Ganoderma* and root rot, free from low bud differentiation, alternate and shy-bearing of Baghugasha and Le Conte and selection of superior clones of Patharnakh and Baggugosha.

**Breeding methods**

**Introduction**

**Kieffer**

Important and popular cultivars such as Bartlett, Anjou, Kieffer are only introductions from Europe and are well acclimatized to the Northern and Southern Indian hills. A lot of variability, however, exists in soft pear plantations for yield, regular bearing, fruit size, shape, skin colour and fruit quality. An extensive survey of pear growing areas in Punjab and adjoining states taken up by the PAU, Ludhiana resulted in the identification of 19

superior strains of softpears. Of these, soft-fleshed selections 'Red Blush" 'Punjab Gold' and "Punjab Nectar" are promising. Red Blush recorded the highest yield (23.7 tonnes/ha) with good quality attributes.

## Questions

1. Cultivated apple is botanically known **as *Malus domestica.***

   **Ans:True**
2. The majority of cultivated apples are diploids (2n=34).

   **Ans:True**
3. Golden Spur Delicious variety is an example for Spur type cultivar.

   **Ans: True**
4. The main objectives of plum improvement programme for subtropical regions are to develop an early maturing cultivar.

   **Ans:True**
5. Peach variety resistant to nematodes is Nemagerad.

   **Ans:True**

## Lecture.23

## History and importance of plantation crops

Plantation crops constitute a large group of crops. The major plantation crops include coconut, arecanut, oil palm, cashew, tea, coffee, cocoa, rubber, palmyra etc. Their total coverage is comparatively less and they are mostly confined to small holdings. However, they play an important role in view of their export potential as well as domestic requirements and in employment generation and poverty alleviation programmes particularly in rural sector. In India, these crops are grown over an area of 3.2 million ha (1.82% of the total cropped area), generating an annual income of over Rs. 1, 00,000 millions and contributing about Rs. 30,000 million to export earnings. Though historically tea, coffee and rubber were raised as industrial crops in larger estates, currently sizeable area under these crops are in smaller holdings in diverse farming systems. There has been considerable research attempts to improve their productivity through genetic means, to formulate package of cultural practices to boost up the yield /ha, to manage major pests and diseases and above all to develop post-harvest technologies and value –added products. Plantation crops are important in many aspects. Coconut "Kalpavriksha" is used as food, edible oil and industrial lubricant. Tender coconut water is a healthy drink. Owing to immense utility coconut is popularly known as the tree of heaven. The timber, leaf petiole, shell husk, etc, are useful for various purposes. Arecanut yields a masticator used with betel leaf and also as panmasala, pan parag and scented supari. Oil palm yields palm oil rich in vitamin A and E. Cashew bears apple and nuts having commercial importance. Cashew nut shell liquid (CNSL) is industrial oil. Cocoa is grown for beans yielding cocoa butter and chocolate cake. Rubber is an industrial crop. Tea and coffee are beverage crops. Palmyra yields padaneer having versatile uses.

**Tea:** India is the largest producer and consumer of tea in the world and accounts for around 28 per cent of world production and 15 per cent of world trade. There is no restriction on export of tea and under the present Exim Policy; import of tea is permitted with an import duty of 70 per cent.

**Coffee:** Coffee is mainly grown in two states – Karnataka and Kerala which accounts for 82 per cent of country's production. Robusta and Arabica are the two varieties accounting for 52 per cent and 48 per cent of the area respectively. During recent years area under robusta coffee is increasing. The major buyers of Indian coffee are the Russian Federation and Western Europe.

**Rubber:** Rubber is cultivated mainly in Kerala and Kanyakumari districts of Tamil Nadu. About 97 per cent of the country's demand for natural rubber is met from domestic production. Export of natural rubber has been insignificant since international prices are often lower than the domestic prices.

**Coconut:** Presently India is the highest producer of coconut in the world. It produces about 14925 million nuts from an area of 1.9 million hectares. The productivity is 7822 nuts /ha which is more than double when compared to that of Indonesia and Philippines.

**Arecanut:** Arecanut plays an important role in the social, cultural and economic activities of the people; India is the largest producer of arecanut in the world. The country earns about Rs.45 million annually by exporting arecanut in different forms. The current production is about 5.59lakh tonnes from an area of 397 thousand hectares. Karnataka, Kerala, Assam and Tamil Nadu are the important states producing arecanut.

**Cocoa:** Cocoa is a crop of humid tropics of South America. The native Mayas and Aztecs prepared a beverage called 'xoxoatl', by roasting and grinding cocoa beans. The word chocolate originated from it. They used cocoa beans even as currency. Later domesticated to many countries and now it is being grown for cocoa products (beverages, chocolate bars, confectionery, powder and liquor). The major producer is Ivory Coast. Africa produces 55% of world production, Asia 23% and America 22%. The first cocoa brought to India is said to be in 1798, when 8 plants were shipped from Amazon and planted at Courtallam in Tirunelveli district of Madras state. Later in 1873 few plants were planted in Burliar fruit station. In South India, states of Kerala, Madras and Mysore (Wood, 1964) were found as suitable. The commercial cultivation of cocoa started in India only in 1960's with Kerala taking the lead. At present, Andhra stands first in area (16,969ha)

and Karnataka in production (7250 MT). The demand in Indian chocolate industry is 30,000 MT as against its production (12,954MT). Thus, there is a wide scope for increasing the area under cocoa.

**Cashew:** Cashew a native of Eastern Brazil introduced to India just as other commercial crops like Rubber, Coffee and oil palm. It was introduced during 16$^{th}$ Century by the Portuguese and the first introduction of cashew in India was mainly considered as a crop for afforestration and soil binding to check erosion. India is also the largest producer and consumer of cashew nuts. It is estimated that total production of cashew is around 0.57 million tonnes from an area of 0.24 million hectares.

Plantation crops – Area, Production and Productivity (2002-2003) in India

| **Particulars** | **Tea** | **Coffee** | **Rubber** | **Cashewnut** | **Cocoa** |
|---|---|---|---|---|---|
| Area (ha ) | 510600 | 347000 | 566555 | 770000 | 46,318 |
| Production (MT) | 826200 | 275275 | 649436 | 500000 | 12,954 |
| Productivity (kg/ha) | 1618 | 793 | 1146 | 760 | 380 |

Average and potential yield of some plantation crops

| **Crop** | **Unit** | **National Average** | **Research Station yield** | **Super potential yield** | **Percentage over National average** | |
|---|---|---|---|---|---|---|
| | | | | | **Res. Station** | **Potential yield** |
| **Coconut** | Nuts/palm | 36 | 175 | 471 | 386 | 1208 |
| **Arecanut** | *Chali (*Kg/palm) | 1 | 5 | 9 | 455 | 900 |
| **Cashew** | Kg/tree | 4 | 16 | 125 | 344 | 3372 |

**Commodity Boards**

- Coconut Development Board – Cochin,
- Coffee Board – Bangalore,

- Rubber Board – Kottayam,
- Tea board – Calcutta

**Directorates (Ministry of Agriculture)**

- Directorate of Arecanut &Spices Development (DASD)- Calicut
- Directorate of Cashewnut and Cocoa Development (DCCD) - Cochin

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3. Journal of Plantation Crops


**Answer the following Questions**

1. Define Plantation crops
2. List out the crops classified under plantation
3. List out the role of plantation crop in Indian economy
4. List the importance of plantation crops
5. Mention the origin of cocoa and cashew
6. List the commodity boards for the plantation crops
7. Why coconut is named as Kalpavriksha?
8. What is the productivity of coconut in India
9. Mention two important beverage crop
10. Mention the importance of rubber cultivation

## Lecture.24
## Origin, distribution, domestication and adoption of plantation crops

**Arecanut**

The nativity has been variously attributed to former Cochin- China, Malay Peninsula and neighboring islands and East Indies. It is also grown in East Africa, Madagascar, Zanzibar, Sri lanka, Pakistan, Bangladesh, Malaysia, Indonesia, China, the Philippines and Fiji Islands. However, scientific cultivation of arecanut is only in India. Nearly 90% of the area and production come from Karnataka, Kerala and Assam. Karnataka is the major arecanut- producing State, accounting for 38% of the Indian production. It is also grown to a small extent in Tamil Nadu, Meghalaya, West Bengal, Maharashtra and Orissa.

**Cashew**

It is a native of Brazil which was spread by the Portuguese to different parts of the world primarily for soil conservation, afforestation and waste land development. Cashew was introduced to India by Portuguese in the Malabar Coast in the 16$^{th}$ century and subsequently dispersed to other parts of the country and also to South- East Asia. Around the same time it was introduced to East African countries. Kerala, Maharashtra, Andhra Pradesh, Karnataka, Orissa, Tamil Nadu, Goa and West Bengal which are presently the main cashew producing States, although it is grown in non traditional areas like Madhya Pradesh, Manipur, Tripura, Meghalaya and Andaman and Nicobar Islands.

**Cocoa**

The primary centre of diversity of cocoa is Upper Amazon basin in South America. The tropical part of Central America qualifies as the secondary centre of cocoa. After Mexico was conquered by Spanish, cocoa was introduced to Caribbean and Venezuela, then to Philippines, Indonesia, India and Madagascar. Though cocoa gone to Africa only in 1822, Ghana, Nigeria and Ivory Coast became the major producers. Central American cocoa is Criollo, which is the 'fine' or 'flavour' cocoa. The common Forastero 'bulk' cocoa, populations Amelonado, Comum, West African Amelonado, Nacional, Matina or Ceylan and Guiana and Trinitarios adopted to cultivation in different countries. In India, cocoa is mainly grown in in Kerala, Karnatak, Andhra Pradesh and

Tamil Nadu as an intercrop in coconut,arecanut,oilpalm gardens and partially cleared forests as under storey crop.

**Coconut**

The origin of coconut is South East Asia or the Pacific Islands. It is grown in more than 80 countries distributed in the tropical belt between 23°N and 23°S of equator. The major coconut growing countries are India, Indonesia, Philippines, Sri Lanka, Malaysia, Thailand, Papua New Guinea, Fiji, Samoa, Zanzibar and Soloman Islands.

**Coffee**

The majority of Coffea species are native to Africa. The *Coffea arabica* is a native of Ethiopia, while *Coffea canephora* is a native to Central Africa. Coffee was introduced to India in 1600 AD by a Muslim pilgrim, Baba Budan. In late 1820s, commercial plantations were established in Coorg, Nilgiris, Palani hills and Wynad. By 1869, Indian coffee established itself producing quality coffee in world trade.

**Oil palm**

Oil palm originated in Guinea Coast of West Africa. In 15$^{th}$ century oil palms were introduced to Brazil and other tropical countries by the Portuguese. Commercial planting of oil palm started in Malaysia during 1917. Malaysia and Indonesia are the leading producers, followed by Nigeria, Thailand, Ivory Coast, Colombia, Papua New Guinea and a few South African, Central and South American countries.

**Palmyrah**

It is a native of tropical Africa. It grows extensively in drier parts of India, Sri Lanka, Myanmar, Thailand, Vietnam, Malaysia and Indonesia. The palm belt in the world roughly extends from 44°South latitude to 45°North latitude. Tamil Nadu and Andhra Pradesh are the major states growing palmyrah.

**Rubber**

It is a native of Amazon River basin of South America. It was introduced to tropical Asia in 1876 through Kew Garden in the UK with the seeds brought from Brazil. It is now distributed in the tropical regions of Asia, Africa and America. The major rubber- growing countries are Indonesia, Thailand, Malaysia, China and India. Indonesia has maximum area under rubber but Thailand has taken the credit of maximum rubber

producer. In India, Kerala is the predominant rubber- growing State. Tamil Nadu and Kerala account for 98% of the total production. The cultivation has extended to non traditional areas like Tripura, Karnataka, Assam, Meghalaya, Maharashtra, Goa and Orissa.

**Tea**

The origin of tea is South- East Asia. The use of tea as beverage could be traced back to the later part of the 8$^{th}$ century AD, when commercialization of tea occurred through the Arabian travelers. It is now spread over in India, China, Africa, Srilanka, Indonesia, Japan, Russia, Malaysia, Mauritius, Australia and Argentina. Tea is grown in 50 countries, predominantly in Asia, Africa and Europe. Of the major tea producers, India, China, Srilanka, Kenya, Russia and Indonesia contribute the maximum share to global production.

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**Answer the following Questions**

1. ------- is the origin of tea
2. In India -------- is the predominant state growing rubber
3. ---------- is the native of palmyrah palm
4. The leading producers of oil palm are --------- and ----------
5. Two species of coffee are ---------- and ----------
6. List out the major coconut growing countries
7. Mention the two major types of cocoa

8. The native of cashew is ---------
9. Mention the areca nut growing countries

## Lecture.25

## Breeding strategies, clonal selection, poly-clonal orchards, bud mutation, mutagenesis and its application in crop improvement of plantation crops

### Breeding strategies

The important objectives are higher yields, resistance to pests and diseases, higher quality, tolerance to abiotic stresses and evolving low input responsive varieties. Most of the plantation crops, with twin advantage of vegetative propagation and viable sexual reproduction offer much scope for crop improvement work, especially for selection, breeding and exploitation of hybrid vigour.

### Clonal selection

A clone is a group of plants produced from a single plant through asexual reproduction. All the members of a clone have the same genotype as the parent plant as a result, they are identical with each other in genotype. Clones are maintained by asexual reproduction.

### Merits of clonal selection

i. It is the only method of selection applicable to clonal crops. It avoids inbreeding depression, and preserves the gene combinations present in the clones.

ii. Clonal selection, without any substantial modification, can be combined with hybridization to generate the variability necessary for selection.

iii. The selection scheme is useful in maintaining the purity of clones.

### Demerits of clonal selection

i. This selection method utilizes the natural variability already present in the population.

ii. Sexual reproduction is a prerequisite for the creation of variability through hybridization.

### Poly clonal orchards

More than one clone is planted and they are allowed to mate randomly. This is mainly done to collect the seeds. The purpose of this is to produce a quantity of seed of known parentage and proven performance. Therefore, the parents used in seed gardens

are selected on the result of progeny trials. Having selected the parents, they are propagated vegetatively by rooted cuttings or by budding or grafting onto a seedling rootstock. The female parents should be self-incompatible, i.e. trees which will not set fruit with their own pollen, as all seed produced on these trees should arisen from pollen from another tree. The desired crosses can be ensured by hand-pollination or by proper design of the seed garden where natural pollination is relied on. With two self incompatible parents, all the pods will result from cross-pollination and can be used for seed, there being no apparent difference between a cross and it's reciprocal. In such cases, equal numbers of each parent were planted, often in double rows of each clone. Where one parent is self-compatible, seed is gathered only from the self –incompatible parent and in such cases the pollen parent was planted in the ratio of one to five female parent trees. Another form is planting a series of self incompatible parents in such an order that a number of different crosses are produced and seed can be collected from all the trees. Garden with two self incompatible parents called biclonal orchard and with multiple self incompatible clones, poly clonal orchards. It is of course, practical to plant a small number of plants of several clones and obtain seed of known crosses by hand-pollination. (e.g. Cocoa and rubber)

**Bud mutation**

Mutation is a sudden heritable change in a character of an organism. Mutations produced by changes in the base sequence of genes are known as gene or point mutation. Some mutations may be produced by changes in chromosome structure, or even in chromosome number they are termed as chromosomal mutations. Mutation occurring in buds of somatic tissues which are used for propagation is called as bud mutation. e.g. clonal crops.

**Mutagenesis**

Treating a biological material with a mutagen in order to induce mutations is known as mutagenesis.

Agents which induce mutations are known as mutagens. Mutagens may be different kinds of radiation (physical mutagens) or certain chemicals (chemical mutagens).

**A. Physical mutagens**

1. **Ionising radiation**
    a) Particulate radiation e.g., α- rays, β-rays, fast neutrons and thermal neutrons
    b) Nonparticulate radiation (Electromagnetic radiation) – X- rays and γ- rays
2. **Nonionising radiation :** ultraviolet radiation

**B. Chemical mutagens**

1. **Alkylating agents :** EMS- ethylmethane sulphonate, MMS-methyl methane sulphonate
2. **Acridine dyes :** acridine orange, acridine yellow, ethidium bromide
3. **Base analogues :** 5- bromouracil, 5-chlorouracil
4. **Others:** nitrous acid, hydroxyl amine, sodium azide.

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**Answer the following questions**

1. What are the breeding strategies of plantation crops?
2. What is a clone?
3. List out the merits of clonal selection
4. List out the demerits of clonal selection
5. What is a poly clone?
6. Name the crops in which polyclones are produced
7. Define mutation
8. What is mutagenesis?
9. Name two physical mutagen
10. Name two chemical mutagen

# Lecture.26
# Hybridization, haploid and ploidy breeding and In vitro techniques in the improvement of plantation crops

## Hybridization

The mating or crossing of two plants or lines of dissimilar genotypes is known as hybridization. In plants, crossing is done by placing pollen grains from one genotype, called the male parent onto the stigma of flowers of the other genotype, referred to as the female parent. It is essential to prevent self pollination as well as chance cross-pollination in the flowers of the female parent. At the same time, it must be ensured that the pollen from the desired male parent reaches the stigma of flowers of the female parent for successful fertilization. The seeds as well as the progeny resulting from the hybridization are known as hybrid or $F_1$.

In Plantation crops, in coconut, intervarietal hybrids with different parental combinations such as Tall x Dwarf, Dwarf x Tall and Tall x Tall were produced in India and Srilanka. The hybrids are popular because of early bearing and high productivity. (Tall x Dwarf hybrids- Keraganga- WCT x Ganga Bondam, Kerasankara- WCT x Chougat dwarf orange, VHC 1 – ECT x Malayan green dwarf, VHC 2- ECT x Malayan Yellow dwarf). These hybrids are characterized by early bearing in 4-5 years, increased yield of nuts with a mean of 100/palm, good quality copra having high content of 176 g and oil recovery of 70%.

**Dwarf x Tall hybrids** :The distinct advantage of this hybrid over T x D is that it could be produced on a large scale by regularly emasculating dwarf mother palms permitting free natural crossing with pollen from tall palms standing nearby. Use of Dwarf orange or yellow as female parent enables the identification of hybrid seedlings because of colour marker (Chandra sankara – Choughat Orange dwarf x WCT).

**Tall x Tall hybrids**: It is produced by intravarietal hybridization of tall cultivars under controlled conditions. Individual palms of high breeding value are identified and these genotypes are grown on isolated seed garden and utilized for production of T x T hybrids.

Though late in bearing, the yield potential of T x T hybrids is good. These hybrids are considered to be high yielding and tolerant to biotic and abiotic stress when compared to D x T hybrids.

In cashew, to combine prolific bearing with other desirable traits with bold nut, cluster bearing habit and compact canopy, hybridization with parents selected for these characters were attempted. Hybrids performed better than the selections. Hybrid vigour could be easily be commercially utilized in cashew through soft wood grafting.

**Cocoa**

The hybrids Trinitarios in cocoa result from natural crosses between Criollo and Forastero types. They are hardier and more productive than Criollo.

**Hybridization**

Self- incompatibility in cocoa is utilized in production of hybrids with specific objectives. Hybrid vigour is established in cocoa. Hybridization programme was started at Vittal in 1980 using selected parents, for high pod yield, dry bean yields, bigger bean size, more fat content and drought tolerance. A comparison of parents and hybrids in progeny trials with 70 cross combinations indicated more vigour in progenies, with positive and significant heterosis.

**Progeny Trial I**

The parents in the first progeny trial included Upper Amazon collections, Imperial College Selections, Scavina series and Nanay series. Hybrid NA-33 x ICS -89 excelled in pod and bean yield.

**Progeny Trial II**

It had a total of 17 hybrids and their parents. Hybrid I-56 x II – 67 gave the maximum pod and bean yield, followed by I-14 x I-56 and I-56 x III-35.

**Progeny Trial III**

It involved Malaysian hybrids and bulk Forasteros. Hybrids ICS-6 x SCA-6, ICS-6 x SCA-12, IMC-67 x ICS-6 and Amelonado x Na 33 are consistent yielders with quality beans.

**Progeny Trial IV**

Nine hybrids with their seven parents were evaluated for yield and drought tolerance. Hybrids II-67 x NC-29/66 and II-67 x NC-42/94 registered the highest pod index with advantageous physiological and biochemical components.

These hybridization works resulted in development of varieties which are vigorous, early, heavy bearing, stable yielders VTLCH -1, 2, 3 and 4 standard bean characters. These are suitable for cultivation in Kerala, Karnataka, Tamil Nadu, Goa, Maharashtra and North Eastern states.

**Establishment of clonal orchards**

For F1 seed production and for supply of quality planting materials, clonal orchards were established. Based on the compatibility reactions self-incompatible but cross-compatible high yielding parents were selected and planted in clonal orchards. Two self-incompatible parents grown together in a bi-clonal orchard will produce F1 pods of specific identity or known parentage through natural crossing. In poly-clonal orchard more self-incompatible clones are assembled together and all the pods harvested are F1 hybrids. These clonal orchards (6 bi-clonal and 1 poly-clonal) with 1200 trees were established at CPCRI, Research Centre, Kidu, Nettana, Karnataka.

**Multiplication**

Vegetative propagation through soft wood grafting method was also standardized for multiplication of selected accessions and high yielding varieties for supply as well as for early evaluation.

In coffee, a spontaneous hybrid of *C. canephora* x *C. arabica* was introduced. Interspecific hybrids *C. congensis* x *C. canephora*, *C. liberica* x *C. eugenoides*. The hybrid resembled Arabica in cup quality and possessed tolerance to drought and rust.

In oil palm, Tenera hybrids between Deli dura x AVROS pisifera with tremendous yield potential were evolved. In India, 2 high yielding teneras selected from cross combinations involving 11 duras of Malaysian origin and 5 pisiferas of Nigerian origin were released for cultivation. Considerable yield improvement was reported for hybrid.

**Haploids**

An individual with the gametic chromosome number is called as haploid. Haploids are weaker than diploids and are of little agricultural value directly. But they are of great interest because they offer certain unique opportunities in crop improvement. They are used for developing homozygous diploid lines, following chromosome doubling in two years. This greatly reduces the time and labour required for the isolation of inbreds and pure lines.

**Tissue culture**

**Cashew :** Production of somatic embryogenesis and plantlet regeneration which could subsequently be useful for genetic transformation to introduce genes for resistance to tea mosquito and stem and root borers, micro grafting techniques, developing haploids and isogenic lines and molecular characterization of existing genetic diversity.

**Coconut:** Embryo culture has become an important tool for safe germplasm movement. The 3 components of an embryo culture protocol are field collection of embryos, in-vitro conservation and retrieval, and ex-vitro establishment of seedling. Success achieved in the routine use of embryo culture for field collection and short-term storage up to 2 months in sterile distilled water and nearly 80 % of the embryos could be retrieved. A medium containing 2g/litre of activated charcoal without sucrose could store the embryos for 6 months which gives 77% germination.

**Cryopreservation of coconut germplasm:** Use of in-vitro culture techniques including slow growth and cryopreservation, represents an important additional option for safe medium and long term conservation of coconut germplasm. Immature embryos from nuts of 7-8 months after pollination could be successfully cryopreserved and retrieved. The embryos are dessicated for 4 hours in air current of laminar flow cabinet, pretreated for 11 -20 hours on a medium containing 600g/lit sucrose and 15% glycerol and then rapidly immersed in liquid nitrogen. Whole plants could be produced from 73.93 % of cryopreserved embryos.

**Coffee :** The major constraints of coffee production where tissue culture techniques can offer solutions are development of resistance through genetic engineering for fungal diseases particularly leaf rust, introduction of Bt gene to control of berry and stem borers, use of embryo rescue for interspecific crosses from resistant species and development of tools for quality improvement for uniform maturity, short maturation cycles, high soluble solids, large bean size and density, better aroma and less caffeine content. Synthetic seed technology for encapsulating embryos in sodium alginate has been developed. Anther culture technique has been successfully employed for callus induction and plantlet regeneration in interspecific hybrid between *C. congensis* x *C. canephora*. Plants are successfully regenerated from the embryo cultures of 3 interspecific crosses involving *C. canephora* as one of the parents and 3 indigenous wild species viz., *C. bengalensis*, *C. travencorensis* and *C. wightiana*.

**Oil palm:** The technique of cryopreservation in oil palm has been standardized and the embryoids could be stored for 15 months in liquid nitrogen and then plantlets can be regenerated from frozen embryoids.

**Rubber:** Isogenic lines evolved from anther culture could be used in heterosis breeding. Gene transformation protocols, through Agrobacterium and by using gene gun have been perfected and further success in this line will lead to improvement of rubber through biotechnological tools.

**Tea:** The major areas where biotechnology would be useful in tea improvement are micropropagation for mass multiplication of elite tea clones, application of molecular markers for characterizing tea clones as well as quality, genetic engineering for developing resistance to blister blight and identification , characterization and gene transfer for low- caffeine tea. Tissue culture-derived clones are more vigorous than conventionally propagated plants through vegetative methods and produced higher number of laterals in response to centering and tipping.

**Cocoa**

**Somatic embryogenesis**

From floral parts genetically identical embryos are formed. These embryos grow and forms seedling like architecture, which is advantageous, reduces pruning (Penn State University, USA). Secondary embryogenesis, single embryos can form multiple secondary embryos each identical to the first.

MS (Murashige and Skoog) + NAA 1.8 + Thiamine $1mgl^{-1}$+ CW (Coconut water) 15% + Sucrose 4% (KAU media for somatic embryogenesis)

MS basal medium supplemented with 0.5 mg/l of NAA and 0.5 mg/l of BAP is found to be best with leaf explants for optimal callus production (CPCRI)

**Cryopreservation** of cocoa shoot tip is carried out by three methods *viz.*,Encapsulation- dehydration, pregrowth- desiccation and Droplet-freezing method. For preculture, McCown's Woody Plant Medium (WPM) supplemented with sucrose 0.75M and ascorbic acid 0.1g/litre, and for retrieval, WPM medium with 0.6M sucrose and BAP(1mg/L), GA3 (0.5mg/L) and NAA(0.2mg/L) are used. In pre growth desiccation method shoot tips were incubated in 1.5M sucrose solution for 24 hours that showed slight enlargement of tissues in both cryopreserved (+LN) and non-cryopreserved (-LN) shoot tips. There is no cell wall breakage or cell shrinkage. The cell viability was tested by using 0.1%TTC (2, 3, 5 triphenyl tetrazolium chloride) solution. TTC test gave positive result (red colour) only for cryopreserved shoot tips following pregrowth-desiccation that resulted in 5% initial survival.

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**Answer the following the questions**

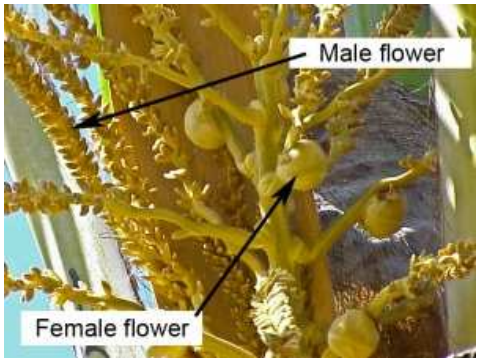
1. Define hybridization
2. What is a hybrid?
3. What is a spontaneous hybrid
4. What is a haploid?
5. Define cryopreservation
6. What is the use of haploid production?
7. Name one intervarietal hybrid in coconut
8. What is an interspecific hybrid
9. Quote an example for interspecific hybrid
10. Mention the advantage of the tissue cultured derived clones.
11. Differentiate between D x T and T x D

**Lecture.27**

**Genetic resources, objectives of breeding, principles and method of breeding and Salient breeding achievements in Coconut**

**Coconut: *Cocos nucifera* L.** **Family: Arecaceae**

Cocos is a monotypic genus and there are no wild forms and hence variability exists only within local types or populations. The genus name cocos and the popular name coconut are derived from Spanish word Coco meaning "monkey face" – a probable reference to the 3 scars on the shell resembling 2 eyes and a nose on monkey's face.




**Research and Development on coconut in India**

CPCRI (Central Plantation Crops Research Institute)

Mandate crops of CPCRI are coconut, arecanut and cocoa. It also co-ordinates research on the mandate crops within the country through AICRP on palms (started in 1970).

CPCRI has three Regional Stations

1) At Kayangulam – Kerala= Research on plant protection in coconut,
2) At Vittal – Karnataka for research on arecanut and cocoa and
3) At Minicoy – in Lakshadweep islands for research on coconut.

**Seed farms**

1. CPCRI maintains the International Gene Bank of coconut for South Asia at the Seed Farm, Kidu.

2. Central Agricultural Research Institute is maintaining its World Coconut Germplasm Centre at Sipighat in Andamans which was earlier established by CPCRI.

**Coconut Development Board**

Started in 1981 under Ministry of Agriculture, GOI, with head quarters at Kochi (Kerala) and regional offices at Bangalore, Chennai and Patna.

**Objectives**

- Adopting measures for the development of coconut industry
- Imparting technical advice to those engaged in coconut cultivation and industry.
- Providing financial and other assistance for the expansion of area under coconut.
- Encouraging adoption of modern technologies for processing of coconut and its products
- Adopting measures to get incentive prices for coconut and its products.
- Recommending measures for improving marketing of coconut and its products.
- Recommending measures for regulating imports and exports of coconut and its products.
- Fixing grades, specifications and standards for coconut and its products.
- Financing suitable schemes to increase the production of coconut and to improve the quality and yield of coconut.
- Assisting, encouraging, promoting and financing agricultural, technological, industrial or economic research on coconut and its products.
- Collecting statistics on coconut and its products and publishing them.
- Undertaking publicity activities and publishing books and periodicals on coconut and its products.

**Crop Improvement**

Research on coconut improvement was given considerable attention as early as in 1916 in India. The major objectives of breeding in coconut are improving the yield by improving the size of nut and per palm yield, improving copra and oil content of nuts,

production of short-statured varieties and resistance to biotic and abiotic stresses. The genetic improvement of coconut is difficult and time-consuming because of long pre-bearing age, perennial habit, heterozygous nature, time lag involved in the study of progeny, low multiplication rate, lack of clonal propagation and requirement of large area for experimentation.

**Cogent**

The international Coconut Genetic Resources Net Work under IPGRI, Rome, has approved the establishment of multi-site International Coconut Gene Bank (ICG) at Indonesia, India, Brazil,Papua New Guinea and Cote d Ivoire. The site selected for ICG for South Asia is CPCRI Seed Farm, Kidu , Karnataka.

Among exotic cultivars, Philippines Ordinary (PO), Philippines Laguna (P) and San Ramon from Philippines, Fiji Tall and Fiji Longtonwon from Fiji Island and Strait Settlement Green from Malaysia are superior. Among indigenous cultivars, Kappadam, Andaman Ordinary and Laccadive Ordinary have higher-yield potential than local West Coast Tall.

**Breeding objectives / Breeding for specific traits in coconut**

**1) Yield improvement:** Hybrids gave 20 –40 % more number of nuts and 40 – 103 % copra /palm/year over local talls.

**2)** ***Breeding for tolerance to drought*** **/ Drought Tolerance**

Breeding for drought tolerance has been initiated during the later half of 1980s. Well-distributed rainfall or adequate irrigation ensures high productivity in coconut. However, in the northern part of Kerala and the Maidan part of Karnataka, the crop is grown under rainfed conditions with about 5-7 months of prolonged dry spell.

The palms are periodically exposed to low rainfall or delayed onset of monsoon or both resulting in poor yield. The adverse effects of drought on coconut persist even for the subsequent 2-3 years. Under these circumstances, evolving a drought tolerant variety

is of paramount importance. Rajagopal *et al.* (1990) standardized the techniques on screening coconut varieties for drought tolerance using epicuticular wax, stomatal frequency and leaf water potential.

They identified WCT × WCT, Federated Malay States (FMS), Java Giant, Fiji, Andaman Giant and LO × COD as drought tolerant. Recently, some more tolerant varieties have been identified and they are all currently being utilized in breeding programmes to identify high yielding hybrids with drought tolerance.

**3) Breeding for resistance/ tolerance to root (wilt) diseases**

Since coconut belongs to the monotypic genus, the possibility of tapping the gene pools from related species is limited.

The root (wilt) disease is one of the major production constraints in Kerala and in view of its phytoplasma etiology, the two strategies followed are:

a) Uprooting the diseased palms and replanting; and

b) Breeding for disease resistance. In the former programme, there is an inbuilt risk of losing the valuable indigenous gene pool. Hence, there is a need to identify disease-free desirable genotype and maintain them in conservation blocks.

The crop loss caused by root (wilt) disease has been indicated earlier and in view of their phytoplasma etiology, effective chemical control measures are not available. Hence, the development of resistant/tolerant varieties to the root (wilt) disease is the only lasting solution.

Screening of the available coconut germplasm starting from 1972 onwards failed to identify any disease tolerant accession. However, in areas where the disease was endemic, high yielding disease-free WCT palms were found. These palms were subjected to physiological and serological studies followed by electron microscopy to ensure that they were free from MLOs. Similarly, disease-free CGD plants were also identified in hot

spot areas. These disease-free palms were utilized for producing WCT × CGD and CGD × WCT hybrids and WCT *inter se* and self-pollinated material. The screenings of these progenies are in progress from 1989 onwards. CPCRI has released two resistant varieties Kalpasree (CGD selection) and Kalparaksha(MGD selection) and one tolerant hybrid viz., Kalpasankara (CGD x WCT). These three varieties are high yielding and have been released for cultivation in root wilt prevalent areas.

**4) Pest Resistant cultivars:** Preliminary screening of cultivars and hybrids against leaf eating caterpillar and rhinoceros beetle has been carried out. Though there is variation among coconut cultivars for the susceptibility, no resistant cultivar was observed.

**5) Quality improvement:** The oil content has a very narrow range in many accessions varying from 65 to 70 percent.

**Higher oil content:** However, cultivars like Laccadive Ordinary have oil content of up to 72%. Efforts have to be directed to improving the oil content of high yielding varieties.

**Quality of oil**

There is also a need to breed varieties for low saturated: unsaturated oil ratio in view of the dietary consciousness of the vegetable oil users.

Tendernut water quality: Consumption of tendernut as a natural, refreshing drink is becoming increasingly popular in our country. Among the cultivars evaluated the cv COD had the maximum total sugars (7.0%) and reducing sugars (4.70 %) coupled with low sodium and potassium levels. CPCRI has released this variety for tendernut purpose.

Coconut cv Phillippines Ordinary, MYD, WCT and Hybrid MYD x WCT are also having appreciable amount of nut water and sugar during seventh month after fruit set and these cultivars are suggested for cultivation for tendernut. The volume of nut water

was the highest in 7 month old tendernuts .The Tall genotype Zanzibar and West Coast Tall and Dwarf genotypes COD and MOD were superior in terms of tendernut water.

**Methods of Breeding**

**Introduction:** The earliest exotic introductions were made in 1924 from Philippines, Malaysia, Fiji, Indonesia, Sri Lanka and Vietnam which formed the nucleus population for many research programmes. The germplasm exchange programme was further intensified in 1952 and in 1958; survey for collection of indigenous germplasm was started. Central Plantation Crops Research Institute (CPCRI), Kasaragod has been designated as the "National Active Germplasm Site" for coconut and maintains the world's largest assemblage of coconut germplasm with 132 accessions which include 86 exotic and 46 indigenous cultivars. The World Coconut Germplasm Centre is located at Sipighat in Andaman and Nicobar Islands. Germplasm collections are also maintained at Regional Research Station, Kerala Agricultural University, Pilicode and at 11 Coordinating centres, in different States under the AICRP on Palms, These collections are being evaluated for the economic characters such as number of nuts/palm/year, number of bunches, average number of female flowers production, setting percentage, weight of copra/nut, oil content (%) in copra and resistance to pests and diseases in comparison with local cultivars.

**Selection:** Selection aims at retention of desired genotypes and elimination of undesirable ones in the population. This is an important method practised for improvement of coconut. Selection is based on certain visible characteristics of palms that are associated with yield potential such as:

1) **Growth:** Stout, straight trunks are associated with short, strong bunch stalks and full crown having umbrella/ Spherical shape. Closely spaced leaf scars are a clear indication of a large number of short, strong and well-oriented leaves. A high-yielding palm has more than 30 fully opened fronds.

2) **Nature and Disposition of Crown:** Short fronds provide adequate support to developing nuts, whereas long fronds fail to support the bunches whereby bunch stalk buckles and causes premature nut fall. The fronds are better oriented in palms with spherical or semi-spherical crown than in those with drooping or erect crown.
3) **Nature of Bunch Stalks:** Short and stout bunch stalks are better supporters of nuts in bunch and do not require artificial propping. Palms with short fronds and petioles have short bunch stalks also.
4) **Number of Inflorescences in the Crown:** The number of inflorescences produced largely depends on the number of leaves produced. Regular and heavy bearers usually possess 4-5 leaves more than the medium and poor yielders, with corresponding number of spadices which range from 12 to 15.

**5) Age of Palm:** In general, palms of 25-60 years old (Middle aged) are recommended because this corresponds to steady period of yield.

**6) High and Consistent Yield of Nuts:** The number of nuts/ palm is highly variable mainly due to the number of female flowers and percentage of set. Most of the palms are regular-bearers even though a few palms show pronounced alternate bearing habit. Selection should be based on large number of spikelets with only one or two female flowers /spikelet and high-setting percentage. In India, 80 nuts/palm/year is taken as standard.

**High Copra Output:** Copra yield is influenced by the number of nuts produced per year and the weight of copra/nut. High degree of correlation exist between weight of husked nuts and that of copra and high heritability values are observed. Palms producing medium-sized nuts with round or oblong shape weighing not less than 600 g of husked nut and mean copra content of 150 g/nut or more are selected,

**High-yielders of Outstanding Breeding Value:** All high-yielding mother palms need not necessarily produce high-, yielding progenies. Mother palms which produce best progenies have high breeding values. The superiority of progeny can be judged from certain characters at the nursery stage itself. Progeny of high-setting mother palms shows early germination, high collar girth, faster rate of leaf production and early flowering.

It is desirable to restrict selection to the best 10% of the palms in each field.

Exploitation of Hybrid Vigour: Discovery of hybrid, vigour by Patel (1937) in crosses between West Coast Tall (WCT) and Chowghat Green Dwarf (CGD) is a significant landmark in the history of coconut improvement. This important finding paved the way for successful breeding programmes for high yield in many coconut-growing countries.

Intervarietal hybrids with different parental combinations such as Tall x Dwarf, Dwarf x Tall and Tall x Tall were produced in India and Sri Lanka. These hybrids are gaining popularity because of early-bearing and high productivity.

**Hybridization:** Hybridization technique involves emasculation of male flowers before female flowers become receptive, collection of mature flowers from pollen parent, extracting pollen, mixing pollen with diluents in a 1:9 ratio and dusting this mixture using a pollen dispenser. The $F_1$ hybrid production requires controlled pollination using bags for pollination.

Two methods for commercial production of hybrids are adopted. They are assisted pollination and mass-controlled pollination. Assisted pollination is done in inter-planted seed garden in which lines of seed parents, usually dwarfs, are alternated with a smaller number of pollen parent rows of talls. This method is limited to one hybrid combination. In mass-controlled pollination pollen is supplied to a seed garden that is totally isolated. Different hybrid combinations can then be produced. In both cases, seed gardens are surrounded by 200-300 m wide/barriers of non-coconut vegetation. Individual palms are inspected daily, inflorescence ready-to-open are emasculated and respective flowers are pollinated.

**Tall x Dwarf Hybrids:** Tall varieties are taken as female parent and dwarf varieties as male parent. Among dwarfs, Chowghat Dwarf Orange and Ganga Bondam are best for production of hybrids with West Coast Tall. These hybrids are characterized by early-bearing in 4-5 years, increased yield of nuts with a mean of 100/palm, good quality copra having high content of 176 g and oil recovery of 70%. The hybrid palms are

easily susceptible to soil moisture fluctuations resulting in shedding of buttons and drooping of leaves during summer. When Laccadive Ordinary was used as female parent, the hybrids showed drought tolerance and better yield. The T x D production is time-consuming and laborious when compared to D x T hybrids, since it requires trained climbers for emasculation and hand-pollination of tall-palms.

**Dwarf x Tall Hybrids:** Dwarf varieties are taken as female parent and tall varieties as male parent. The distinct advantage of this hybrid over T x D is that it could be produced on a large scale by regularly emasculating dwarf mother palms, permitting free natural crossing with pollen from tall palms standing nearby. Use of Dwarf Orange or Yellow as female parent enables the identification of hybrid seedlings because of colour marker. Yellow, orange or red petiole colour is recessive to brown and green pigments and hybrids show a greenish-brown or brownish petiole depending on the colour of talls used in crossing. Occurrence of natural cross hybrids (NCD) of dwarfs in the open-pollinated progeny of dwarf is a well-known phenomenon. NCDs are present to the extent of 20%. Hybrid seedlings are selected based on increased vigour and petiole colour.

D x T hybrids are more vigorous than either of the parents and are prolific yielders. They come to bearing in 4-5 years and out yielded the tall. Field evaluation of coconut hybrids indicated that among T x D and D x T hybrids, D x T was definitely superior to T x D. It was also noticed that tree-to-tree variation was minimum in the hybrid. The nut and copra characters are superior to dwarfs and more or less similar to talls. The hybrids occasionally show a tendency for alternate-bearing, bunch, buckling, and susceptibility to moisture fluctuations, resulting in button shedding and drooping of leaves.

Use of Malayan Yellow Dwarf as female parent gives 95-97% recovery of hybrids, since it is more homozygous due to self-pollination. In combinations involving Chowghat Dwarf Orange, hybrid recovery is only 30% since it is not completely homozygous. For production of stable hybrids with high economic value, selection of

cultivars with wide genetic make-up, selection of hybrid combiners and use of inbred talls as male are recommended.

**Tall x Tall Hybrid:** The T x T hybrids are produced by intravarietal hybridization of tall cultivars under controlled conditions. Individual palms of high-breeding value are identified and utilized for production of T x T hybrids. Though late in bearing, the yield potential of T x T hybrids are good.

**Breeding for Special Characteristics**

Drought Tolerance: A low average rainfall (< 150 mm/ month) and erratic distribution adversely affect the yield of palm. The traits identified for predicting drought tolerance in coconut are accumulation of epicuticular wax on leaf surface, low stomatal frequency, low stomatal resistance and leaf water potential. Based on these characters, the drought tolerant cultivars identified are Federated Malay States, Java Giant, Fiji, Laccadive Ordinary and Andaman Giant. Laccadive Ordinary was more tolerant to drought and hybrids LO x COD and LO x Ganga Bondam also, show tolerance to drought.

**Disease Resistance:** Screening of the germplasm collections and hybrid combinations against root wilt, the most devastating disease in coconut, was not successful. 'Hot spot' areas of root wilt were surveyed and palms were identified.

Chowghat Green Dwarf (CGD) palms, which are disease-free, are being utilized in breeding programmes. Breeding for resistance to coconut root wilt disease resulted in the development and release of two resistant varieties viz. Kalparaksha (MGD selection) and Kalpasree (CGD selection) and one tolerant hybrid viz. Kalpasankara (CGD x WCT) for cultivation in the root wilt prevalent areas.

**Germplasm Exchange:** Prevalence of root wilt disease in Kerala, *Tatipaka* disease in Andhra Pradesh, Tanjavur and Ganoderma wilts in Tamil Nadu restrict the movement of germplasm especially with other countries. However, coconut germplasm from India can be obtained with the approval or ICAR, New Delhi. The nodal agency for coordinating germplasm exchange in India is NBPGR, New Delhi, while CPCRI, Kasaragod, is the agency for phytosanitary clearance. At the international level, Inter-

national Coconut Genetic Resources Net Work (COGENT) under IPGRI is responsible for the introduction and exchange of coconut germplasm with the financial support from FAO and ADB. The COGENT restricts the movement of coconut germplasm through seeds and permits zygotic embryos.

**Breeding achievements in coconut**

Coconut varieties released through selection

| Sl. No. | Cultivar | Released under the name | State for which recommended |
|---|---|---|---|
| 1 | Laccadive Ordinary | Chandrakalpa | A.P., TN, Karnataka, Maharastra, and Kerala |
| 2 | Banawali Green Round | Pratap | Coastal Maharastra |
| 3 | Philippines Oridinary | Kerachandra | Coastal Maharastra, Coastal AP and WB. |
| 4 | Andaman Ordinary | VPM-3 | All districts of Tamil Nadu |

**VPM 3:** It is a selection from material received from CPCRI, Kasaragod, Kerala. It yields 72-92 nuts and 15 kg copra per palm per year with high oil content. The duration is 80-100 years and suited to all districts of Tamil Nadu.

**ALR (CN) 1**: It is single line selection from Arasampatti tall (Dharmapuri district) released from Coconut Research Station, Aliyar nagar. This variety comes to bearing in five years of planting and continues to bear and yield well up to 80 years. It is a drought tolerant, early bearer (5 years), high yielding, tall variety. 7645 nuts give one-ton copra. This variety tolerates the incidence of important pests of coconut. It is suitable under both rainfed and irrigated conditions.


**ALR (CN) 2**

It is a selection from Tiptur tall with an average yield of 109 nuts/palm /year. Comes to bearing in 5½ years with regular bearing habit. It produces 12 inflorescences per year. The weight of copra is 135g/nut with an oil content of 64.7 per cent. It possesses drought tolerance and is moderately resistant to rhinoceros beetle, red palm weevil and leaf blight.

**Hybrids:** The manifestation of heterosis or hybrid vigour in coconut was first reported from India in 1937. The intervarietal hybrids produced for commercial plantings are T x D and D x T with different parental combinations. These hybrids are gaining popularity because of their early bearing and high productivity. The plants are dwarf in stature and start yielding from 3-4 years after planting.

Eg: Lakshaganga, Ananda Ganga, Chandra Laksha, Keraganga, Kerasree, VHC-1, VHC-2, etc.

B) Evaluation and release of Hybrids in coconut.

Steps involved in commercial production of coconut hybrids are as given below;

- 1. Emasculation of male flowers before female flowers come to receptivity,
- 2. Collection of mature male flowers
- 3. Extracting pollen from male flowers
- 4. Mixing of pollen with diluents in the ratio of 1:9
- 5. Dusting of pollen + diluents mixture using a pollen dispensor

Field performance of hybrids derived from different cross combinations of talls and dwarfs are due to the different combining ability of the parents. Hybrids gave 20 – 40 % more number of nuts and 40 – 103 % copra /palm/year over local talls. Commercial production of hybrids has been undertaken in seed gardens established in Kerala, Karnataka, TN and Orissa.

**Hybrids**

1) CHANDRASANKARA (COD x WCT): This hybrid is between COD x WCT and was released by CPCRI Kasaragod in 1985. It is an early bearing and high yielding hybrid with an average annual yield of 116 nuts per palm. The copra content is 215 g/nut.
2) CHANDRALAKSHA (LO x COD): This is a tall x dwarf hybrid with an annual yield of 109 nuts per palm. This hybrid comes to bearing in about 6 years.

3) KERASANGARA (WCT x COD): This hybrid comes to bearing in 4-5 years and attains steady bearing by the 6th or 7th year after planting. The mean annual yield is 108 nuts/palm with a copra content of 187g/nut.

4) LAKSHAGANGA (LO x GB): This hybrid was released by Kerala Agricultural University. It comes to bearing in about 5 years. The mean yield is 108 nuts/palm/year and copra content is 195g/nut. The oil content is 70 percent.

5) ANANDAGANGA (AO x GB): This is a hybrid between Andaman Ordinary and Gangabondam with an annual average yield of 95 nuts. The copra content is 216 g/nut and oil content is 68 percent.

6) KERAGANGA (WCT x GB): This is yet another hybrid released by KAU. The average annual yield is 100 nuts/palm. The copra content is 201 g/nut and oil content is 69 percent.

7) KERASREE (WCT x MYD): This is a recently released hybrid from KAU. The annual mean yield is 112nuts/palm with a copra content of 216g/nut.

8) KERASOUBHAGYA (WCT x SSG): This is a cross between West Coast Tall and Straight Settlement Green. Comes to bearing in about 5-6 years with an annual yield of 116 nuts/palm. Copra content per nut is 196g and oil content is 65%.

9) VHC-1 (ECT x GB): It is a hybrid between East Coast Tall and Malayan Dwarf Green. It's pre bearing age is 4 years, with an yield of 98 nuts/palm/year. Copra content per fruit is 135 g with an oil content of 70 per cent.

10) VHC-2 (ECT x MYD): It is a hybrid evolved by crossing, East Coast Tall and Malaysian Yellow Dwarf at Veppankulam,Tamil Nadu. It yields more than 100 nuts per tree per year, which is 55% higher than local varieties and 8% over VHC 1. It yields as much copra yield as VHC 1 with 11% higher oil content. The buckling of bunches is negligible with a high degree of stability.

11) VHC-3 (ECT x MOD): VHC 3 (East Coast Tall x Malaysian Orange Dwarf) records a mean yield of 156 nut/palm/year and copra yield of 25.2 kg/palm/year with an increased nut yield of 10 per cent and copra yielded 19.7 per cent over VHC 2. Oil content is 70 per cent. The estimated oil yield is 2.55 tonnes / ha as against 2.13 and 1.13 tonnes/ha in VHC 2, ECT respectively. High nut weight, kernel weight and copra weight are the special features of VHC 3. The hybrid recorded high copra out turn of 162 g/nut as against 146 g in VHC 2. For one tonne of copra it requires 6180 nuts, whereas VHC 2 and ECT requires 7680 and 6675 nuts respectively.

**Varieties/ Hybrids released from CPCRI, Kasargod, Kerala**

| Name | Area for which recommended | Nut yield | Copra (g/nut) | Oil content (%) |
|---|---|---|---|---|
| **Varieties** | | | | |
| Chandrakalpa | Kerala, Karnataka, TN | 97 | 195 | 70.0 |
| Kerachandra | AP, Maharashtra, | 110 | 198 | 66.0 |
| Chowghat Orange Dwarf | All coconut growing regions | Tender nut variety | | |
| Kalpa Pratibha | West Coast region and peninsular India | 91 | 256 | 67.0 |
| Kalpa Dhenu | West Coast region and Andaman and Nicobar Islands | 86 | 242 | 65.5 |
| Kalpa Mitra | West Coast region and West Bengal | 80 | 241 | 66.5 |
| Kalparaksha | West Coast region and root (wilt) disease tracts of Kerala | 65 | 215 | 65.5 |
| Kalpasree | Root (wilt) prevalent tracts of Kerala and adjoining states. | 90 | 96.3 | 66.5 |
| **Hybrids** | | | | |
| Chandra Sankara | Kerala, Karnataka, Tamil Nadu | 110 | 208 | 68.0 |
| Kera Sankara | Kerala, Karnataka, Maharashtra, AP | 106 | 198 | 68.0 |
| Chandra Laksha | Kerala, Karnataka | 109 | 195 | 69.0 |
| Kalpa Samridhi | West coast of India | 117 | 220 | 67.5 |
| Kalpa Sankara | Root (wilt) prevalent tracts of Kerala and | 84 | 170 | 67.5 |

| | | | | |
|---|---|---|---|---|
| | adjoining states. | | | |

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**Answer the following**

1. What is the botanical name and family of coconut?
2. Expand CPCRI
3. What is COGENT
4. Mention two important breeding objectives of coconut
5. Name two D x T hybrids
6. Name two T x D hybrids
7. Mention two varieties for tender coconut
8. List out the steps involved in hybrid production in coconut
9. Mention two objectives of breeding for special feature
10. List out the methods of breeding in coconut
11. List two resistant varieties in coconut
12. List one variety released for ball copra production

**Lecture.28**

**Genetic resources, objectives of breeding, principles and method of breeding and Salient breeding achievements in Areca nut and oil palm**

**Arecanut:** ***Areca catechu*** **Family: Arecaceae**

India is the largest producer of arecanut in the world. The country earns about Rs. 45 million annually by exporting arecanut in different forms. The current production is about 5.59 lakh tonnes from an area of 3.97 lakh hectares. Compared with 1960-61 figures, it is seen that the area has increased by two and a half times and production by three and a half times. The productivity increased from 845 kg/ha to 1243kg/ha. Karnataka, Kerala, Assam and Tamil Nadu are the important states producing arecanut.

Areca palm, a monocot, belongs to **Family: Arecaceae (**Syn: Palmae). Areca was a monospecific genus. The genus expanded rapidly from its monospecific status and at present contains about 76 species. *Areca catechu* is the only cultivated species used as a masticatory, though nuts of *Areca triandra* also can be chewed. The *A.triandra* has ornamental value due to suckering habit and heavy bunches of red nuts. The *A. concinna* is another suckering palm with scarlet red fruits. In Sri Lanka, its fruits are occasionally chewed.

**Research Centres working on arecanut**

1) **CPCRI Regional Station, Vittal. Karnataka**
2) **CPCRI Research Centre, Mohitnagar (W.B)**
3) **CPCRI Research Centre, Kahikuchi (Assam)**

**Cultivars of *Areca catechu***

Four botanical varieties of Areca catechu were reported, namely Areca catechu var. communis, *A.catechu* var.*silvatica, A.catechu* var. *batanensis* and *A.catechu* var. *longicarpa* based on the size and shape of fruits and kernel. A new cultivar *A.catechu* var.*deliciosa* with sweet kernel has been reported from Karnataka. The somatic chromosome number of *A. catechu* is 2n = 32.

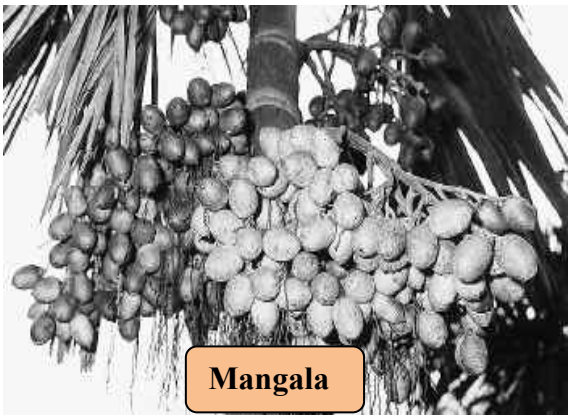
**Germplasm and Varieties**

Arecanut is one of the very few examples, wherein crop improvement work combined with improved input technologies contributed to revolutionize production and productivity. Evolving high-yielding and improved varieties of arecanut has been successful through the introduction of indigenous and exotic types and selection of mother palms, seed nuts and seedlings. In recent years, hybridization and exploitation of dwarfing genes for breeding dwarf and high-yielding varieties have been initiated.

Germplasm repository at CPCRI regional station, Vittal, Karnataka, consists of 164 accessions. This includes 23 exotic introductions from Fiji, Mauritius, China, Sri Lanka, Indonesia, Vietnam, Singapore and Australia, representing 6 species of Areca and 141 indigenous types obtained from different parts of India.

Screening of germplasm accessions led to the release of several high-yielding varieties, like the following:

**Mangala (VTL-3):** An introduction from Peking China released for cultivation during the year 1972.




**Features**

1) A semi tall variety with good chewing and marketing quality,
2) Early bearing with high percentage of fruit set and high yield,
3) Quicker stabilization of production, Yield : 3.0 kg *chali*/palm/year
4) Nuts are medium size with oval or egg shape.

**Recommendation:** For Coastal Karnataka and Kerala. (up to an altitude of 800m). Mangala variety suffers if planted in heavily shaded old plantation.

**Sumangala (VTL-11):** It is an introduction from Indonesia. Palm is tall with partially drooping habit. Under ideal conditions, it flowers in 4-5 years. The nuts are deep yellow to orange *in* colour and oblong to round in shape. It gives an average yield of 17.25 kg ripe nuts/palm/year at $10^{th}$ year.

**Sree Mangala (VTL-17):** An introduction from Singapore, its habit, flowering and fruit characters are similar to Sumangala. It gives an average yield of 15.63 kg/palm/year.

**Swarnamangala** (VTL-12)

Selection from Saigon.Regular bearer, consistent yielder with homogenous population .Trees are semi tall to tall, stem sturdy with shorter internodes having partially drooping crown with well placed bunches. Average number of bunches/palm/year - 3.90. Orange to deep yellow color oblong to round and bold ripe nuts. Bears from the $4^{th}$ year with a potential yield (kg chali/palm/year) - 6.28 and average yield (kg chali/palm/year) -

3.88 with high recovery of chali (26.52%) from fresh nuts. Recommended regions/areas for cultivation- Irrigated areas of Karnataka and Kerala

General recommendation for production of genetically superior planting material is Inter *se* mating between typical palms to produce true to type planting materials

**Mohitnagar:** This is an indigenous cultivar from West Bengal. The important feature of this variety is its greater uniformity. The bunches are well-spaced and nuts are loosely arranged on the spikes which help in uniform development and enable efficient plant-protection measures. Early stabilization of yield and high annual yield potential of 3.7 kg chali/palm (15.8 kg ripe nuts) are its characteristics.

**Calicut 17:** Recommended for Andaman and Nicobar Islands, this is tall with longer internodes and crown. The striking feature of this variety is its consistent and high yield potential (18.89 kg ripe nuts/palm/year with a chali yield of 4.34 kg/ palm) having well-placed bunches with round and bold nuts.

**SAS1 (Sirsi Arecanut Selection- I):** Recommended for the hill zone of Karnataka. It is tall with compact canopy. It is a regular-bearer. Nuts are round and even sized and closely arranged on compact bunches. It is suitable for both tender and ripe nut processing. It has high curing percentage, yielding 4.60 kg chali/palm/year.

Besides, there are several cultivars designated by their name of the place where they are grown.

| | |
|---|---|
| **Thirthahalli** | Grown in Malnad area of Karnataka preferred for tender nut processing. |
| **Hirehalli Dwarf** | A dwarf mutant with closely spaced internodes from Karnataka |
| **South Kanara** | Largely grown in South Kanara district of Karnataka and Kasargod of Kerala. Palms are regular-bearing with large-sized nuts. Yields about 7 kg ripe nuts/palm/year giving 1.5 kg chali per year. |
| **Sreevardhan** | It is grown in coastal Maharashtra; Nuts are oval with marble white kernel and tastier endosperm which are rated as the best quality. Yield is comparable |

| | |
|---|---|
| | to South Kanara |

The other important varieties grown in different States are Hirehalli Local (Karnataka), Mettupalayam (Tamil Nadu) and Kahikuchi (Assam).

**Hybridization**

Hybridization programme in arecanut was initiated at Central Plantation Crops Research Institute (CPCRI) Regional Station, Vittal, with specific objective of evolving high-yielding and regular-bearing varieties, combining large-sized fruits with more number of nuts/bunch, ≠combining semi tall, early bearing and high yield of Mangala with quality of Sreevardhan, transferring more number of female flowers and high fruit setting percentage from *A. triandra* and studying the combining ability for exploitation of hybrid vigour. Intervarietal hybridization carried out among Mangala, Sumangala, Sree Mangala, Mohitnagar, Thirthahalli and Hirehalli Dwarf and evaluation of hybrid seedlings with respect to their performance did not result in selecting useful arecanut hybrids so far. Utilization of dwarf mutants seems to be encouraging. The attempts in the direction to establish plantation with short-statured palms are in progress. Hirehalli Dwarf x Sumangala cross is promising with respect to yield (2.65 kg chali/palm) and combining the dwarf stature.

**Vittal Areca Hybrid- 1 (VTLAH-1)**

- Hybrid between Hirehalli Dwarf x Sumangala.
- Dwarf type with reduced canopy and very sturdy stem.
- Super imposition of nodes on the stem gives mechanical support to palms.
- Partially drooping crown with well spread leaves.
- Moderate yielder but early stabilization in nut yield.
- Medium sized oval, yellow to orange nuts.
- Average yield (kg chali/palm/year)- 2.54.
- Recovery over fresh nut- 26.45 %.

- Specific recommendation for seed production- Artificial crossing is suggested between Hirehalli Dwarf and Sumangala for hybrid seed production. Only sprouts/seedlings will be supplied after sorting and selection in the nursery.
- Recommended regions/areas for cultivation- Coastal Karnataka and Kerala.
- Harvesting and spraying easy because of the dwarfing nature and lesser cost of cultivation.
- Sun scorching and wind damage is minimal due to dwarfing nature.

## OIL PALM

**Oil palm: *Elaeis guineensis* Jacq.** **Family: Arecaceae**

Elaeis is derived from the Greek word elaion meaning oil while the specific name guineensis shows its origin from the Guinea coast. The other species under the genus are *E.olerifera* and *E. odora*. *E.oleifera*, known as American oil palm. *Elaeis guineensis* (African oil palm) is a diploid with 2n = 32.

**Differentiating features of American oil palm and African oil palm**

| Sl. No | Features | American oil palm | African oil palm |
|---|---|---|---|
| 1 | Botanical name | *Elaeis oleifera* | *Elaeis guinensis* |
| 2 | Stature | Dwarf | Tall |
| 3 | Leaflet arrangement on the frond | On one plane | Alternative arrangement of leaflets |
| 4 | Quality of oil | Better | Comparatively poor |
| 5 | Yield | Less | More |
| 6 | Distribution | Found only in America | Cultivated in America, Asia and Africa. |

**Classification of cultivars in African oil palm**

Cultivars in the strict sense do not occur. The best classification is based on fruit structure.

**Dura:** Shell usually 2-8 mm thick, low to medium mesocarp content (35-55%) kernels large, no fibre ring. In Deli Durapalms, kernels tend to be larger, comprising 7-20% of weight of fruits.

**Tenera**: Shell 0.5-4mm thick, medium to high mesocarp content (60-90%) fibre ring darker in colour and encircles the endocarp. Higher sex ratio and larger number of bunches than Dura.

**Pisifera:** Shellless with small pea- like kernels in fertile fruits. It is of little commercial value, but is important in breeding commercial palms.

Oil palms can also be classified based on the colour of exocarp as follows:

**Nigrescens:** Unripe fruit deep violet to black at apex and ivory coloured towards base. This is the commonest type. Two forms are recognized on ripening. They are Rubro nigrescens (ripe fruits deep reddish orange) it has the highest content of carotenoids and carotene. It is the commonest form in West Africa and Rutilo nigrescens (ripe fruits paler-orange with black cap on upper half).

**Virescens:** Unripe fruits green, ripening to light reddish orange with small greenish tip. Anthocyanins little or absent.

**Albescens:** Fruits lack reddish colour at maturity as it contains little or no carotene. It ripens to pale-yellow or ivory with a blackish or green cap on upper half.

**Features differentiating fruit types of oil palm**

| Sl. No | Characters/Composition | Dura | Tenera | Pisifera |
|---|---|---|---|---|
| 1 | Mesocarp proportion in fruit (%) | 35-50 | 60 –96 | 98 |
| 2 | Shell thickness (mm) | 2 to 8 | 0.5 to 4 | -- |
| 3 | Oil percentage | 15 % | 36 % | 25 % |
| 4 | Average proportion of shell in fruit (%) | 30 | 10 | -- |
| 5 | Average proportion of kernel in fruit (%) | 16 | 16 | 10 |

## Germplasm Collection

***World Collection:*** Search for assemblage of germplasm in oil palm started after the Second World War. The first collection of *E. guineensis* was established at Nigerian Institute for Oil-Palm Research (NIFOR) during 1961-1964. Subsequently prospection for genetic materials was taken up at Ivory Coast, Palm Oil Research Institute of Malaysia (PORIM) and at Republic of Zaire. A large germplasm was gathered at PORIM and the collections from Nigeria provided valuable genes for high yield, dwarfism and un saturation.

The *Elaeis oleifera* germplasm was assembled by PORIM, International Bureau of Plant Genetic Resources (IBPGR) and United Brands Company in Central America from Central and South America, Surinam, Colombia, Panama, Costa Rica, Nicaragua and Brazil.

***Indian Collection:*** Oil palm was introduced to India towards the end of the 19th century out of botancial curiosity. Systematic collection of oil palm materials was initiated during 1960s by the Department of Agriculture, Kerala. They introduced material from Malaysia and Nigeria which consisted of Dura x dura, Dura x tenera, Dura x Pisifera and Tenera x Tenera were planted at Oil Palm Station at Thodupuzha, Kerala. Active collection of oil palm accessions was taken up by the Indian Council of Agricultural Research during 1979 and *ex-situ* field gene banks consisting of accessions from 11 countries are maintained at National Research Centre for Oil Palm, Pedavegi (Andhra Pradesh), and Research Centre of NRC for Oil Palm, Palode (Kerala). A cold tolerant accession of oil palm is available at CPCRI Research Centre, Mohitnagar, West Bengal.

## Crop Improvement

The main emphasis of breeding is to evolve varieties with high yield of palm oil, the commercial oil extracted from the mesocarp, although the endosperm also contains oil. Better oil quality with higher percentage of unsaturation reduced height increment, tolerance to drought, pest and disease as well as precocity are also important considera-tions.

Evaluation and selection of germplasm material and hybridization between selected *dura, Tenera* and *Pisifera* were attempted for yield improvement. In India, evaluation of introductions revealed that palms from Cote d'Ivoire are superior to NIFOR palms. The population of Deli Dura is used around the world as a female line for production of seeds. The AVROS line is the source of pisifer as used in Malaysia and Indonesia owing to its good production capacity when it is combined with Deli duras. In PORIM, the work was concentrated on *inter-se* crossing of materials from various origins to form a new breeding population. Tenera hybrids between Deli Durax AVROS Pisifera with tremendous yield potential were evolved. In India, 2 high-yielding teneras selected from cross combinations involving 11 duras of Malaysian origin and 5 pisiferas of Nigerian origin were released for cultivation. Considerable yield improvement was reported in hybrid. The yield potential of salient hybrids is as follows

**Yield potential of hybrids**

| Combinations | FFB Yield (tonnes/ha) | Oil yield (tonnes/ha) |
|---|---|---|
| **Malaysian hybrid** | | |
| DD x AVROS (4 hvbrids) | 31.0 - 34.5 | 6.9 - 8.9 |
| DD x Pumpy AVROS | 33.3 | 8.6 |
| **Indian hybrid** | | |
| Palode I | 18.0 | 4.59 |
| Palode II | 17.5 | 4.46 |

To impart resistance to vascular wilt, spear rot and cercospora leaf spot, identification of parental materials with improved resistance and breeding with such materials and interspecific hybridization with E. *oleifera* are being attempted, The E. *oleifera* produces oil with lower melting point (22° C), higher iodine value and unsaturation (80%) giving a large liquid fraction which increases the commercial value of oil. Crosses with E. *oleifera,* are being evaluated to develop progeny with superior quality oil. In breeding for short compact palms, E. *oleifera,* Dura selections such as Dumpy dura, Pobe dumpies and Indian dwarf are utilized as gene source for dwarfness. The features of inter-specific hybrid with E. *oleifera* are given below.

**Features of inter-specific hybrid with E. *oleifera***

| Features /Character | E. *guineensis* | E. *guineensis* x E. *oleifera* | E. *oleifera* |
|---|---|---|---|
| Height increment (m) | 0.34 | 0.18 | 0.09 |
| No. of leaflets | 321 | 256 | 188 |
| FFB 8 kg/ palm/yr | 148 | 190 | 120 |
| Bunch weight (kg) | 18 | 12 | 12 |
| Oil (%) | 50 | 34 | 30 |
| Unsaturated fatty acids | 52 | 66 | 79 |

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**Answer the following**

1. Mention the botanical name and family of Areca
2. Mention the botanical name and family of oilpalm
3. What is FFB in oil palm
4. How is the oil plam classified
5. what is the chromosome number of oilpalm
6. Differentiate American and African oil palm
7. Mention the places of research on arecanut

8. Name two species other than *A.catechu*
9. How oil palm is classified based on the colour
10. Name two varieties of areca nut

**Lecture.29**

**Genetic resources, objectives of breeding, principles and method of breeding and Salient breeding achievements in palmyrah palm and rubber**

## PALMYRAH PALM

**Palmyrah Palm: *Borassus flabellifer*** **Family: Arecaceae**

The distinguishing characters of palm in this genus are their palmate, fan like leaves and dioecious character –*i.e.,* male and female flowers are borne on separate trees. Next to coconut, palmyrah is the most abundant palm found in the world.

### Crop Improvement

Yield potential of *padaneer,* height of the palm, bearing capacity, flowering in off-season besides the main season and sugar content of the sap are the major economic traits. The yield of *padaneer* in 38 palms was recorded for 3 consecutive years from 1982 at Srivilliputhur Palmyrah Research Station, Tamil Nadu. Of the 38 palms studied, 36.33%, 34.2% and 28.93% yielded *padaneer* in 1, 2 and 3 out of 3 years considered. The samples of trees observed for 3 years together reveal that 68.4%, 36.82%, 31.56% and 5.26% of the palms are poor, low, moderate and good yielders respectively.

Male palm -excelled female palms in all characters except percentage of jaggery recovered from *padaneer.* The tree with good yielding capacity can be used in hybridization programme to evolve high-yelding palms.

| Particulars | Sex of palm | |
|---|---|---|
| | Male | Female |
| Yield of *padaneer* per palm (litres) | 115.87 | 107.31 |
| Mean number of days of tapping | 54.8 | 48.1 |
| Recovery of *padaneer* W/W | 14.98 | 15.44. |

| | | |
|---|---|---|
| Quantity of jaggery obtained (kg/palm) | 17.36 | 16.88 |

The tapper has to climb palmyrah palm 2-3 times a day. The tappable palm is about 15-20 m or more in height. The height of palms becomes a limiting factor for the tapper to cover more number of palms. Accidents, sometimes fatal, are not uncommon. Screening for dwarf types is a very important objective in palmyrah breeding. With this objective, 213 palms were observed for their height, among the mature palms available at the Palmyrah Station Srivilliputhur, Tamil Nadu. Nearly 43.7% were semi-dwarf palms. These trees can be utilized in hybridization programme to evolve dwarf plants.

The palms have been classified based on percentage of jaggery recorded for padaneer. A total of 43 palms were considered.

Considering the criteria, plantation is screened and 16 (9 male and 7 female) palms have been identified as elite palms for higher content of jaggery.

**Mother palm selection in palmyrah**

1) **Age of the palm :** Middle aged – 30 to 40 years
2) **Stature of canopy:** Dwarf and stout palms are selected. Trees with compact leaves are preferred to long slender stemmed trees
3) **Selection of seed nuts**
    i. **Stage of maturity:** Select bunches with 80 to 90 per cent ripe fruits. Heap the selected fruit bunches for 5 to 6 days for automatic detachment from bunches. Select plumpy and healthy seed nuts.
    ii. **Removal of mesocarp:** Allow fruits to ferment for easy removal of mesocarp. While removing mesocarp, the fibre adhering to seed nut should be retained which help in absorption of water leading to better germination.
    iii. **Sex of nuts**

b. Seeds of single nut give == female trees

Double nuts give == one female and one male

Trinuts === Two male and one female

To maintain male and female ratios, it is better to collect 10 to 15 per cent of double nuts.

**Varieties**

In India, there is no recognized variety. But palmyrah palms growing in Sri Lanka can be broadly classified into 2 varieties based on pigmentation of fruit skin. They are black and red skinned fruits.

Black-skinned fruits have comparatively less red pigment on their skin. Red skinned fruits have variable amounts of black pigments along with very liberal distribution of red in their skin. Fruits and nut number per tree are significantly greater in this variety. But pulp weight per nut is less; sugar, starch and protein constitute 77%, 10% and 2.5% of the pulp respectively. The alkaloids, amino acids and minerals are in greater amount in red skinned varieties. The other favourable fruit features, along with the sap-yielding characteristics of these varieties, seem to favour selection of red-skinned fruit variety for commercial exploitation.

**Released varieties**

**SVPR**-1: Palmyrah research station, Srivaliputhur (TNAU) has released one improved variety namely SVPR-1 Palmyrah palm.

**Features**

- Semi-dwarf type
- High padaneer yield of 298 litres per palm in a tapping duration of 95 days.
- Quality of padaneer**:** The padaneer of this variety has a high jaggery content (144 g per litre of padaneer i.e., 14.40 %) and a high brix content.

# RUBBER

**Rubber: *Hevea brasiliensis*** **Family: Euphorbiaceae**

Genus *Hevea* comprises of 10 species. All the species are diploids with 2n = 36 and can be crossed interspecifically by artificial pollination. Bark of all species contain latex in all parts of their plants.

**Rubber Research Institute of India (1995)**

RRII was started on a hillock, 8 km east of Kottaym town, Kerala. The Central Experiment Station of the Institute is located at Chethackal (Ranni) 50 km away from Kottaym. It is a member of IRRDB (International Rubber Research and Development Board.

**Research Stations under RRII under different agroclimatic situations**

Agartala (Tripura): Rubber Research Complex for North East India

Regional research stations at

1) Agartala (Tripura)
2) Guwahati (Assam)
3) Tura (Meghalaya)
4) Kolsab (Mizoram)

RRII has also set up regional research stations at

1) Dapchari (Maharastra)
2) Kamakhyanagar (Orissa)
3) Nagrakatta (WB)
4) Sukma (Chattisgarh)
5) Burliar (TN)
6) Nettana (Karnataka) and
7) Padiyoor (Kerala)

**Major research Priorities are**

1. Evolving and introducing location specific high yielding clones – Molecular biology and genetic engineering
2. Efficient field management systems to reduce immaturity period.
3. Introducing appropriate rubber based farming systems in different agroclimatic regions.
4. Exploitation systems to reduce tapping cost.
5. Optimization of plant protection schedule and molecular approaches in plant disease control.

**Crop Improvement**

Improvement of a tree crop like rubber is relatively slow and laborious. Nearly 30 years are required for recommending a new clone for commercial planting. The phenomenal increase in yield of rubber has been achieved after years of repeated selection of high-yielding mother trees followed by their vegetative multiplication, controlled pollination among high-yielding clones and further selection from among progeny. "'Current approach is to breed clones with diverse desirable characters such as resistance to biotic and abiotic stresses and utilizing wild germplasm in breeding programmes.

**Germplasm:** The spectrum of *Hevea* germplasm can be broadly classified into those existing in the primary centre of diversity in Brazil and those developed in centres of secondary diversity. Thus, it is a collection of all genotypes that represent the entire genepool, including current popular clones, obsolete clones and wild accessions from the centre of diversity in Brazil. Rubber Research Institute of India, Kottayam, Kerala, maintains a collection of 174 exotic and indigenous clones of Wickham origin in a clone museum. In addition, 4,967 accessions representing the wild Brazilian germplasm collected through germplasm exchange programmes are also maintained. International Rubber Research and Development Board (IRRDB) and Association of Natural Rubber Producing Countries (AN-RFC) are agencies associated with the clone exchange programmes.

**Clones**

Clones are group of plants produced by vegetative propagation from single trees. All individual trees of a clone possess identical genetic constitution, which is responsible for the uniformity existing among them. Clones are usually named after the estates, institutes or stations from where they have originated and indicated as abbreviations. Based on the type of mother tree, from which the clone is derived, they are classified as:

**Primary clone:** Mother tree is of unknown parentage, selection of mother tree is based on superior performance in the existing plantation. Tjir - I, GT I, PB 86, PR 107 and PB 28/59 are primary clones.

**Secondary clone:** Mother tree is evolved by controlled pollination between 2 primary clones. RM 600 (Tjir I X PB 86) and RR II 105 (Tjir I X GL - I) are secondary clones.

**Tertiary clone:** Mother tree is evolved by controlled pollination in which at least one or both parents are secondary clones. RRIM703 (RRIM 600 x RRIM 500) is an example. In order to obviate the potential risks involved in the monoclone culture, cultivation of a mixture of clones which is categorized as follows is recommended:

**Category I:** Clones like RRII 105 (in traditional areas) along with RRIM 600 and GT I (in non-traditional areas) to cover upto 50% of the total area. Other important clones under this category are PB 260, RRII 414 and RRII 430**.**

**Category II:** Clones like RRIM 600, GT 1, PB 28/59, PB 217 and RRIM 703 to cover upto 50% of the total area. Other important clones in this category are RRII 5, RRII 203, RRII 417 and RRII 422.

**Category III:** The cultivars under it are divided into 3 categories which can cover upto 15% of the total area in aggregate. They are:

• RRII 5, RRII 203, PB 255, PB 2611 and PB 235

• Tjir I, PB 86, GI 1, PR 107 and RRIM 605

• RRII 50, RRII 51, RRII 52**,** RRII 109, RRII 116 and RRII 176

**Important clones are described below**

**RRII105:** A clone evolved by Rubber Research Institute of India and currently enjoying maximum popularity in the country. Parents are Tjir I and GI 1. Trunk is tall and straight. Branching is good with strong unions, canopy dense, foliage dark green, leaflets long and glossy, wintering, and refoliation early and partial, Virgin and renewed bark thickness good. Average yield is 2,400 kg/ha/year. Latex is white and DEC high. The clone has a fair degree of tolerance to abnormal leaf fall. Highly susceptible to pink disease and incidence of powdery mildew is medium. Occurrence of tapping panel dryness is high and therefore, to be tapped under half spiral once in 3 days ($s_2d_3$).

**RRIM 600:** It is a high-yielding variety evolved by the Rubber Research Institute of Malaysia and extensively grown in all rubber growing countries. Parents are Tjir 1 and **PB 86.** Tall straight trunk, moderate to fairly heavy branching and branch unions rather weak. It shows normal wintering and refoliation. Girth at opening is low. Girth increment after opening high and virgin bark thickness is low. Thickness of renewed bark is high usually results in trend. Average annual yield is 1,387 kg/ha. Latex is unsuitable for concentration. It is susceptible to diseases caused by *Phytophthora*.

**GT 1:** A primary clone developed in Indonesia and extensively planted in all rubber-growing countries. Trunk upright with variable branching habit. Wintering and refoliation late and often partial. Girth at opening medium to high. Girth increment on tapping and virgin and renewed bark thickness medium. Average annual yield is 1,400 kg/ ha/year. Latex is white. Occurrence of tapping panel dryness and incidence of pink disease mild. Abnormal leaf fall mild to medium and powdery mildew medium to severe.

**RRII 414**

| | |
|---|---|
| Country of origin | India |

| | |
|---|---|
| Developed by | Rubber Research Institute of India |
| Parentage | RRII 105 x RRIC 100 |

| Mean Yield | 4 Years | 10 Years |
|---|---|---|
| Small scale evaluation(g/tree/tap) | - | 74.02(40%)* |
| Large scale evaluation(g/tree/tap) | 56.68(26%)* | |

* Values in brackets indicate percentage improvement over RRII 105

| | |
|---|---|
| Vigour | High |
| Girth increment on tapping | Average |
| Trunk | Tall, straight and cylindrical with prominent leaf scar, slightly leaning |
| Branching pattern | Very high heavy branches with strong union |
| Canopy | Open, broad and heavy |
| Virgin bark thickness | Above average |
| Renewed bark thickness | High |
| Number of latex vessel rows | Above average in both virgin and renewed bark |
| Incidence of major diseases and pests | Pink – moderate<br>Powdery mildew – high<br>Abnormal leaf fall – moderate<br>*Corynespora* leaf fall - low |
| Reaction to stresses | Wind - average tolerence |
| Occurrence of TPD | Low |
| DRC | Above average |
| Color of latex | White |
| Special features | Yield better than RRII 105 in the first year of tapping in the on-farm trial and comparable to that of RRII 105 in the multilocation trials |

**RRII 430**

| | |
|---|---|
| Country of origin | India |
| Developed by | Rubber Research Institute of India |
| Parentage | RRII 105 x RRIC 100 |

| Mean Yield | 5 Years | 10 Years |
|---|---|---|
| Small scale evaluation(g/tree/tap) | - | 63.37(20%)* |
| Large scale evaluation(g/tree/tap) | 61.09(36%)* | |

* Values in brackets indicate percentage improvement over RRII 105

| | |
|---|---|
| Vigour | Above average |
| Girth increment on tapping | Average |
| Trunk | Tall straight cylindrical stem with smooth bark |
| Branching pattern | Balanced branching with strong branch union. Moderate to heavy branches |
| Canopy | Open broad and heavy with large glossy leaves |
| Virgin bark thickness | High |
| Renewed bark thickness | High |
| Number of latex vessel rows | Above average in both virgin and renewed bark |
| Incidence of major diseases and pests | Pink – low<br>Powdery mildew - very high<br>Abnormal leaf fall – low<br>*Corynespora* leaf fall - low |
| Reaction to stresses | Wind - high tolerance |
| Occurrence of TPD | Low |
| DRC | High |
| Color of latex | White |
| Special features | Yield better than RRII 105 in the first year of tapping in on-farm trial and in multilocation trials |

**PB 28/59:** A Malaysian clone with fluted and crooked trunk sometimes showing tendency for leaning, Moderate to heavy branches, Girth at opening medium and girth increment on tapping poor. Virgin bark thickness low thickness on renewal above average. Average annual yield is 1,423 kg/ha/year. Susceptibility to wind damage is medium. Occurrence of tapping panel dryness is severe. The clone is highly prone to abnormal leaf fall, pink and powdery mildew diseases.

**PB 217:** The parents of this Malaysian clone are PB 5/51 and PB 6/9. Trunk tall and straight. Wintering and refoliation are normal to late. Girth at opening is medium, girth increment on tapping high. Virgin bark thickness is low but renewed bark is medium in thickness. Average yield is 1,257 kg/ha/year. Latex colour is light yellow. Wind damage is very low. Tapping panel dryness mild. Incidence of phytophthora severe in Malaysia but low in India. Pink and powdery mildew diseases severe.

**RRIM 703:** The parents of this clone are RRIM 600 and RRIM 500. It has an upright trunk. High yielding with yield trend from the eighth year of tapping. Girth at opening is high to medium and girth increment on tapping low. Virgin bark thickness is high and renewed bark thickness medium to high showing tolerance to powdery mildew. The average annual yield is 1,310 kg/ha/year. Latex colour is light yellow. Wind damage and tapping panel dryness high. Abnormal leaf fall is severe in India, though reported to be only mild in Malaysia. Occurrence of powdery mildew is mild. The clone is prone to severe pink disease.

**PB 217**

| | |
|---|---|
| Country of origin | Malaysia |
| Developed by | Prang Besar Estate |
| Parentage | PB 5/51 x PB 6/9 |

| Mean Yield | 5 Years | 10 Years | 15 Years |
|---|---|---|---|
| Large scale evaluation(g/tree/tap) | 38.39 | 48.86 | 59.90 |

| | | | |
|---|---|---|---|
| Commercial evaluation(kg/ha/yr) | 1262 | 1510 | 1508 |

| | |
|---|---|
| Vigour | Average |
| Incidence of major diseases and pests | Pink-severe<br>Powdery mildew-severe<br>Abnormal leaf fall - moderate |
| Reaction to stresses | Cold-average tolerance<br>Drought-above average tolerance with respect to yield but growth is affected |
| Occurrence of TPD | Low |
| DRC | Average |
| Special features | A hardy clone suitable for small growers. Shows good response to stimulation. |

**RRII 5**

| | |
|---|---|
| Country of origin | India |
| Developed by | Rubber Research Institute of India |
| Parentage | Primary clone (Selected from Malankara Estate, Thodupuzha) |

| Mean Yield | 5 Years | 10 Years | 15 Years |
|---|---|---|---|
| Large scale evaluation(g/tree/tap) | 55.30 | 65.27 | 71.44 |
| On farm evaluation(kg/ha/yr) | 1352 | | |

| | |
|---|---|
| Incidence of major diseases and pests | Pink – mild<br>Powdery mildew - moderate to severe<br>Abnormal leaf fall - moderate to severe<br>Wind - above average tolerance |
| Reaction to stresses | Wind - above average tolerance |
| Occurrence of TPD | High |
| DRC | Average |
| Special features | Very vigorous clone with above average yield. Can be |

| | |
|---|---|
| | used as a latex timber clone |

**RRII 203**

| | |
|---|---|
| Country of origin | India |
| Developed by | Rubber Research Institute of India |
| Parentage | PB 86 x Mil 3/2 |

| Mean Yield | 5 Years | 10 Years | 15 Years |
|---|---|---|---|
| Small scale evaluation(g/tree/tap) | 56.08 | 78.19 | 82.12 |
| Large scale evaluation(g/tree/tap) | 50.19 | 58.64 | 61.62 |
| On farm evaluation(kg/ha/yr) | 1396 | 1649* | 1811 |

* Average yield from 2 locations

| | |
|---|---|
| Incidence of major diseases and pests | Pink-moderate<br>Powdery mildew-moderate<br>Abnormal leaf fall-moderate |
| Reaction to stresses | Cold - average tolerance<br>Wind - average tolerance |
| Occurrence of TPD | Low |
| DRC | High |
| Special features | Latex coagulation shows black discolouration which does not affect the quality of rubber. Can be used as a latex timber clone. |

**RRII 417**

| | |
|---|---|
| Country of origin | India |
| Developed by | Rubber Research Institute of India |
| Parentage | RRII 105 x RRIC 100 |

| Mean Yield | 5 Years | 10 Years |
|---|---|---|
| Small scale evaluation(g/tree/tap) | - | 70.52(33%)* |

| | | |
|---|---|---|
| Large scale evaluation(g/tree/tap) | 53.06(18%)* | |
| * Values in brackets indicate percentage improvement over RRII 105 | | |

| | |
|---|---|
| Vigour | Above average |
| Girth increment on tapping | Average |
| Trunk | Tall and more or less straight with smooth bark |
| Branching pattern | High, balanced with moderate to heavy branches |
| Canopy | Broad, partially closed and heavey with semi glossy dark green leaves restricted to the top |
| Virgin bark thickness | Average |
| Renewed bark thickness | High |
| Number of latex vessel rows | Above average in both virgin and renewed bark |
| Incidence of major diseases and pests | Pink – moderate<br>Powder mildew - very high<br>Abnormal leaf fall - low to moderate<br>*Corynespora* leaf fall - moderate |
| Reaction to stresses | Wind - high tolerance |
| Occurrence of TPD | Low |
| DRC | High |
| Color of latex | White |
| Special features | Yield better than RRII 105 in the first year of tapping in on-farm trial and in multilocation trials. |

**RRII 422**

| | | |
|---|---|---|
| Country of origin | India | |
| Developed by | Rubber Research Institute of India | |
| Parentage | RRII 105 x RRIC 100 | |
| Mean Yield | 4 Years | 10 Years |

| | | |
|---|---|---|
| Small scale evaluation(g/tree/tap) | - | 64.94(23%)* |
| Large scale evaluation(g/tree/tap) | 61.16(36%)* | |

* Values indicate percentage improvement over RRII 105

| | |
|---|---|
| Vigour | Above average |
| Girth increment on tapping | Average |
| Trunk | Crooked and high branching |
| Branching pattern | Moderate heavy branches with strong union |
| Canopy | Open, narrow and dark green glossy leaves |
| Virgin bark thickness | Average |
| Renewed bark thickness | Above average |
| Number of latex vessel rows | Above average in both virgin and renewed bark |
| Incidence of major diseases and pests | Pink – low<br>Powdery mildew – high<br>Abnormal leaf fall – low<br>*Corynespora* leaf fall - moderate |
| Reaction to stresses | Wind - tolerance |
| Occurrence of TPD | Low |
| DRC | High |
| Color of latex | White |
| Special features | Yield better than RRII 105 in the first year of tapping in on-farm trial and in multilocation trials |

**RRII 52**

| | |
|---|---|
| Country of origin | India |
| Developed by | Rubber Research Institute of India |
| Parentage | Primary clone |

| | |
|---|---|
| Mean Yield | 5 Years |

| | |
|---|---|
| Small scale evaluation(g/tree/tap) | 44.08 |
| Vigour | Average |
| Trunk | Straight and cylindrical |
| Branching pattern | Balanced with acute angled secondaries |
| Canopy | Medium sized and open |
| Incidence of major diseases and pests | Moderate |
| Occurrence of TPD | Low |
| DRC | Average |

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**Answer the following questions**

1. List out the steps involved in mother palm selection in palmyrah
2. List out the steps involved in seed nut selection in palmyrah
3. Describe SVPR1
4. What is the botanical name and family of rubber?
5. What is ploidy status of rubber? mention the chromosome number of rubber
6. List out the major research priorities in rubber
7. What is secondary clone?
8. Describe RRII105
9. Where is RRII located?
10. Name the centres work under RRII

**Lecture.30**

**Genetic resources, objectives of breeding, principles and method of breeding and salient breeding achievements in cashew**

**Cashew: *Anacardium occidentale*** **Family: Anacrdiaceae**

The family Anacardiaceae comprises about 60 genera and 400 species of trees and shrubs with resinous bark. Though Anacardium is described as a small genus with only 8 species, over 20 species are known to exist in Central and South America. The species of Anacardium vary largely with respect to size, shape and colour of peduncle and size and shape of nut and leaves. The *A. gigantium* from Surinam has the biggest apple, whereas *A. rhinocarpus* and *A. spruceanum* possessing hard wood are useful as root stocks and *A. occidentale* is a diploid with 2n= 42.

Cashew Flower

Cashew Fruit

**Germplasm:** The early attempts for germplasm collection in India were made during 1952-1957 with sanctioning of adhoc schemes in Kerala (Kottarakkara), Karnataka (Ullal) Andhra Pradesh (Bapatla), Assam (Daregaon) and Maharashtra (Vengurla). A total of 1,490 germplasm accessions have been conserved at National Research Centre on Cashew at Puttur and at different cashew research stations in India, These are primarily indigenous types' selected from the seedling progenies of the limited initial introductions with few exotic types from Brazil, Nairobi, Lindi, Nacala, Mozambique, Ex Tanganya, Singapore, Australia and Republic of Panama. The

germplasm collections also include allied species of Anacardium such as A. microsepalum, A. pumilum and A. orthonianum.

*In-situ* conservation of cashew germplasm is done only in the Amazon forests of Brazil, the original home of cashew. Subsequent to the establishment of NRCC at Puttur (Karnataka) in 1986, (now it is upgraded as Directorate of Cashew Research (DCR)) germplasm collection through seeds was discontinued. In the National Gene Bank of NRCC, Puttur, *ex-situ* conservation of 392 clonal germplasm collections are maintained. Similarly, Regional Cashew Gene Bank is established at AICRP on Cashew at Vengurla, Bhubaneswar, Madakathara and Chintamani. Immediate priority of Indian cashew germplasm programme is to enhance the genetic variability through introduction of exotic types from Central America and Brazil, where diverse types including dwarf ones are existing.

**Breeding objective in cashew**

**1) High yield with bold nuts:** Cashew being primarily export oriented crop, it is necessary to give utmost priority for developing varieties and hybrids with export grade kernels. Nuts should be **big and plumpy** to produce more of W-180 grades. Yield of more than 10 kg per tree per year.

**Fruit setting percentage in cashew: 1 to 18 %**

**2) Dwarf and compact canopy:** To facilitate high density planting.

**3) Short flowering phase:** To reduce the chances of losing crop due to pest infestation and also to minimize the cost of collection of nuts.

**4) High sex ratio:** Adequate care should be exercised in selecting the trees with high bisexual flowers. Recent studies have also emphasized the importance of staminate flowers to provide more efficient pollen so the trees with mixed phase and also high sex ratio are to be preferred as parents over types which have distinct male phase and hermaphrodite phase.

**5) Breeding for tea mosquito resistance:** One of the production constraints in cashew is the severe incidence of tea mosquito bug in some areas. So production of varieties which show field tolerance to tea mosquito bug needs priority.

**6) High shelling percentage:** Processing industries look forward for high recovery of cashew kernels. Currently, for release of any variety standards fixed stipulate that a minimum of 28 % shelling percentage should be recorded.

**7) Nutrient quality index:** Develop varieties with high nutritive value. In cashew high protein (> 35 g protein, lysine > 50 micro gram per mg protein and < 14 g of sugar is suggested).

Cashew kernel is good even compared to almond. It contains protein = 32 to 70 g and have more of lysine i.e., quality protein, Starch = 21 to 33, Lipids

**Breeding achievements in cashew:** In the past cashew was primarily propagated for soil conservation and forestation. At present due to the effort of research more than 40 varieties/hybrids have been released. Of these 25 varieties are selection from germplasm and 15 are developed through hybridization and selection.

**Varieties and Hybrids:** Since cashew is primarily a cross-pollinated crop, it is highly heterozygous and segregation has resulted in considerable variations in its seedling population. An ideal cashew plant should have dwarf and compact canopy with intensive branching habit, short flowering and fruiting phase, > 20% perfect flowers, 8-10 nuts/panicle, medium to bold nuts (8-10 g) with higher shelling percentage of > 28, high yield potential (> 20 kg/tree/year) and tolerance to major pests and diseases.

Evaluation of seedling progenies at different cashew research stations resulted in the identification of superior genotypes for several economic characters.

In order to combine prolific bearing with other desirable traits like bold nut, cluster-bearing habit and compact canopy, hybridization with parents selected for these characters were attempted. Hybrids performed better than the selections. Hybrid vigour could easily be commercially utilized in cashew through softwood grafting. Among the 15 hybrids released in India 11 have kernel grade of W 180 to W 210. These 11 hybrids have at least one of the parents with bold nut character (Brazil-18, K-30-1 and Vetore-56)

and thus prove the usefulness of selecting parents with bold nut character for transmitting this trait to hybrid. Short duration of flowering (Anakkayam1), high sex ratio and longer mixed phase, intense branching, high shelling (%) and high nutritive value of kernels are also looked in the parents.

**Cashew varieties developed through selection from germplasm in India**

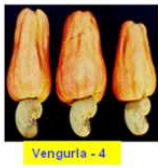
| Research Station | Variety | Source of germplasm | Yield potential (kg/tree) | Nut weight (g) | Kernel weight (g) | Shelling (%) | Kernel grade |
|---|---|---|---|---|---|---|---|
| Directorate of Cashew Research Puttur, Karnataka | Selection 1 | VTH 107/31 | 10.0 | 7.6 | 2.2 | 28.8 | W 210 |
| | Selection 2 | VTH 40/11 | 9.0 | 9.2 | 2.5 | 28.6 | W210 |
| Horticultural Research Station, Ullal, Karnataka | Ullal 1 | 8/46 Taliparamba | 16.0 | 6.7 | 2.1 | 30.7 | W210 |
| | Ullal 2 | 3/67 Guntur | 9.0 | 6.0 | 1.8 | 30.5 | W240 |
| | Ullal 3 | 5/37 Manjeri | 14.7 | 7.0 | 2.0 | 30.7 | W210 |
| | Ullal 4 | 2/77 Tuni | 9.5 | 7.2 | 2.2 | 31.0 | W 210 |
| | (UN-50) | 2/27 Nileshwar | 10.5 | 9.0 | 2.9 | 32.8 | W 180 |
| Agricultural Research Station, Chintamani, Karnataka | Chintamani | 18/46 Taliparamba | 7.2 | 6.9 | 2.1 | 31.0 | W210 |
| Cashew Research Station, Bapatla, Andhra Pradesh | BPP 3 | 3/3 Simhachalam | 11.0 | 4.8 | 1.3 | 28.1 | W400 |
| | BPP 4 | 9/8 Epurupalem | 10.5 | 6.0 | 1.3 | 23.0 | W 400 |
| | BPP 5 | Tree No.1 | 11.0 | 5.2 | 1.2 | 24.0 | W 400 |
| | BPP 6 | Tree No. 56 | 10.5 | 5.2 | 1.2 | 24.0 | W400 |
| Regional Research Station, Jhargram, West Bengal | Jhargram 1 | Tree No. 16 of Bapatla | 8.5 | 5.0 | 1.5 | 0.0 | W 320 |

| Research Station | Variety | Source of germplasm | Yield potential (kg/tree) | Nut weight(g) | Kernel weight (g) | Shelling (%) | Kernel grade |
|---|---|---|---|---|---|---|---|
| Cashew Research Station, Anakkayam, Kerala | Anakkayam 1 | BLA 139-1(T.No. 13-9 of Bapatla) | 12.0 | 6.0 | 1.7 | 28.0 | W280 |
| | Sulabha | K-1 0-2 | 23.34 | 9.8 | 2.5 | 25.51 | W210 |
| | Mridhula | PTR 1-1 | 3.31 | 3.6 | 1.4 | 38.87 | W450 |
| Cashew Research Station, Madakkathara | Madakkathara 1 | BLA 39-4 (T.No.39 of Bapatla) | 13.8 | 6.2 | 1.6 | 26.8 | W 280 |
| Anakkayam , Kerala | Madakkathara 2 | NDR 2- 1 (Nedunellur2-1) | 17.0 | 7.3 | 2.0 | 26.2 | W 280 |
| | K 22 1 | Kottarakkara 22 | 13.2 | 6.2 | 1.6 | 26.5 | W 280 |
| Regional Fruit Research Station, Vengurla, Maharashtra | Vengurla 1 | Ansur 1 | 19.0 | 6.2 | 1.9 | 31.0 | W 320 |
| | Vengurla 2 | WBDC - VI | 24.0 | 4.3 | 1.4 | 32.0 | W 320 |
| Regional Research Station, Vridhachalam, Tamil Nadu | VRI 1 | M 10/4 (Vazhisodhanai Palayam) | 7.2 | 5.0 | 1.4 | 28.0 | W 320 |
| | | | | | | | |
| | VRI 2 | M 44/3 (T.No. 1668of Kattupalli) | 7.4 | 5.1 | 1.4 | 28.3 | W 320 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | VRI 3   | M 26/2 (Edayanchavadi) | 10.0 | 7.2 | 2.1 | 29.1 | W 320 |
| | VRI 4 | Selection from Vazhisodanipalayam of Cuddalore taluk of Tamil Nadu | 18.10 | 6.63 | | 28.5 | |

## Cashew hybrids developed India

| Research station | Hybrid | Yield (kg/tree) | Nut weight (g) | Kernel weight (g) | Shelling (%) | Kernel grade |
|---|---|---|---|---|---|---|
| Cashew Research Station, Bapatla, Andhra Pradesh | BPP1 (H2/11) | 10.0 | 5.0 | 1.3 | 27.5 | W400 |
| | BPP2 (H2/12 | 11.0 | 4.0 | 1.0 | 25.7 | W450 |
| | BPP8 (H2/16)   | 14.5 | 8.2 | 2.3 | 29.0 | W210 |
| Cashew Research Station, Madakkathara, Kerala | Dhana (H 1608) | 17.5 | 9.5 | 2.2 | 28.0 | W210 |
| | Kanaka (H 1598) | 19.0 | 6.8 | 2.1 | 31.0 | W210 |
| | Priyanka (H 1591) | 16.9 | 10.8 | 2.8 | 26.5 | W 180 |
| | Amrutha (H 1597) | 18.4 | 7.2 | 2.2 | 31.6 | W210 |
| Cashew Research Station, Anakkayam, Kerala | Dharasree | 15.0 | 7.8 | 2.1 | 26.9 | W280 |
| | Anagha (H-8-1-) | 13.7 | 10.0 | 2.9 | 29.0 | W180 |
| | Akshaya (H-7-6) | 11.8 | 11.0 | .3.1 | 28.4 | W 180 |

| Research station | Hybrid | Yield (kg/tree) | Nut weight (g) | Kernel weight (g) | Shelling (%) | Kernel grade |
|---|---|---|---|---|---|---|
| Regional Fruit Research Station, Vengurla, Maharashtra | Vengurla 3 | 14.4 | 9.1 | 2.4 | 27.0 | W 210 |
| | Vengurla 4   | 17.2 | 7.7 | 2.4 | 31.0 | W210 |
| | Vengurla 5 | 16.6 | 4.5 | 1.3 | 30.0 | W 400 |
| | Vengurla 6 | 13.8 | 8.0 | 2.2 | 28.0 | W 210 |
| | Vengurla 7   | 18.5 | 10.0 | 2.9 | 30.5 | W 180 |
| Regional Research Station, Vridhachalam, Tamil Nadu | VRI (CW) H1 M 26/2 x M 26/1 | 16.5 | 7.2 | 2.2 | 30.5 | W210 |

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**Answer the following questions**

1. Write the botanical name and family to which the cashew belongs

2. Mention the chromosome number of cashew

3. List out the breeding objectives of cashew

4. What is the fruit setting percentage of cashew?

5. What is the nutritive content of cashew?

6. Where is the headquaters for cashew research located?

7. Mention the places where cashew research is taken up

8. Mention any two varieties evolved through selection

9. List out the hybrids released in cashew

10. How is the cashew kernels graded?

**Lecture.31**

**Genetic resources, objectives of breeding, principles and method of breeding and salient breeding achievements in coffee**

**Coffee: *Coffea species*** **Family: Rubiaceae**

Eucoffea includes most of the useful species of the genus. *Coffea arabica, Coffea canephora* and *Coffea liberica* are some of the species that found their place into commercial cultivation in India. The basic genome in the genus coffea is x = 11. In Eucoffea, all species are diploids with 2n = 22 except *C. arabica* (2n= 44) which is tetraploid.

**Arabica Coffee:** The *C.arabica* is a small tree with dark green leaves. The flower buds are produced during October – March and flowers blossom 9-10 days after the receipt of blosoom showers. Arabica is self fertile. The fertilized ovary grows into a fruit in 8-9 months.

**Robusta Coffee:** The *Coffea canephora* is bigger tree than Arabica. Flowers per clusters are more. It is a lowland coffee with wider geographic distribution. It grows under relatively more open and humid conditions than Arabica.

**Tree Coffee:** The *Coffea liberica* is a large bearing big broad, dark green and leathery leaves. The flowers and fruits are larger and take one year to mature. The ripe fruits are yellow to reddish- brown in colour.

**Origin**

**Arabica coffee**: **Ethiopia** – In a place called Caffa.

It occurs naturally in forests between 450 to 600 m elevation (1400 to 1800 ft elevation)

**Robusta coffee** = Of **Central African** origin

Liberica coffee: Cultivated almost at sea level in Liberia.

**Coffee Research in India**

**1892** : UPASI (United Planters Association of South India was organized to tackle various problems of coffee industry

**1925** : By the efforts of Dr. L. C. Coleman (Then Director of Agriculture) Coffee Experiment Station (CES) was started at Balehonnur, with following objectives;

1) To breed rust resistant selections
2) To undertake research on control of pests and diseases

**1938** : Release old arabica selections (S-288 and S-333) from CES

**1946** : Coffee Experiment Station was taken over by Coffee Board and established Central Coffee Research Institute (CCRI)

Substations and regional stations to tackle regional problems in coffee

Sub Stations at Chettalli, Coorg Dist.

Regional Coffee Research Stations, At

1) Chintapalli, RV Nagar (Raghavendra Nagar), AndraPradesh,
2) Chundale, Kalpatta, Kerala – For Robusta Coffee
3) Thandikudi, Palani Hills, T.N.
4) Diphu, Assam

**Crop Improvement**

**Germplasm Collections:** The earlier collections made during 1930s totalling 1,462 were of indigenous origin from seeds collected from vigorous, disease resistant Arabica and Robusta plants from various estates. This included many putative hybrids such as Kents, Coorgs, 5.26 and 5.31 (both Liberica x Arabica origin) and Devamachy hybrid Robusta x Arabica origin)

Collection of exotic germplasm was started in 1953 and introductions were made from all coffee growing countries including Ethiopia, the homeland of coffee. Early

introduction of Robusta coffee was from Sri Lanka and Indonesia, although later introductions were made from Costa Rica, Uganda, Madagascar and Ivory Coast. The germplasm collections were maintained in the gene bank of **Central Coffee Research**

**Institute, Balehonnur:They were**

C. *arabica:* About 280 varieties, cultivars and selections

C. *canephora:* 21 exotic collections including 3 varieties and one sub-variety

**Other Species:** 18 species belonging to the genus *Coffea* and closely related genus *Psilanthus.*

**Hybrid lines:** Coffee lines and hybrid lines showing varying degrees of resistance to leaf rust were introduced from Central Rust Research Centre, Portugal

**Hybrido-de-Timor:** a spontaneous hybrid of *C. canephora* x C. *arabica* from Timor Islands was introduced, whereas Catimor: Caturra x hybrids-de-Timor; Villa Sarchi x Hibrido-de-Tirrior and Catirnor x Catuai (Caturra x Mundo Novo) were also collected.

**Interspecific hybrids**: *C. Congensis x C. canephora; C. liberica* x *C. eugenioides*

The hybrids resembled Arabica in cup quality and possessed tolerance to drought and rust.

**Varieties:** The selections and introductions were further improved by employing pure-line breeding, intervarietal crossing, back-crossing and interspecific hybridization. The selections were released for cultivation after zonal assessment.

***Arabica Varieties***

**Selection 1 (S 288):** This variety is a tetraploid hybrid derived from S-26 which is supposed to be a progeny of natural cross between' C. *liberica* x C *arabica.* It is resistant to leaf rust race I and II. Though this is a high-yielder with quality similar to Arabica,

seed abnormalities are very frequent. However, because of its wide adaptability to varied agroclimatic conditions, it is still being cultivated in some areas.

**Selection 3 (S-795):** It is a cross-bred line of S-288 x Kents. It has bold fruits and seeds of good quality. The variety is resistant to race I and II of leaf rust. It has a yield potential of 700-1,200 kg clean coffee/ha with 75%; "A" grade and cup quality 5-6.

**Selection 5:** It "is derived from a cross between Devamachy x S-881 (wild Arabica from **Rurne Sudan.** Devamachy is a spontaneous hybrid of Robusta x Arabica spotted in Coorg, It has small, oblong, leathery leaves and oblong fruits and seeds. It has an yield potential of 900 to 1,100kg clean coffee/ha.

**Selection 6:** A hybrid between S-274 (Robusta) x Kents. Its plants are larger with Robusta type branching. Fruit is medium to bold with cup quality similar to Arabica. It has an yield potential of 900 to -1,000 kg clean coffee/ha with high "A" grade beans.

**Selection 7:** Derived from San Ramon (a dwarf Arabica variety from Columbia) crosses. San Ramon was crossed with S-1406 to obtain Selection 7.1. Selection 7.2 is a cross between dwarfs of 7.1 x Agaro. This hybrid when crossed with Hybrido-de-Timor, Selection 7.3 was obtained. Selection 7.3 shows high resistance to leaf rust. Its plants are dwarf.

**Selection 8:** It is derived through pure-line selection of Hybrido-de-Timor (HDT). It shows the highest resistance to leaf rust. It produces drooping branches, bears moderately bold fruits with quality similar to Arabica.

**Selection 9:** Cross-bread line of Hibrido-de-Timor x Tafarikela, its plants are drought hardy. Bean is medium to bold. Nearly 70% of the plants in the progeny are resistant to rust.

**Selection 10** ***(Caturra crosses):*** Caturra is a'dwaf' type in Arabica. Some crosses of Catura with S 795, Cioccie and Hibrido-de-Timor show resistance to many races of rust. Selection 11: Progeny of *C. liberica* x C. *eugenoides.* Its plants show field resistance to rust and drought hardiness.

**Cauvery:** It is derived from Catimor lines which is a cross between Caturra and Hibrido-de-Timor. The plants are dwarf and highly suitable for high-density planting. It shows high degree of synchronised flowering, fruit set and fruit ripening. It shows a high yield potential of 1,000 to 2,000 kg clean coffee/ha. It produces more A grade coffee with superior cup quality.

**Chandragiri coffee**:

It is a newly released coffee in 2007-08 by Coffee Board with the original source from Portugal .It was introduced in the year 1975 to CCRI Balehonnur from Portugal. Farm trials and intensive research trials were taken up at CCRI Balehonnur.

**Features**

1. Bushy growth with slightly bigger leaves than Cauvery coffee
2. Bigger sized berries: It produces 25 per cent bigger sized berries compared to other varieties.
3. Resistant to leaf rust: Lower (5 to 7 %) leaf rust incidence in this variety is reported compared to other varieties (20 to 40 %).
4. Tolerant to drought

**Robusta Varieties**

Coffea canephora was introduced to India after the appearance of leaf rust in Arabica. Now, it has become popular as a cultivated species of coffee. Robusta coffee is highly cross-pollinated and high-yielding selections were recommended for cultivation.

**Sel-lR (S-274):** This is a single plant progeny giving 1,400-2,500 kg clean coffee/ha. It can come up even at lower elevations and shows high resistance to leaf rust Growth is vigorous but with shallow root system. Its fruits are bold giving 43% "A" grade coffee. Sel-2R (S-270): This also is a single plant progeny selection Robusta giving high yield but fruits are not as bold as in Sel-lR.

**Sel-3 R:** An interspecific hybrid between *C. congensis* and *C. canephora* with back crossed to *C. canephora. C. congensis* is a native of Congo in Africa, showing compact plant size, better quality and lower caffeine content. The hybrid showed bush size of congenesis, fruits as in Robusta with low-caffeine content and quality of cogenesis. A dwarf mutant of this hybrid population has been recently spotted in Wynad.

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**Answer the following**

1. Name the two species of coffee
2. Mention the ploidy level of two species with the chromosome number
3. Compare and contrast the Arabica and robusta coffee
4. What is tree coffee?
5. List out the main objectives of coffee breeding
6. Expand CCRI and mention its location
7. List out the varieties of Arabica coffee
8. List out the varieties of robusta coffee
9. Name an interspecific hybrid in coffee

10. List out the features of Chandragiri coffee

**Lecture.32**

**Genetic resources, objectives of breeding, principles and method of breeding and salient breeding achievements in tea**

**Tea: *Camellia sinensis*** **Family: Camelliaceae (Theaceae)**

The genus comprises about 45 species of evergreen shrubs and trees in tropical and subtropical Asia. Botanist distinguished 3 distinct tea- producing taxa which were referred as jats.

**China type:** (*Camellia sinensis*): China type grows as a shrub 1-3m high with erect branches. Two morphological forms are identified in this type, viz. macrophylla with broad and long leaves and parviflora with small narrow leaves. Plants are resistant to cold and adverse conditions but low yielding.

**Assam type** (*Camellia assamica*): Assam type is a small tree growing up to 10-15 m adapted to tropical conditions. Two types are recognized, viz., Assam type with light green leaves giving higher yields of better quality tea and Manipuri type with dark green leaves, drought resistant but with poor yields and quality.

**Cambodean hybrid type** (*Camellia assamica* ssp *lasiocalyx*): The cambod type is conical in appearance reaching a height of 6-10m. Leaves semi erect vary in size between China and Assam types. In most species particularly the commercial jats, diploid chromosome number is 2n = 30.

**Research Stations Board working on tea cultivation and in India**

1. UPASI = United Planters Association of Southern India, UPASI Tea Research Institute, Nirar Dam B.P.O, Valparai – 642 127, Dist: Coimbatore, TN.
2. TES - Tea Experiment Satation, Tocklai, Jorhat, Assam

**Crop improvement**

From the very early days of tea cultivation in India, seeds were used for planting and it remained so far over 120 years.

1949: The use of vegetatively propagated plants was started in 1949 after the release of clones by Tocklai Experimental Station.

Tea being a highly cross-pollinated crop, the seedling populations is highly heterogeneous and comprises a large number of genetically distinctive genotypes which can be grown in a range of agro climatic conditions. The genetic and phenotypic variability of seedlings is high.

**Objectives of crop improvement in tea**

The final aim of tea breeding programme is to develop a high yielding tea of acceptable quality. Yielding capacity is based on the yield per unit area of bush surface which is dependent upon number of plucking points and the size of shoots. Hence the following characters are important in selection programmes and for developing superior clones of tea

1) **Vigour of the bush:** Select bushes which come into plucking quickly and give continuously high yields.
2) **Adaptability:** Adaptability to local environment including drought resistance for dry areas and frost resistance were required.
3) Resistance to pests and disease
4) **Hairiness of terminal bud:** It denotes high polyphenol content.
5) **Stature:** Spreading habit and tight plucking tables of bushes with ample leaves below the plucking table
6) Minimal tendency to produce dormant buds (Bhanjhi buds) and without tendency to flower.
7) Evenness of flush
8) **Shoot and leaf features:**Large heavy shoots with long internodes and without markedly erect leaves . (Because such leaves are more difficult to pick)

9) **Leaf flexibility:** Select bushes producing flexible leaves which are easier to roll and ferment easily and have good colour in the finished product giving an infusion of appropriate colour, aroma and astringency.
10) **Suitability for vegetative propagation:** Select bushes which have capacity to root easily from cuttings.

New cultivars are selected from the existing seedling populations or by hybridization, polyploidy, mutation or genetic engineering. The genetic base of our tea plant population should be broad-based and, therefore, a policy of clone-seed-clone-seed cycle is preferred.

**North India:** The Tocklai Experimental Station has so far released 29 TV series clones, over 130 TRA/garden series clones, 100 industry clones and 9 Tocklai biblical seed stocks.

**South India:** For use in south India, the UPASI Tea Research Foundation Valpari, has released 28 clones, about a dozen estate selections and 5 biclonal seed stocks.

The UPASI TRF has also developed 7 nursery graft combinations using high-yielding clones as scions and drought-hardy clones as rootstocks.

**Clonal selection**

Exploitation of heterogenity in seedling population, arising out of cross pollination, through clonal selection has played a vital role in tea improvement programme.

Selection of elite mother bushes is an important step in the development of its clones. (Mother bushes are selected based on visual assessment of characters like large pluck size and higher unit weight, higher density of plucking points, semi-orthotropic branching, and healthy and robust branching. Quality of made tea such as light green leaves and pubescence of leaves and branches are also looked into. The yield potential of mother bushes is calculated based on bush yield/unit area, out of field yield / unit area. Yield over two pruning cycles are considered and yield potential of more than one is considered high yielding. Subsequent processes in the development of clones involve the

assessment of rooting performance in the nursery, establishment in the field and survival in succeeding drought period, yielding ability, quality of tea and tolerance to biotic and abiotic stresses. Then select the best performing clones. These are then tested in different tea-growing areas. Based on comprehensive assessment, clones are released for commercial planting. The whole process from time of selection of mother bushes to release of clones for commercial cultivation takes about 10-12 years. The long time required for release of a clone is the limitation and methods for early yield prediction of clones are necessary. However, clonal selection has resulted in the development of several superior clones for commercial use in different tea growing regions. Twenty-eight clones have been developed by United Planters Association of South India.

Development of Seed Stock: Use of monoclones or few clones, is 'hazardous due to narrow genetic base and susceptibility to pests and diseases. Seed stocks are hence developed to widen the genetic base. (For development of seed stocks, elite clones are selected and planted in a specific statistical design in an isolated area, natural cross-pollination is allowed and seeds are collected. Seeds obtained from crosses involving more than 2 clones are referred to as polyclonal seeds, while that resulting from 2 clones are called biclonal seeds. In view of the comparatively greater phenotypic uniformity in progeny, biclonal seeds are preferred to polyclonal seeds. Now clonal selection is done in biclonal progenies.

**Interspecific Hybridization:** In general, progeny of interspecific and wide crosses is usually vigorous but lacks quality and morphological uniformity. A highly productive clone, TV 24, has been developed by producing F; hybrid between C. *irrawadiensis* x C. *assamica,* and crossing this with Assam-China hybrid (TV 2).

Induced polyploids in tea are vigorous and show resistance to environmental stresses. They are not grown commercially owing to poor quality.

**Clones developed by United Planters' Association of South India (UPASI)**

| Clone | Number | Character |
|---|---|---|
| UPASI (Evergreen) | 1 | Hardy |
| UPASI (Jayaram) | 2 | Hardy, high yielding |
| UPASI (Sundaram) | 3 | High-yield |
| UPASI (Brook lands) | 6 | Hardy |
| UPASI (Golconda) | 8 | High-yielding |
| UPASI (Athrey) | 9 | High-yielding |
| UPASI (Pandian) | 10 | Hardy, suited for windy areas |
| UPASI (Singara) | 14 | High quality |
| UPASI (Spring field) | 15 | High quality suited for windy areas |
| UPASI (Swarna) | 17 | High-yielding |
| UPASI | 24 | Hardy |
| UPASI | 25 | High-yielding |
| UPASI | 26 | Hardy |
| UPASI | 27 | High-yielding |
| UPASI (UPASI 10 x TRI 2025) | 28 | Biclonal, 6,120kg made tea/ha, good strength |

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**Answer the following**

1. What are the three distinct taxa of tea?
2. List out the crop improvement objectives of tea
3. What is clonal selection in tea?
4. Explain the development of seed stock in tea
5. Give an account of interspecific hybrization in tea
6. Expand UPASI &TES and mention its location
7. What are the clones developed by UPASI?
8. Differentiate China tea and Assam tea
9. What is the Cambodia tea?

**Lecture.33**

**Genetic resources, objectives of breeding, principles and method of breeding and salient breeding achievements in cocoa**

**Cocoa: *Theobroma cacao*** **Family: Sterculiaceae (Malvaceae)**

Theobroma is the name given by Linnaeus meaning "Food of the Gods" (Greek name Theos = Gods and Broma = Food) to the chocolate tree cocoa. *Theobroma bicolor* and *grandiflorum* are other better known species. *T. bicolor* is typical with the inflorescence appearing in the axils of new leaves and the branches bent down as the pods reach maturity. Seeds of *Theobroma bicolor* are used as adulterant. *Theobroma cacao* is a diploid with 2n = 20. *Theobroma cacao* ssp.cacao includes Criolla populations of Central and South America and *Theobroma cacao ssp. sphaerocarpum* which includes other populations like Forastero and Trinitario**.**

**Classification**

The most accepted classification divides cultivated and wild cocoa into 3 groups, based on Venezuelan terminology namely Criollo, Forastero and Trinitario.

**Criollo:** Pods yellow or red when ripe, usually deeply furrowed, often markedly warty, usually conspicuously pointed, pod wall thin in section so that pod compresses under hand pressure; seeds large, plumpy and almost round in cross-section; cotyledons white or pale-violet. Beans ferment quickly; comparatively low yield. It produces the best quality cocoa; but only small quantities are available in the world market. Criollos typically lack vigour and jorquette. They are reported to be extremely susceptible to bark canker, witche's broom and cocoa swollen shoot virus. Two types are distinguished in

criollo. Central American criollo, the unripe pod is green in colour and turns to yellow while ripening; Venezuelan criollos, this cultivar shows greater degrees of variation from tree-to-tree in colour, size and shape of pods. The unripe pod is usually red in colour.

**Forastero:** This is a large group which consists of cultivated, semi-wild and wild populations. Of this, Amelonado population is the most extensively grown. Unripe pods are whitish or green and turn yellow on ripening, usually inconspicuously ridged and furrowed, surface often smooth, ends rounded or very bluntly pointed, pod walls relatively thick and often with a woody layer, difficult to cut, seeds flattened, fresh cotyledons deeply pigmented and dark violet cross-section; usually giving an astringent product. These are hardier, more vigorous and higher yielding than criollo types.

**Trinitario:** These are hybrid populations result from natural crosses between criollo and forastero types. They are highly heterogeneous showing wide range of morphological and physiological characters. Colour of unripe pod may be whitish, green, red, variable in shape and wall thickness, surface ranging from smooth to warty; beans plump to flat; pigmentation of cotyledons white to nearly black. They are hardier and more productive than criollo, the best clones combine the vigour of Amazonian with much of quality of criollo, while other clones are very inferior.

**Germplasm Collection**

Research Stations working on cocoa in India:

1) CPCRI Regional Station, Vittal, South Kanara, Karnataka

2) KAU Vellanikkara, Thrissur

In a little more than 2 century, commercial cultivation of cocoa has extended from its centre of origin in South America to West Africa, the Far East and Oceania. It has become an important crop throughout the humid tropics. However, material for commercial plantings has been derived from a very narrow genetic base leading to low productivity in cocoa. Realizing the need to improve the genetic diversity, scientific expeditions were conducted to collect wild cocoa from the natural habitats. The materials collected in these expeditions are now maintained in national and international germplasm collections in Central and South America and in the Caribbeans. Collections at Centro Agronomico Tropical de Investigacion & En-senanza (CATIE), Costa Rica International Cocoa Gene Bank (ICG), Trinidad and CEPLAC, Brazil have been designated as primary collections and the germplasm is freely available to breeders. Transfer of germplasm from International Germ-plasm Centres to user countries is done through intermediate quarantine, of 2 years, with the facilities at Reading University, UK and at CIRAD, Montpellier, France. In order to undertake long-term breeding activities, the International Group for the Genetic Improvement of Cocoa (INGENIC) was created in 1993.

The important parent materials for cocoa germplasm are:

- ICS selections from Imperial College of Tropical Agriculture in Trinidad
- Upper Amazon parents like IMC, NA, PA and SCA
- Amelonado which originated in West Africa

In India, cocoa germplasm collections are conserved with further exploration at CPCRI Regional Station, Vittal (291 accessions) and College of Horticulture, Kerala Agricultural University, Vellanikkara (500 accessions).These collections were from Mslsysia, Ghana, Nigeria, Amazon, Trinidad, Brazil, Ecuador, UK, Mexico, Jamaica clones and few local collections from Wynad, Kerala and Shiradi ghats, Karnataka.

Presently, germplasm accessions are conserved in field either in the form of seedlings or as clones. The standardized clonal multiplications at various centres have paved the way for multiplication and maintenance of accessions with greater degree of true breeding values.

**Crop Improvement**

The cocoa germplasm has been utilized for crop improvement, in some ways. They are:

- Evaluation and selection of superior clones which are adapted to the locality with desired traits like higher bean yield and resistance/ tolerance to biotic and abiotic stresses, testing their performance in comparative yield trials and large-scale production of clonal materials from elite clones.
- Production of first-generation hybrids of self-incompatible high-yielders, assessment of their performance and selection of superior hybrids. The important-biotic factors considered are resistance to black pod disease and vascular streak die-back and drought tolerance among abiotic stresses.

**Selection criteria in cocoa**

- Trees with medium canopy under intercropping system
- Earliness in bearing
- Vigor and yielding efficiency
- Compatibility reaction
- Trees bearing lot of fruits with 70 – 100 pods/tree/year
- Medium to large pods of not less than 350g weight, smooth or shallow furrows on the surface without prominent constriction at the neck
- Pod value (Number of pods required to produce 1 kg beans) to be not more than 12
- Husk thickness of pods to be more than 1cm
- Number of beans per pod should be more than 35
- Bean weight should be more than 1gram
- Dry bean yield should be more than 1kg/tree/year
- Shelling percentage- 10 -15%

- Fat content > 50%
- Resistance breeding (India) – Black pod disease (*Phytophthora*), Vascular Streak Die back, *Ceratocystis* wilt, tea mosquito bug and drought.

**Varieties**

Several high-yielding varieties/hybrids have been released from India, Indonesia, Trinidad and Costa Rica.

**India**

Five varieties were released from Cadbury-Cocoa Research Project, Kerala Agricultural University, Thrissur, Kerala, through single plant selection from local populations and exotic collections. All the clones are tolerant to vascular streak die-back.

**CCRP I:** Pods are medium-sized, green which changes to yellow on ripening, constricted at the base, blunt beak and moderately deep ridges and furrows. The trees are self-incompatible. Mature pods weigh 385 g, with 46 beans and 0.8 g oven-dry bean weight. On an average, a tree yields 56 pods /year, with an yield potential of 72 pods.

**CCRP II:** It is a single plant selection from local population. It has spherical pods with obtuse apex. No ridges and furrows in the pods and yields 54 pods /tree /year.

**CCRP III:** It is a selection from open pollinated seedling of T76/1224/1201 (Amazon). It has elliptic pods with moderate ridges and furrows. It yields 68 pods per tree with 42 beans /pod.

**CCRP IV:** Pods large, purple tinged, turning yellow on ripening, beaked with acute tip, basal constriction shallow or absent, pericarp deeply rugose with deep ridges and furrows. The trees are self -incompatible. Mature pods weigh 402 g with 45 beans and 1.1 g oven-dry bean weight. On an average, a tree yields 66 pods/ year with a yield potential of 93 pods.

**CCRP V:** Pods large, elliptical, green when immature turn yellow on ripening, moderately deep ridges and furrows, apex acute. Trees are self-incompatible. Mature pods weigh 425 g with 45 beans and 0.8 g oven-dry bean weight. Average yield is 38 pods/tree/year with a yield potential of 55 pods.

**CCRP VI:** Pods very big, green turning to yellow on ripening, thick rind, elliptical without basal constriction, apex obtuse, pod surface rugose with shallow ridges and furrows. Trees are self-incompatible. Mature pods weigh 895 g with 48 beans and 1.9 g oven-dry bean weight. Average yield is 50 pods/tree/year with an yield potential of 180 pods.

**CCRP VII:** Pods large, elongated, green, turning to yellow on ripening, beaked with acute apex, slight basal constriction, pod surface rugose, moderately deep ridges arid furrows. The trees are self-incompatible. Mature pods weigh 526 g with 47 beans and 0.9 g oven-dry bean weight. Average yield 78 pods/tree with an yield potential of 95 pods.

**CCRP 8:** Hybrid between CCRP 1 x CCRP 7. Trees are self-incompatible. Pods green, medium sized, turning yellow on ripening, apex attenuate, base intermediate, rugosity intermediate. Mature pods weigh 389 g with 49 beans and 0.88 g oven dry bean weight. Average yield 90 pods/tree giving 11.40 kg wet beans.

**CCRP 9:** Hybrid between CCRP 1 x CCRP 4. Trees are self incompatible. Pods green, medium sized, turning yellow on ripening, apex attenuate, base strong, rugosity intermediate. Mature pods weigh 370 g with 37 beans and 0.8 g oven dry bean weight. Average yield 106 pods/tree giving 8.97 kg wet beans.

**CCRP 10:** Hybrid between CCRP 3x GVI 68. Trees are self incompatible. Pods green, medium sized turning yellow on ripening, apex attenuate, base intermediate, rugosity intermediate. Mature pods weigh 332 g with 41 beans and 1.1 g oven dry bean weight. Average yield is 80 pods/tree giving 8.15 kg wet beans

***Central Plantation Crops Research Institute, Regional Station, Vittal (Karnataka)***

Drought tolerant accessions NC 23, NC 29, NC 31, NC 39 and NC 42 have been identified

**Cocoa Varieties**

***Central Plantation Crops Research Institute, Regional Station, Vittal (Karnataka);***

| | |
|---|---|
| **Vittal Cocoa Hybrid (VTLCH) 4**<br><br>Specialty: Early, heavy bearer, suited to water limited condition.<br>Dry bean yield: 1.245 kg/ tree/ year<br>Yield per ha: 847 kg |  |

| | | |
|---|---|---|
|  | **VTLCH 3 Vittal Cocoa Hybrid 3**<br>Specialty: Early bearer, high yielder, suited to water scarcity conditions.<br>Dry bean yield:1.478 kg/ tree/ year<br>Yield per ha: 1005 kg | |

| | |
|---|---|
| | **VTLCH 3 Vittal Cocoa Hybrid 3**<br>Specialty: Early bearer, high yielder, suited to water scarcity conditions.<br>Dry bean yield:1.478 kg/ tree/ year<br>Yield per ha: 1005 kg |

| | |
|---|---|
| **VTLCH 2 : Vittal Cocoa Hybrid 2**<br>Specialty: Early, heavy bearer, medium canopy, black pod disease tolerant<br>Dry bean yield: 1.145 kg/ tree/ year<br>Yield per ha : 800 kg |  |

| | |
|---|---|
|  | **VTLCH 1 Vittal Cocoa Hybrid 1**<br>Specialty : Vigorous, early and heavy bearer. Dry bean yield : 1.48 kg/ tree/ year<br>Yield per ha : 1006 kg |

| |
|---|
| **VTLCC 1 Vittal Cocoa Clone 1**<br>Specialty : Early, heavy bearer, self & cross compatible<br>Dry bean yield : 1.33 kg/ tree/ year<br>Yield per ha : 904 kg |

***Indonesia***

*DR-1, DR-2, DR-21 and DR-35 are resistant to cocoa moth.*

***Trinidad***

*ICS-l, ICS-45 and ICS-92 are high yielding selections, showing varying degrees of tolerance to 'witches broom'* .***Hybrids****;* ICS-1 x SCA-6; (ICS-1 x SCA-6) x SCA-12; ICS-6 x SCA-6, (ICS-6 x SCA-6) x SCA-12 and TSH-999 are high-yielding hybrids released from the Tropical Research Station, Trinidad.

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**Answer the following**

1. What do mean by Theobroma?
2. What are the three major classification of cocoa?
3. Compare and contrast the Criollo and Forestero type of cocoa
4. What is Trinitario cocoa?
5. List out the Research centres working on cocoa
6. What are the major breeding objectives of cocoa?
7. List out the varieties developed by KAU
8. Name the varieties developed by CPCRI
9. Cocoa research work is mainly concentrated in the ---------- centre of CPCRI
10. What the exotic varieties developed in cocoa?
11. Distinguish between Criollo, forastero and Trinitario

**Lecture.34**

**Genetic resources, objectives of breeding, principles and method of breeding and salient breeding achievements in kokam & betelvine**

**Kokam: *Garcinia indica*** **Family: Clausiaceae (syn : Guttiferea)**

Kokam is dioecious, but seems to be highly variable in sex forms.

**Origin of kokum trees: Native to evergreen forests of western mountain range**

Sex types: The trees could be designated into the following types on the basis of preponderance of particular type of flowers and the bearing tendency of individual tree.

Kokum Flower

Kokum

**Tree type -1 – Staminate or male tree**

The flowers have mostly long pedicels, mass of stamens crowded on receptacle and sometimes rudimentary pistil with pointed apex. They are incapable of producing any fruit and serve as pollinators only.

**Tree type- II- Hermaphrodite or bisexual**

Young fruits produced by the tree are generally irregular in shape containing 0 to 6 underdeveloped seeds. Yield per tree may vary from 1 to 3 kg of fruits.

**Tree type III- Pistillate or female**

Flower is identified by short pedicel, well developed pistil and two or four tufts of staminodes below. Fruits are round to globose, dark red when ripe and contain 1 to 7 well developed seeds. Adult tree bears heavy crop. In a population of 62 trees observed 37 per cent turned out to be male, 8 per cent bisexual and 55 per cent female.

Constraints and suggestions for Kokum Development in India

1. Scattered production: No organized production of kokum at present. Most homesteads have a few trees from which fruits are collected from a wider area and it adds to the cost of production.
2. Federations/ Cooperative groups, Processing and marketing federations of collectors and growers should be formed. Collective farming system should be adopted.

3. Short harvesting period: Fruit harvest in kokum is only for about six weeks in a year, which is a short period for processing. During the first half of the summer the demand of kokum has to be met out of the production of the previous year and then supplying the production of current year for the second half.
4. Spoilage of the produce: Kokum starts fruiting from March and it extends until the first week of June. If it rains during the fruiting season the fruits will be spoiled. Premonsoon showers will spoil part of kokum produce.
5. Regional and seasonal demand: Though kokum drink is superior to many synthetic soft drinks in the market, its use is not known through out India. It is suggested to popularize kokum drink as a health drink than a soft drink.

**Varieties**

At KKV, Dapoli, fourteen kokum types with early maturity, bigger sized fruits and high yield have been identified.

**Konkan Amrit**: Released from KKV Dapoli (Dr. B.S. Konkan Krishi Vidyapeeth.). Konkan Amrit variety fruits are bigger in size weighing about 30 g.

**Yellow kokum**: A unique variety of kokum in Uttara Kannada dist. It is locally called as bili murugalu though the colour is yellow. It is believed to posses more medicinal properties. Skin will turn yellow at the time of ripening.

Kokum is one of the important non timber forest produces (NTFPs) collected from the western ghats of Karnataka.

Variety Konkan Amritha was developed by clonal selection. This variety is considerably early having short harvesting period (78days) with a few pluckings. The yield is high (138.28kg) with medium sized fruits (34.45g) having rind of 17.55g. Filled seeds were 3.55 per fruit. This variety is a pure female.

## Betel vine

**Betel vine: *Piper betle*** **Family: Piperaceae**

Betel vine is a perennial, dioecious evergreen creeper. There are about 100 number of cultivars recognized by the growers and traders in India. These are classified based on leaf size, shape, texture, quality and taste. The morphological differences in terms of length: breadth ratio due to sexual dimorphism do exist in betelvine. Male plants have leaves which are narrowly ovate with 1.84 length: breadth ratio and female plants have cordate or ovate leaves with 1.26 length: breadth ratio. Leaves of the female plants are mostly pungent and male plants are non pungent.

**Origin:** Malaysia (Central and Eastern Malaysia). It was introduced to India in pre historic times. It is believed to have come originally from Java.

**Important cultivars of different betelvine growing countries**

| Country | Cultivars |
|---|---|
| India | Bangla, Meetha, Sanchi, Karpoori, Kashi, Tellaku, Mahai, Kariyale, Deshawari, Desi Bangla, Kallipatti, Godi Bangla, Naua Bangla, Pachakodi, Vellaikodi, Mahoba Bangla, Ghanagatte, Ambadi,Bangla, Simurali Bhavana, Ramtek Bangla, Kali Bangla, SB -35 |
| Sri Lanka | Ratadalu, Gelathoda, Kahaneru, Nagawalli |
| Malaysia | Sireh China, Sireh Malaya, Sireh Hudang |
| Indonesia | Sireh Hitam, Sireh Buah, Sireh Balawi |

In India two high yielding cultivars have been developed in recent years of which SGM-1 is for cultivation in southern States. DPB-6 was released by Maharashtra state and Bidhan pan was released by West Bengal and Orissa. This cultivar was also recommended for cultivation in North Eastern States under protected cultivation. Characteristics of commonly traded and improved cultivars are as follows

**Bangla:** It is one of the widely traded types which encompass a large number of land races of betelvine. It grows vigorously and are generally very pungent. Leaves are having 7-9 prominent secondary veins, petioles are 8-10cm in length and lamina are 8.5-15.5 x 11-19cm, dark green in colour with yellowish tinge. Leaves are cordate to roundish having widest part of the lamina below the middle point, entire and glabrous. Leaves are also fibrous with nearly having 82% eugenol.

**Meetha:** Grown mostly in three districts of West Bengal namely, East Midnapore, South 24-Parganas and Howrah. Leaves are comparatively thinner than Bangla, waxy, cordate to broadly ovate, dark green in colour with characteristic pale yellowish specks and having short apex but pointed. The characteristic aroma in leaves is due to presence of the anethole as one of the constituents.

**Sanchi:** Leaves are medium to large in size, narrow and ovate with long base, lobes less prominent than Bangla. Leaf margin is entire. Leaves are dark green and fibrous. Leaves are pungent.

**Kapoori:** It is grown mostly in Tamil Nadu, Andhra Pradesh, Maharashtra, Kerala and Karnataka. Vines are moderately vigorous, highly branched and leaves are narrow to ovate with thin lamina and soft in texture. The aroma is due to presence of high percentage (20%) of terpenyl acetate.

**Deshawari:** It produces large cordate leaves with short, pointed, acuminate and characteristically curved apex. It has mild sweet taste which is due to low anethole content.

**Khasi:** This cultivar is somewhat wild in character and mainly grown in North Eastern hilly region. Leaf colour is dark to dull green.

**SGM 1:** It is a clonal selection from a Palghat type. It is adaptable to all betel vine-growing areas of Tamil Nadu. It produces a higher leaf yield of 109 lakh leaves per hectare in a crop duration of 2 to 2½ years. The vines are dwarf statured with vigorous bushy growth having thick hardy stem with short internodes and multilateral. Leaves are attractive yellowish green colour with desirable pungency. It is the first betel vine variety released by TNAU from Southern India.


**SGM (BV) 2:** This is a pureline selection from Dindigul local. It possesses multilateral vines (17-20/vine) with long petioles and attractive dark green leaves. The leaves are moderately pungent with good chewing quality. It is a high yielder with good market appeal. The duration of the crop is 2-2½ years. The suitable season for cultivation was January – March and June – August for Agathi and March – May and August – October for betelvine. The crop is moderately resistant to phytopthora wilt, blight and nematodes. It yields about 49 lakh leaves / ha / year which is 25.4% increase over SGM 1, 33.8% increase over Karpoori and 62.0% increase over vellaikodi. It can be cultivated all over Tamil Nadu and is suitable for open trench cultivation.

**Bidan Pan:** It is a selection from the local Bangla cultivar. The characteristic feature of the plant is short internode length. The productivity goes high due to short internodal length.

**DBP-6:** It is a selection from a local Karpoori collection from Maharashtra. The cultivar has given about 10-18 percent increase in productivity over the cultivars of Maharashtra. Leaf characters are similar to Karpoori.

Cultivated types including wild and semi wild types should be extensively collected and should be grown under uniform conditions and various traits like yield, quality, disease and pest resistance should be evaluated in wild and semi wild types which may be valuable sources for resistance genes.

Procedure for selection in the several progenies includes a) cultivars can be inbred to produce seeds and selection is to be done among the progenies varied there from. b) Inter breeding of cultivars and selection in resulting progenies. Induction of new variations can be achieved through mutation; somoclonal variations through tissue culture of cultivars; haploid can be intercrossed to develop heterotic hybrids. Betelvine can be crossed with other sister species (inter specific hybridization) ad the resulting $F_1$ and $F_2$ there from can be studied for desirable variants.

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**Answer the following**

1. What is the botanical name and family of kokam?
2. What are the sex types in Garcinia?
3. Mention the constraints for kokam development in India
4. What are the varieties developed in kokam?
5. What is the botanical name and family of betelvine?
6. the origin of betelvine is ----------
7. List out the cultivars of different betelvine growing areas
8. Describe the features of SGM1 & 2
9. Narrate the procedure for selection of progenies in betel vine
10. What is Bidan pan?