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Breeding of Fruit and Plantation Crops

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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

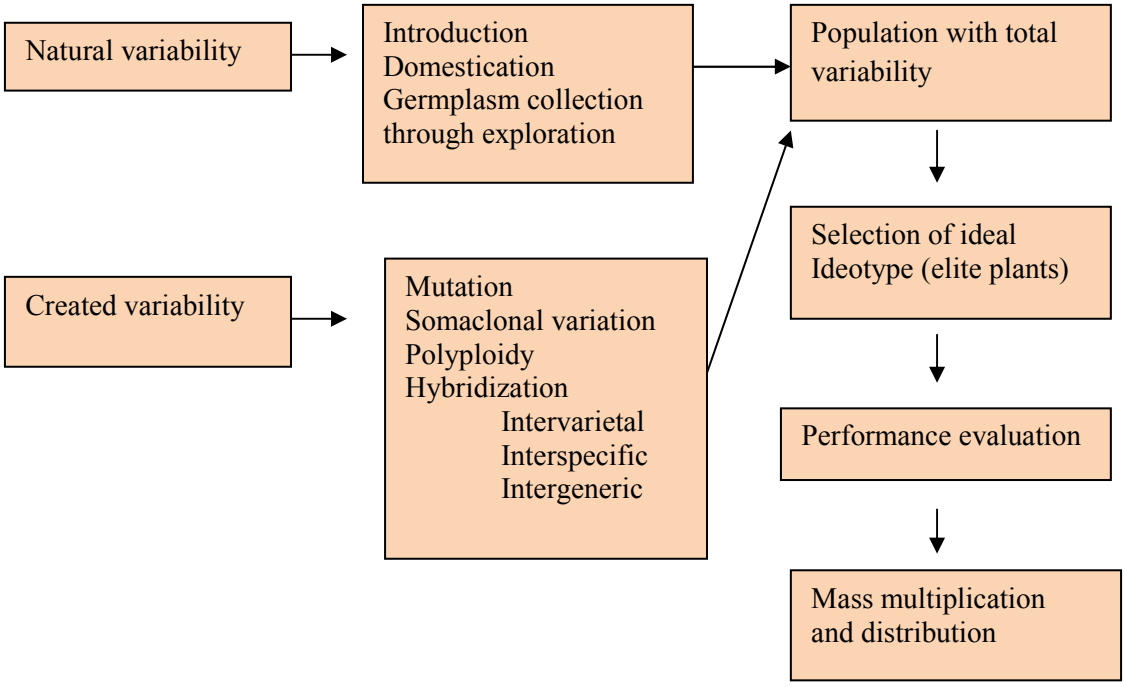
- Dwarf stature
- Regular, precocious and prolific bearing per unit canopy area
- High productivity with good quality fruits
- Resistance to biotic and abiotic stresses
- Attractive fruit colour with pleasant aroma
- Suitable for processing and export

- 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

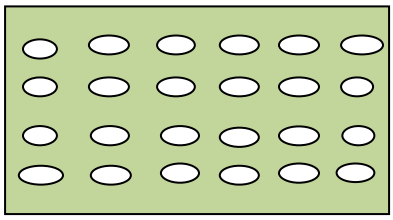
The phenotypic value of a plant or a clone is due to its genotype (G), the environment (E) and the genotype x environment interaction (GE). Of these, only the G

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.

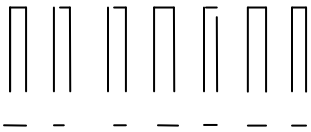
The various steps involved in clonal selection are briefly described below and are depicted.

I year



Select plants of superior clones

II year separately



Evaluate selected clones

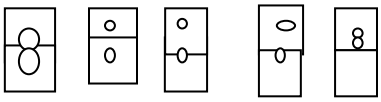
select desirable clones

III year

Preliminary yield trial with

suitable check and selected outstanding clones.

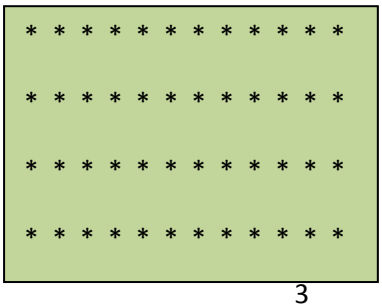
IV year to VIII year



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.

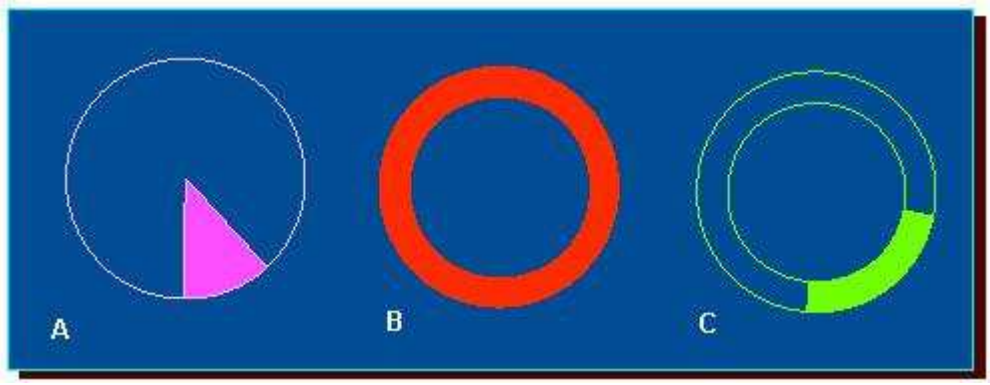
Treatment of seeds and vegetative propagules commonly produces chimeras.. Shoot tip meristem usually has two functional layers; the outer layer, giving rise to epidermis and a part of leaf mesophyll, and the inner layer producing the rest of the plant tissues including reproductive organs.

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. 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. 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. 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, 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

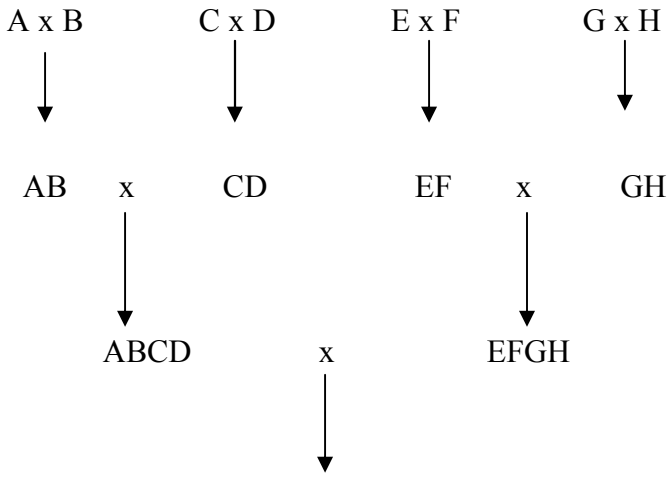
↓ ↓

(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.

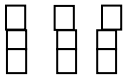
Backcross Method of Breeding

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 PARENT A PARENT B ↓ **F** X RECURRENT PARENT A ↓ **BC_1** X RECURRENT PARENT A ↓ **BC_2** x RECURRENT PARENT A ↓ **BC_3** X RECURRENT PARENT A ↓ **BC_4** X RECURRENT PARENT A ↓ **BC_5** X RECURRENT PARENT A ↓ **BC_6** X RECURRENT PARENT A ↓ **BC_6F_1** x SELFED ↓ **BC_6F_2** **111111111111**	B is the disease resistant parent and A is the disease susceptible parent Disease resistant plants in F_1 is backcrossed with recurrent parent (A) Disease resistant plants with similar characteristics as that of recurrent parent A are selected & again backcrossed with A. As in BC_1 generation As in BC_1 generation As in BC_1 generation Disease resistant plants self pollinated and seeds harvested separately. 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.
--- --- --- --- --- --- --- --- --- --- --- --- --- --- ---	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)

MID TERM EXAMINATION

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.

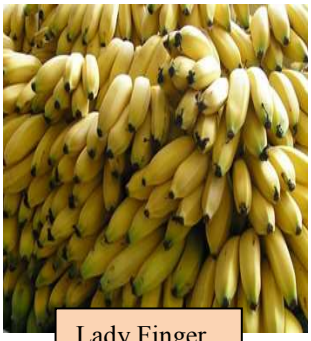
Taxonomic classification of edible banana (Simmonds and Shepherd, 1955)

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

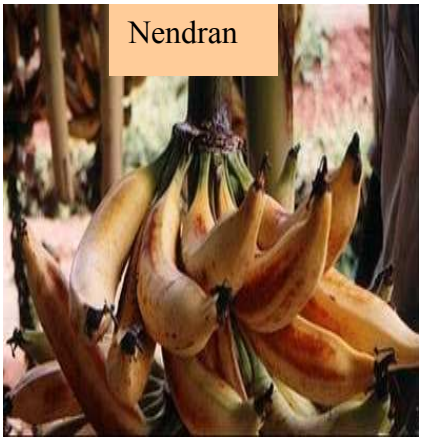
PITA-9: A Black Sigatoka Resistant (BSR) hybrid from the "False Horn" plantain, a tetraploid hybrid having black Sigatoka resistance has been developed at International Institute of Tropical Agriculture (IITA), Nigeria.'BITA-3' is a tetraploid starchy banana hybrid with low partial resistance to black 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. Incertae 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

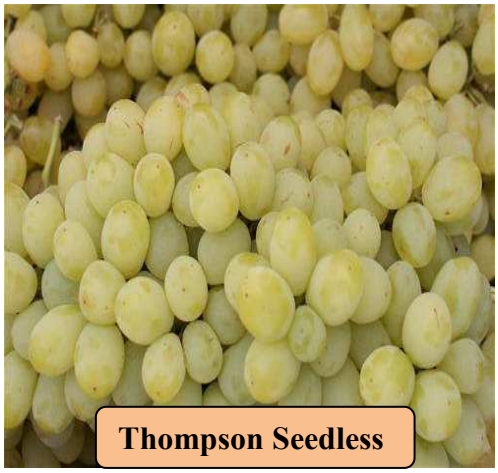
For the tropics the objectives of breeding should be:

- 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_3treatment.
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

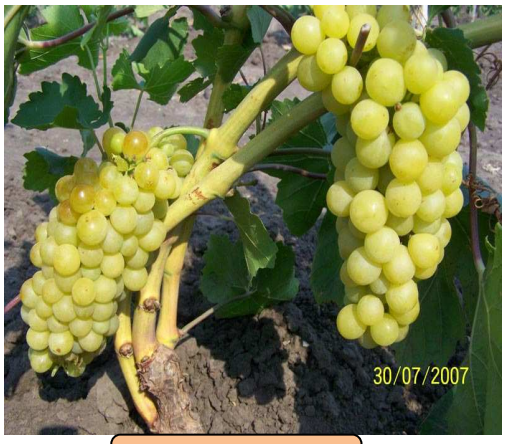
(ii) Emasculation and pollination

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.19
Crop improvement in papaya

Botanical name: *Carica papaya* L.

Family: Caricaceae

Chromosome number: 2n=2x=18

Papaya is an ideal fruit crop for growing in kitchen garden, backyards of home as well as orchards, especially those places nearer to cities or big town. It is also grown as a filler plant in orchard. The ripe fruits of papaya are consumed throughout the tropics and subtropics. Fruits are also used in preparation of jam, soft drinks, ice cream flavor, crystallized fruits and syrups. Unripe fruits are commonly used as vegetables. Papain is prepared from the latex of immature fruits. It is a proteolytic enzyme used for tenderizing the meat as well as in leather tanning and cosmetics etc. The ripe fresh fruit is a rich source of vitamin A (2020 I.U), vitamin C (40-60mg/100g) carbohydrates and minerals. Papaya, on account of producing fruit in a short period after planting has attracted the attention of fruit growers for large scale cultivation in the country. It is known as wholesome fruit which is valued for its nutritional and medicinal properties. Due to its nutritional, industrial and export demand, papaya is recognized the most potential fruit crop for commercial cultivation. The variable sex forms, susceptibility to frost and water logging, fungal and viral diseases are well identified problems in its cultivation. Economically the productive life span of papaya is 3 years and every time new plantation has to be raised.

Centre of diversity

Papaya is native to Tropical America. The South America and Costa Rica are the micro centre of origin of papaya. It is a close relative of *Carica peltata*. In India, it was introduced in the early part of the 16th century from Philippines through Malaysia. It was widely spread in different parts of the country particularly tropical and sub-tropical zones. India is the largest producer of


Vasconcellea peltata

papaya in the world. It is also cultivated in Brazil, Mexico, Australia, Hawaii, Malaysia, Taiwan, Peru, Florida, Gold Coast, South Africa and Bangladesh. In India it is widely cultivated in Uttar Pradesh, Bihar, Karnataka, Jharkhand and Madhya Pradesh.

Germplasm resources

The family Caricaceae consist of six genera and 35 species. *Carica* and *Vasconcellea* are the important generas. The genus Carica has only one species, *Carica papaya* the cultivated species. *Vasconcellea* contain 21 species, which are considered as the wild relatives of papaya. Their diversity is common in South America

Variations with respect to plant stature, sex types, fruit shape and size, seed content are observed in papaya. Presently, germplasm is being maintained at TNAU, Coimbatore, IIHR, Bangalore, IARI Regional Station, Pusa, Bihar, CHES, Ranchi, CHES, Bhubaneshwar and CISH, Lucknow for further characterization and evaluation.

Important wild relatives of papaya

Some *Vasconcellea* species are used in interspecific hybridization for resistance breeding e.g. *Vasconcellea* Carica cauliflora is resistant to viruses. *Vasconcellea candamarcensis* and *Vasconcellea pentagona* are resistant to frost. Based on the crossability and compatibility it has been observed that *Vasconcellea monoica*, *Vasconcellea cauliflora* and *Vasconcellea candamarcensis* are easily crossable with each other and producing viable seeds. But inter-generic hybridization of these species with C*arica papaya* did not produce mature seeds. However, by using embryo culture technique, immature embryo can be developed into mature embryo. Further, cross between *Carica papaya* and *Vasconcellea goudotiana* was found to be a failure. The species, *Vasconcellea cauliflora*, *Vasconcellea pubescens*, *Vasconcellea stipulata* and *Vasconcellea candicans* are resistant to papaya Ring Spot Virus (Capoor and Verma, 1961)

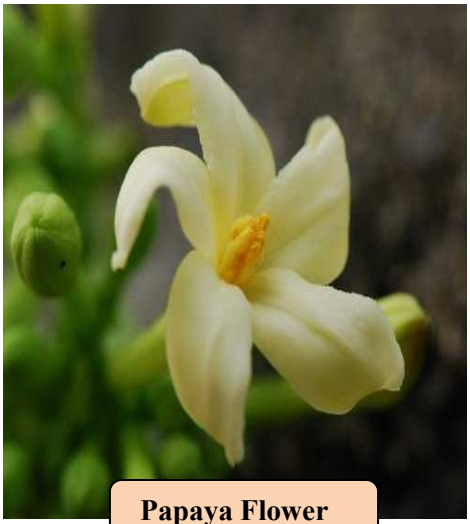
Objectives

- To develop dwarf statured and early bearing varieties.
- To evolve varieties with high yield and good quality fruits.
- To develop varieties with low cavity index and more pulp thickness.
- To breed varieties having good keeping quality and suitable for export.
- Breeding for high latex yield with high proteolytic enzyme activity
- To develop varieties resistant to biotic and a biotic stresses (virus, frost, water logging etc).

Botany

Papaya belongs to family *Caricaceae* and genus *Carica* having about 40 species. It is a dioecious plant but gynodioecious cultivars are also available. The stem is hollow and soft wooded. It is usually unbranched when young but at later stage upright shoots develop at its terminal growth due to obstruction. The leaves are palm like with long stalks. Flowers are cymose, fragrant borne in leaf axils. The fruit is a fleshy berry. The fruits from pistillate flowers are ovoid-oblong to nearly spherical in shape and the fruits from hermaphrodite flowers are pyriform, cylindrical or grooved.

Floral biology and pollination



Papaya Flower

Dioecious papaya produces male and female trees separately on different plants in the ratio of 1:1, while gynodioecious cultivars produces both female and andromonoecious trees in the ratio of 1:2. Female and male flowers develop within 32 and 42 days respectively after bud initiation. The period from bud initiation to anthesis is shorter for male than female flower bud (Dhaliwal et al., 1991). Stamen development occurred prior to ovary development in the hermaphrodite flower and stamen differentiation was observed 56-59 days before anthesis. Anther dehiscence starts

18-36 hours before the flowers opening and continues depending upon the weather conditions and stigma becomes receptive a day before the flower opening and remaining receptive for 6 days. The peak anthesis was observed between 5.00-6.00 a.m. The receptivity of stigma was found maximum on the day of anthesis in most of the species (Subramanyam and Iyer, 1986). To ensure good fruit set in the dioecious cultivars of papaya (e.g. CO1, CO2, CO4, CO5, CO 6, Pusa Giant, Pusa Dwarf, Pusa Nanha,), the female and male ratio should be 20:1. However, maximum number of andromonoecious trees are retained in gynodioecious varieties (eg. CO3, CO7, Coorg Honey Dew, Sun Rise Solo, Sun Set Solo etc.) Further, insects are the major pollinating agents in papaya.

Sex forms

There are two major sex forms in papaya

1. **Dioecious:** male and female trees segregate in the ratio of 1:0.sibmating is done for maintaining of purity.
2. **Gynodioecious**: Female and andromonoecious (female + bisexual flowers in a single tree) trees segregated in the ratio of 1:2. Selfing of bisexual flowers is done for obtained pure seeds

Breeding methods and achievements

Inbreeding and selection

In dioecious lines, suitable male plants are selected from the same progeny which have resemblance to female plants in vegetative characters, such as stem and leaf colour, stem thickness and height at flowering etc. Progenies raised from S_1 inbreds are screened and desired male and female plants are selected for further sibmating i.e., crossing between the female plant and male plant of the same cultivar. The process is to be continued for 7-8 generations to achieve uniformity for a group of characters. In this method, the progeny will have male and female in equal proportion. Many dioecious cultivars have been bred by this method.

Development of cultivar with high papain content was started at TNAU, Agricultural College and Research Institute, Coimbatore. As a result of intensive breeding programme, four cultivars i.e., CO1, CO2, CO5 and CO6 were developed through inbred selection which are dioeicous(Rao, 1974, Sundarajan and Krishnan,1984, Shanmugavelu *et al*., 1988) at Coimbatore. Recently during 2011, CO 8 papaya was developed in the dioecious group through sib-mating of CO2 variety, which is a red-fleshed variety and this variety is unique for the red pulp colour which is not exist in any of the dioecious papaya varieties developed. Systematic work for breeding of uniform varieties with high yield and good quality for wider adaptability was started at IARI Regional Station, Pusa, and Bihar in 1966. As a result of inbreeding and selection for 8 generations during 1966-1982, uniform lines of Pusa Delicious, Pusa Majesty, Pusa Giant and Pusa Dwarf with desirable attributes were developed. At Coorg, Aiyappa and Nanjappa (1959) selected Coorg Honey Dew which is gynodioecious. Based on the two season evaluation of papaya germplasm in Nainital, cultivars Barwani Red, Coorg Honey Dew, BR 1, 2, 3, 4, Coimbatore 1B and Washington have been found promising for commercial cultivation. Considerable genetic variability was found in many plants with respect to fruit characteristics like fruiting height, fruit weight, size shape, TSS, taste and number of fruits per tree.

Important cultivars of papaya developed through selection are as under

CO1	Plant is dwarf; fruit is round, selected from cultivar Ranchi
CO2	It is pure line selection from local type, suitable for papain production in terms of high enzyme activity. Dual purpose variety for dessert fruit as well as papain
CO3	It is a hybrid between CO2 x Sun Rise Solo, plant is vigorous, fruit is medium in size with good keeping quality.
CO4	It is a hybrid between CO1 x Washington, fruit is large, keeping quality is good, and flesh colour is yellow.
CO5	It is a selection from Washington; it is also good for papain production in terms of high latex yield
CO6	It is a selection from ‘Giant. Fruits are bigger weighing 2.5 to 3.0 kg. Suitable for papain and dessert purpose

CO7	It is gynodioecious hybrid between CP75 x Coorg Honey Dew. It has red flesh. Fruit cavity round
CO8	It is a red-fleshed dioecious variety bred through selective sib-mating in the population of CO.2. Suitable for dessert purpose, processing and papain production
Coorg Honey Dew	It is gynodioecious selection from Honey Dew at Coorg\
Pusa Majesty	It is selection from cv. Ranchi. It is gynodioecious variety suitable for high papain.
Pusa	A gynodioecious selection from cv. Ranchi, it has good fruit

Induction of polyploidy

Hofmeyer (1945) reported on polyploidy in papaya. They found that the quality of tetraploid fruit was better than the diploid and it was also compact with small seed cavity. But tetraploids were less fertile than diploid as indicated by comparative seed count. However, according to Singh (1955) there was complete sterility in both female and male tetraploids and expressed doubt about their commercial utilization. Further, Zerpa (1957) reported that colchicine induced tetraploid hermaphrodite plants, which were used as male parent in a cross with a female diploid produced a few seeds without endosperm, by embryo culture, two triploid plants were obtained which turned out to be hermaphrodite.

Hybridization

A few hybrid varieties have been developed by the intervarietal or intergeneric hybridization. But still there is great scope for development of superior cultivars with better quality and yield. At TNAU, Coimbatore three varieties have been developed viz. CO3 (CO2 x Sunrise Solo), CO4 (CO1 x Washington) and CO7 (CP.75 x Coorg Honey Dew). At IIHR Bangalore, two hybrids IIHR-39 named as Surya (Sun Rise Solo x Pink Flesh Sweet), and IIHR-54 (Waimanalo x Pink Flesh Sweet) were developed (Dinesh and Yadav 1998), Hybrid HPSC-3 (Tripura local x Honey dew) was developed by the ICAR

Research Complex Tripura (Singh and Sharma, 1996). Cultivar Cariflora was developed by crossing K_2xK_3 line of papaya which is tolerant to PRSV (Conover et al.,1986).

Inter-specific hybridization was also attempted in the genus *Carica*. The cross between the *Carica* papaya and *Carica caulifora* did not form mature seed but immature embryos could be germinated and grown by embryo culture. F_1 hybrids of *Carica papaya* x *carica pubescens* and *Carica papaya* x *Carica quercifolia* were vegetatively vigorous. *Carica papaya* x *Carica cauliflora* F_1 progenies are slow growing and those of *Carica papaya* x *Carica stipulata* developed apical necrosis before reaching maturity. Iyer and Subramanyam (1984) attempted interspecific hybridization and reported that F_1hybrids of *C.cauliflora* x *C.monoica* when crossed with *C.papaya* gave fertile hybrids, although the *C.cauliflora* and *C.monoica* are incompatible with *C.papaya* but hybrids of *C.cauliflora* x *C.monoica* are compatible.

Heterosis breeding

Dai (1960) reported heterosis in the cross between Philippines x Solo varieties. F_1 hybrid tended to have reduced seed number and enhanced plant vigour. Heterosis up to 111.4% for yield and yield traits was obtained in Solo yellow x Washington whereas high heterosis for potential economic competitiveness was noticed in Thailand x Washington (Iyer and Subramanyam, 1981). At IIHR, Bangalore, an F_1 hybrid namely, Surya (Sun Rise Solo x Pink Flesh sweet) was released recently. It is gynodioecious in nature and produces about 75-80 fruits of medium size weighing about 600-800g. the flesh is red in colour, firm, sweet to taste with a TSS of 14° brix.

Mutation breeding

Ram and Majumder (1981) developed a dwarf mutant line by treating papaya seed with 15K gamma rays. Initially, 3 dwarf plants were isolated from M_2 population. Repeated sibmating among the dwarf plants helped in establishing a homozygous dwarf line Pusa Nanha.

Biotechnology

In-vitro propagation and genetic engineering technique can serve as a potential tool to overcome major constraints in *Carica papaya*.

Embryo culture

In papaya, incompatibility is mainly due to the failure of endosperm formation. The hybrid embryo resulting from interspecific cross of *C.papaya* and *C.cauliflora* has been successfully rescued on White's medium in 30 days by Yung (1986).

Transgenic papaya

Transgenic papaya has been developed against Papaya Ring Spot Virus (PRSV) using coat protein mediated resistance in University of Hawaii by Dennis Gonsalves. The coat protein gene from PRSV was isolated, cloned and used for transforming papaya to provide resistance against the severe strain of the same virus. The target cultivars used in transforming papaya were the Red fleshed, Sun Set Solo and the Yellow Fleshed Kapoho Solo. Transformation with coat protein gene was done using micro projectile bombardment technique using embryogenic tissues of papaya.

Two transgenic lines Sun UP from Sun Set Solo and UH Rainbow from Kapoho were developed which have shown excellent resistance to PRSV. Sun UP, which is homozygous for CP (Coat Protein gene), was resistant to most isolate of PRSV, from other geographical locations except Taiwan's YK isolate of PRSV. Rainbow was found susceptible to PRSV isolates from outside Hawaii but was resistant to the severe strain of Hawaiian PRSV (HA isolates).

Important varieties and species

CO1 CO2	Plant is dwarf; fruit is round, selected from cultivar Ranchi. It is pure line selection from local type, suitable for papain production in terms of high enzyme activity. Dual purpose variety for dessert fruit as well as papain

CO3	It is a hybrid between CO2 x Sun Rise Solo, plant is vigorous, fruit is medium in size with good keeping quality.
CO4	It is a hybrid between CO1 x Washington, fruit is large, keeping quality is good, and flesh colour is yellow.
CO5	It is a selection from Washington; it is also good for papain production in terms of high latex yield
CO6	It is a selection from 'Giant. Fruits are bigger weighing 2.5 to 3.0 kg. Suitable for papain and dessert purpose
CO7	It is gynodioecious hybrid between CP75 x Coorg Honey Dew. It has red flesh. Fruit cavity round
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Coorg Honey Dew	It is gynodioecious selection from Honey Dew at Coorg
Pusa Majesty	It is selection from cv. Ranchi. It is gynodioecious variety suitable for high papain.
Pusa Delicious	A gynodioecious selection from cv. Ranchi, it has good fruit quality.
Pusa Giant	A dioecious selection from cv. Ranchi, it is tolerant to strong wind.
Pusa Dwarf	It is a selection from cv. Ranchi, plant is dwarf and dioecious in nature, fruit shape is oval.
Pusa Nanha	It is developed through mutation; plant is dwarf, suitable for high density planting, fruit quality is good.
Pant Selection.1	Selection made at GBPUAT, fruit shape is oblong.
Pant Punjab Sweet	It is a selection made at PAU Ludhiana. It is frost tolerant and dioecious in nature.
Surya	It is a gynodioecious hybrid (Sun Rise Solo x Pink Flesh Sweet), developed at IIHR, Bangalore, it has high yield with good quality fruit.

HPSC-3	It is a hybrid between Tripura Local x Honey Dew. This cultivar is resistant to Papaya Mosaic

Questions

1. Papaya known as wholesome fruit.

   Ans: True

2. Papaya is Fleshy berry type of fruit.

   Ans:True

3. Name a transgenic papaya

   Ans: U.H Rainbow

4. Name two papaya varieties suitable for papain extraction as well as table purpose CO2 and CO5.

   Ans:True

5. ***Vasconcellea cauliflora*** is resistant to papaya Ring Spot Virus (PRSV).

   Ans:True

6. Pusa Nanha is developed through mutation breeding.

   Ans:True

7. Two major sex forms in papaya are Dioecious and Gynodioceious.

   Ans:True

Match the following

1. Dioecious - CO7
2. Gynodioecious - tolerant to strong wind

3. IARI, Bihar - CO 5
4. Pusa Giant - resistant to papaya mosaic
5. HPSC-3 - Pusa Majesty

Ans

1. Dioecious - CO5
2. Gynodioecious - CO7
3. IARI, Bihar - Pusa Majesty
4. Pusa Giant - tolerant to strong wind
5. HPSC-3 - resistant to papaya mosaic

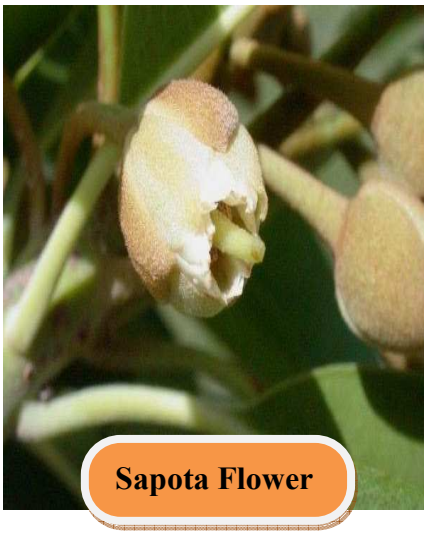
Lecture.20

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 17th 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.

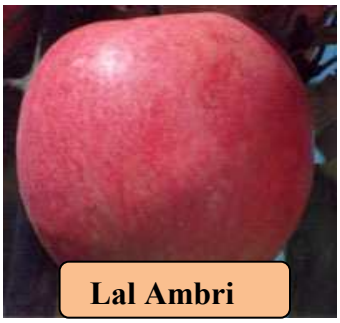
Williams (1959) calculated that the percentage of desirable seedlings that can be expected as the main product of an apple breeding programme for polygenically controlled characters is seldom more than 40 per cent and for every additional character, the figure rapidly decreases. Thus, for a programme 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_1s 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.*

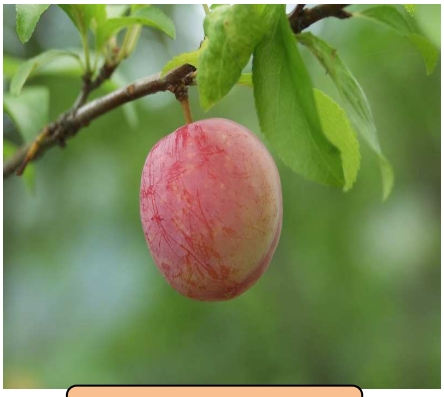
Planned hybridization work on peach was started in 1957 at Saharanpur. Peach Saharanpur Prabhat (Sharbati x Flordasun) was released. Fruits of this variety are attractive, sweet, maturing at least 4 days earlier than Flordasun.

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 16th 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 16th 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 15th 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 8th 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

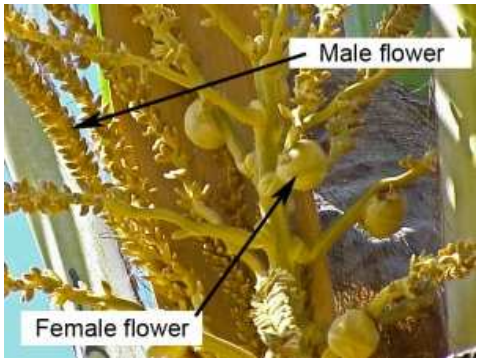
1. Define hybridization
2. What is a hybrid?
3. What is a spontaneous hybrid
4. What is a haploid?
5. Define cryopreservation
6. What is the use of haploid production?
7. Name one intervarietal hybrid in coconut
8. What is an interspecific hybrid
9. Quote an example for interspecific hybrid
10. Mention 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.

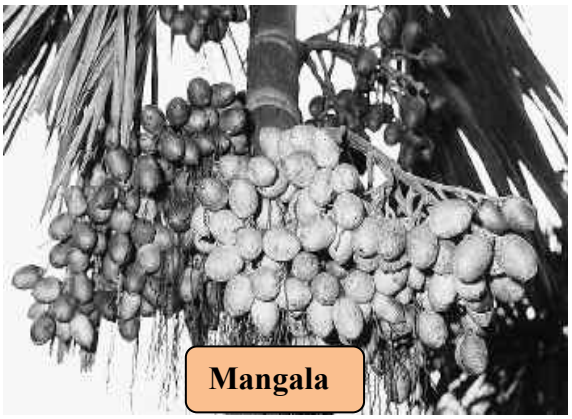
Germplasm and Varieties

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 phe-nomenal 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 Powdery mildew – high Abnormal leaf fall – moderate *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 Powdery mildew - very high Abnormal leaf fall – low *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 Powdery mildew-severe Abnormal leaf fall - moderate		
Reaction to stresses	Cold-average tolerance 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 Powdery mildew - moderate to severe Abnormal leaf fall - moderate to severe 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 Powdery mildew-moderate Abnormal leaf fall-moderate		
Reaction to stresses	Cold - average tolerance 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 Powder mildew - very high Abnormal leaf fall - low to moderate *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 Powdery mildew – high Abnormal leaf fall – low *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

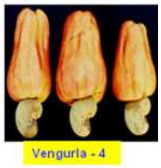
Research Station	Variety	Source of germplasm	Yield potential (kg/tree)	Nut weight (g)	Kernel weight (g)	Shelling (%)	Kernel grade
Directorate of Cashew Research Puttur, Karnataka	Selection 1	VTH 107/31	10.0	7.6	2.2	28.8	W 210
	Selection 2	VTH 40/11	9.0	9.2	2.5	28.6	W210
Horticultural Research Station, 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 Specialty: Early, heavy bearer, suited to water limited condition. Dry bean yield: 1.245 kg/ tree/ year Yield per ha: 847 kg	

	**VTLCH 3 Vittal Cocoa Hybrid 3** Specialty: Early bearer, high yielder, suited to water scarcity conditions. Dry bean yield:1.478 kg/ tree/ year Yield per ha: 1005 kg	

	VTLCH 3 Vittal Cocoa Hybrid 3 Specialty: Early bearer, high yielder, suited to water scarcity conditions. Dry bean yield:1.478 kg/ tree/ year Yield per ha: 1005 kg

VTLCH 2 : Vittal Cocoa Hybrid 2 Specialty: Early, heavy bearer, medium canopy, black pod disease tolerant Dry bean yield: 1.145 kg/ tree/ year Yield per ha : 800 kg	

	**VTLCH 1 Vittal Cocoa Hybrid 1** Specialty : Vigorous, early and heavy bearer. Dry bean yield : 1.48 kg/ tree/ year Yield per ha : 1006 kg

VTLCC 1 Vittal Cocoa Clone 1 Specialty : Early, heavy bearer, self & cross compatible Dry bean yield : 1.33 kg/ tree/ year 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?

Exercise.1

Study of Floral Biology and Anthesis Time in Mango and Cashew

CLASS : Dicotyledonae

SUBCLASS : Polypetalae

SERIES : Disciflorae

ORDER : Sapacadales

FAMILY : Anacardiaceae

GENUS : *Mangifera*

SPECIES : *Indica*

BOTANICAL NAME: *Mangifera indica*

2n = 40

The origin of mango is Indo – Burma region.

Mango is the most popular fruit for million of people. It is considered as the choicest of all fruits. Its cultivation started before four thousand years. Other species of Mango are,

1. Mangifera caseia

2. Mangifera foetida

3. Mangifera odorata

4. Mangifera zeylanica

5. Mangifera similis

6. Mangifera sylvatica

These species are cultivated in different places but the fruits are of inferior quality.

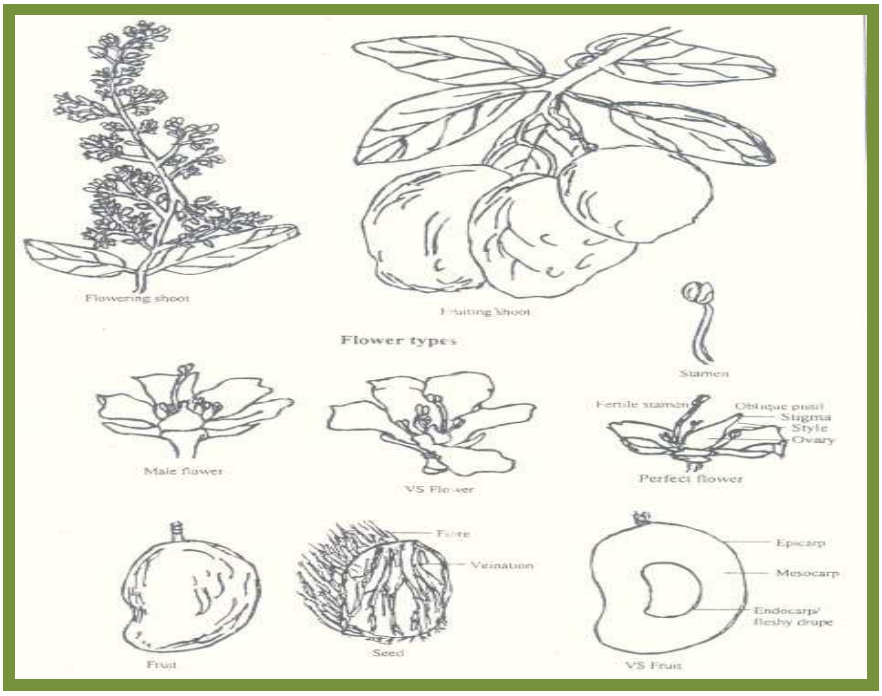
Habit: This is an erect evergreen tree growing 10 to 40 m height with dense dome shaped canopy.

Root: Long tap root, goes up to 6m depth and dense surface mass of feeding root. It is having pronounced trunk with greyish brown bark is thick or black in colour.

Leaves: Simple leaves, alternate, exstipulate, young leaves usually reddish in colour, latter turn dark shiny green and remain on the tree for a year or more. Petiole is 1 to 10 cm, flattened on the upper surface, leaves are narrowly elliptic or lanceolate, mid rib prominent, having up to 30 pair of lateral veins stomata on both the surface but greater number on the low surface.

Inflorescence: Inflorescence is widely branched, terminal panicle 10-60 cm in length with 1000-6000 flowers, polygamous flowers, with male and hermaphrodite flowers in the same flower, out of which 0.74-69.8% perfect flower or hermaphrodite flower. The branches are usually pubescent.

Flowers: They are 5 to 8mm in diameter, sub-sessile sweet scented.



Calyx: The sepals usually 5 rarely (4-7) free, concave in shape, yellowish green.

Corolla: The petals usually 5 rarely (4 to 7) twice as long as calyx green colour with 3 to 5 dark yellow ridges on the inner surface. Petals later becoming pink in colour and fleshy annular, 5 lobed disk in between corolla and androecium.

Male Flowers: The stamens usually 5, rarely 3 to 7 inserted on the outer margin of the disk of which 1 or 2 are occasially fertile and others staminodes. Stamens usually pink in colour turning purple on anthesis. The pistil is abortive in male flower. Hermaphrodite flower, the stamens are as described above and sessile one celled ovary which is set on disc and lateral style and small simple stigma approximately same length of that fertile stamen.

Fruits: Fleshy drupe contains a stony endocarp and the size of the fruit is 2.5 to 3.0 cm long, shaped round to ovoid to oblong colour varying with green, yellow and red. A small projection developing laterally at the distal end of the fruit is known as beak and the sinus present above the beak. The basal end may be depressed intermediately. The endocarp is fairly thick, edible mesocarp, varying thickness.

Seed: The seed is inside the stony endocarp, two fleshy cotyledons, mono embryonic with one zygotic embryo, others are poly embryonic with two to twelve embryos in which apomictic embryos are produced from epidermal cell of nucleus to which zygotic embryo may or may not be supported.

Pollination and fruits: flowering usually seen in the month of November to December in India. The panicles located in the inner position of the tree have higher percentage of perfect flowers than the panicles located outside.

Flowers open early in the morning its maximum anthesis from 8-12 a.m. The stigma receptivity at the time of flower opening. The nectar secreted by the disc. Mode of pollination by flies, nearly 65 – 85% flowers remain unpollinated and only 0.1-1% reach the harvesting stage. Fruit drop occur at all stages. After fertilization, maturity attains in 2 to 5 months.

CASHEW

BOTANICAL NAME: *Anacardium ccidentale*

FAMILY: Anacardiaceae

Chromosome No: 2n= 42

Inflorescence

Terminal panicle is either conical or pyramidal in shape. The time from visual emergence of inflorescence to opening of first flower takes about 5- 6 weeks. An inflorescence contains on an average 120-1,100 flowers.

Flowers

The flowers are scented, white in colour at first but soon turn pink after a few days. Flowers have pubescent bract. They are andromonoecious (polygamous) with male and hermaphrodite flowers in same inflorescence. Each flower has 5 sepals and petals each. In male flower, there are 10 stamens of which 9 are short and one long stamen with red anther projecting above the corolla. The ovary is rudimentary. In hermaphrodite flowers, 9 stamens are short as in male flower and the long stamens projects just above the corolla but remains below the stigma. Ovary is one locular with single ovule; style simple and exserted. The flowering starts from December and extends to April.

Pollination

Peak anthesis is between 9 am and 11 am, the stigma is receptive as soon as the flowers open and remains receptive for 48 hours from anthesis. The anther dehiscence takes place 1-5 hours after anthesis. Pollination takes place through bees which transfer the sticky pollen to stigma.

Fruit set

Cashew produces 10% of perfect flowers of which 85% are fertilized and only 4-6% are carried to final maturity, the rest being shed at various stages. It takes about 60 days from fruit set to maturity.

Exercise.2

Study of floral biology and different cultivars of banana and their genome

Class	:	Monocotyledon
Subclass	:	Monochamydae
Series	:	Epigynae
Order	:	Zingiberales
Family	:	Musaceae
Genus	:	*Musa*
Species	:	*M.acuminata* or *M.balbisiana*

Botanical Name : *Musa sp.*

2n = 22

It is the second important fruit crop in India. It is a tropical fruit. The edible banana is originated from south East Asia. India is believed to the one of the centres of banana

1. *Musa*
2. *Ensete*

Under *Musa* there are five classes viz., *Eumusa, Rhodochlamys, Australimusa, Callimusa and Inserte sedis*

Eumusa is the largest section

M. acuminata

M. balbisiana

The basic chromosome number is n=11 and the edible bananas may have 22, 33, 44 chromosomes and are respectively referred to as diploid, triploid or tetraploid.

All the cultivated crops are inter-specific crosses of these two species.

Based on the ploidy level, bananas are classified as diploid, triploid and tetraploids. Among these ploidy levels, based on the scoring for predominance of *acuminata* and *balbisiana* characters they are classified as AA, AB, AAA, AAB, ABB, AAAA, AAAB, AABB and ABBB

Description of Important Cultivars

Brief descriptions of important banana cultivars that are being cultivated commercially.

Dwarf Cavendish (AAA)

(Syn: 'Basrai Dwarf', 'Kullan', 'Kabuli', Vamanakeli', 'Pachavazhai', 'Maurititus', 'Moris', 'Bhusavai', 'Kuzhi Vazhai', 'Kulla Vazhai', 'Kutta Vazhai' and 'Nilavazhai')

The stature is dwarf but produces moderately bigger bunches weighing approximately 18-20 kg producing 8-10 hands. The duration of this variety is 10-12 months.

Robusta (AAA)

(Syn: 'Bombay Green', 'Harichal' and 'Pedda Pacha Arati')

Robusta is semi-tall sport of 'Dwarf Cavendish'. The fruits retain the full green colour of the rind even when ripe. The bunch weight ranges from 20 to 25 kg under conventional system and as high as 40-50 kg with hi-tech practices. The number of hands may be 8-11 depending on cultural practices.

Red Banana (AAA)

(Syn: 'Lalkela', 'Chenkadali', 'Sevvazhai' and 'Rathambala')

This variety has a free suckering habit. The colour of the pseudostem, petiole, midrib and fruit rind is purplish red. The fruit is of good size, slightly curved with a blunt apex. The bunch weight is about 20-25 kg with more than 80 fruits borne on 6-7 hands. It is a long duration variety and takes about 18 months from planting to harvest.

Poovan (AAB)

(Syn: 'Mysore', 'Champa', 'Lal Valechi', 'Karpura Chakkarakeli' and 'Palayankodan')

The fruits are small to medium in size, yellow skinned, firm fleshed with a sub-acid taste. The pseudostem is tall, hard and grows vigorously. The variety is also suitable for the ratooning system. The duration varies from 11 to 14 months. The average bunch weight is about 14 kg. Each bunch may have 8-12 hands, each hand bearing 12-18 fingers each. Individual fingers have prominent nipple.

Rasthali (AAB)

(Syn: 'Silk' 'Mutheli', 'Malbhog', 'Martaman', 'Karkanduvazhai', 'Amruthapani' and 'Rasa Bale', Poovan')

The average bunch weight is about 12 kg; 60 to 80 fruits/bunch in five to seven hands. The ripe fruits drop off easily from pedicel; rind thin, the colour changes to yellow with reddish spots upon ripening. The pulp is cream coloured, mealy with very sweet and excellent flavour but often with 'hard lumps'. Duration of the cultivar is 14 to 16 months. It is highly susceptible to 'Panama wilt' disease.

Hill Banana (AAB)

(Syn: 'Virupakshi', 'Malavazhai', 'Vellavazhai' and 'Sirumalai')

The average bunch weight is 12 kg with about 80-90 fruits per bunch. Duration of this variety is about 14 months. If cultivated in plains, hill bananas will lose their fruit quality.

Nendran (AAB)

(Syn: 'Ethankai' and 'Plantain')

The fruits are relatively longer and thicker than most other bananas. The bunch is not compact and has 4-6 hands; 8-10 fingers per hand. Each bunch weighs 12 to 15 kg. fruit with 3 prominent ridges strongly held. The duration of this variety is about 11-12 months.

Karpooravalli (ABB)

(Syn : 'Karpura Vazhai', 'Raja Vazhai' and 'Kostha Bontha')

Stem light green with purplish tinge, 3 m tall, leaves are large. Bunches are heavy with 8-9 compact hands, each hand having 13-14 fingers. Tip of the finger is distinct. Skin yellow with ashy coating, pulp cream coloured, crisp, sweet with a pleasant taste and flavour.

Ney Poovan (AB)

(Syn: 'Elakkibale', 'Safed Velchi', 'Sonery', 'Kadali', 'Rasakadali' and 'Deva Bale')

The fruits are invariably small and the average bunch weight is about 12 kg with about 150 fruits per bunch. The duration of this variety is about 13 months.

CO.1 (AAB)

It is a multiple hybrid synthesized and developed at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore and released during 1983.

Ladan X *Musa balbisiana*

(AAB) (BB) Clone Sawai

F1 (AB) X Kadali (AA)

CO.1 (AAB)

The fruits have flavour and taste similar to hill banana, at the same time the plants can be grown in plains. The plants are medium tall (2.7 m). The bunch weighs on an average 10.5 kg having 7 hands with a total number of 80-85 fruits. Each fruit weighs about 150-160 g. TSS 22.6°brix. The crop duration is 14-15 months.

Sannachenkadali (AA)

The trees resemble that of red banana with purplish red colour in pseudostem, petiole, and midrib and fruit rind. This variety is tolerant to leaf spot.

Monthan (ABB)

(Syn: 'Bontha', 'Kanch Kela', 'Bankel', 'Pisang Nanka', 'Batisa' and 'Bluggoe')

This is an important commercial culinary banana in Tamil Nadu and in several others states of India. The duration is 12 to 14 months. Bunch weighs around 18-22 kg with about 60 fruits per bunch.

Floral Biology

Habit: It is a tall herb, growing to a height of 2-6 m, monocarpic, monocotyledons, perennial

Underground stem: The real stem is called 'corm'. The growth is called 'sympodial'. The corm has short internodes. Bananas are clumped in habit since the corm is covered in closely packed leaf scars. The corm terminal growing point produces leaf in spiral succession. In the axils of each leaf, a bud is present.

Aerial stem / pseudostem: The pseudostem made of number of leaf sheaths completely enclosing the axis of the stem. The leaf sheaths are white in colour, after being exposed to sunlight it becomes green in colour.

Leaves: Spirally arranged and consist of a sheath, petiole and leaf lamina or blade. Sheaths are circular and tightly packed into non-woody pseudo stem. Petiole is rounded below and channelled above. The shape of bunch blade is blunt at the tip and taper round at the base. Venation is parallel.

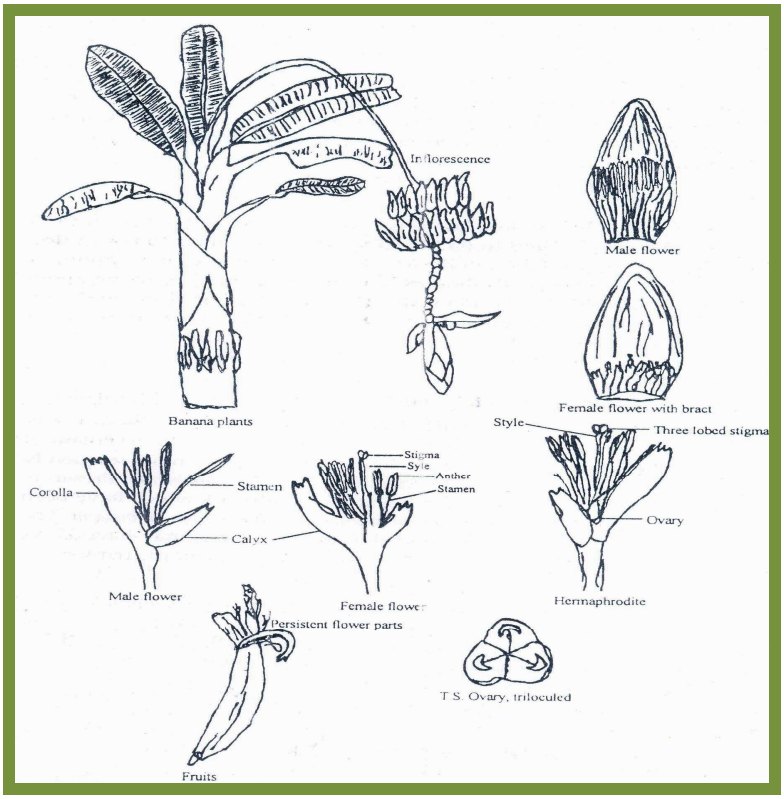
Infloresence: The peduncle is thick, globular and pubescent. Each spike covered with a boat shaped, coloured attractive bract arranged spirally, the bracts are deciduous.

Flowers: Flowers are placed in the axile of bract arranged biserially, commonly 12 to 20 in number. The basal flower is pistillate while terminal flowers are staminate. At the lower end, they may form a bulbous male bud. The male bud is retained along with bract in the inflorescence. The individual flowers are bracteate.

Perianth: Zygomorphic, composed of two structure and total six membrane and five compound tepals and one free tepal. This is similar for pistillate and staminate flower. In the cultivated banana the number of free tepal 3, vary from 1 to 2.

Pistillate flower: Large in size and have well developed ovary. The stamens are 5 in number and reduced to staminodes. Ovary is inferior, trilocular, tricarpellary, two ovules per locule in axile placentation. Some flowers have more than 1 ovary. It results in Siamese banana. The style is thick and long. Stigma is club shaped and sticky.

Staminate flower: Stamens 5, long filament free anthers two lobed, linear and basifixed. The sixth stamen is considered to be represented by free tepal of inner whorl called as tetraplloid stamen. The ovary is not functional.



Anthesis and pollination: Cultivated banana is parthenocarpic and sets fruit without pollination. The diploid bananas are cross pollinated. The flowers are dispersed by bats, birds, bees, ants, wasp and other large insects. Male and female flowers open from 6.00 to 8.00 am.

Exercise.3

Study of different species of citrus and morphological description

CLASS : Dicotyledonae

SUBCLASS : Polypetalae

SERIES : disciflorae

ORDER : gereniales

GENUS : Citrus

FAMILY : Rutaceae

2n = 18

Most probably citrus has originated in the drier monsoon areas rather than the tropical rain forests, because plants show dormancy and water storing hairs (pulp vesicles) which help seed to develop under such conditions. Natural hybridization takes place between cultivars and species without any difficulties, thereby resulting in wide range of variations in the form of complex hybrids. Human intervention in selection is based on edible juice, desirable flavour, juice storing vesicles etc.

Description of important species

Citrus aurantifolia (Christm.) Swing 2n = 18.

Lime is very distinct species, hybridizes easily with other citrus species, but is not related closely to them. Plants are short trees (5m tall) much branched, irregular in outline, heavily marked with short sharp spines. Leaves are simple, alternate, small (4-8 x 2-5 cm), ovate-elliptic to sometimes oblong ovate, margins crenulated, wing narrow. Inflorescence short occurs axillary usually 1-7 flowered, sometimes 10 flowered. Flowers are white, small flowering over long period, calyx cup shaped 4-6 lobed, petals white, 4-5 (12 x 4mm), stamens 20-25, ovary 9-12 loculed, style distinct. Fruit is a berry, small, greenish yellow, oval, ovoid or globose in shape about 3-6 cm in diameter, with distinct

apical papillae at calyx end, rind/skin or peel thin with numerous glands, adhering tightly to very acid yellow green vesicles, which are juicy and fragrant. Seed, plump, small, oval, ovoid cotyledons white, polyembryonic, are tenderer than other citrus speices.

Horticulturally limes are divided into acid and sweet limes. Apart from the most commonly grown 'Mexican' or 'West Indian' or ' key' ' lime', Tahiti or Persian lime (2n=3x=27), a triploid type and hybrid of lime and citron (*C. medica*) are also important. This lime is hardier and is more adapted to subtropical conditions. The fruits are globose, longer, high in acid, almost seedless, less fragrant than the common lime. The sweet lime is a hybrid of lime sweet, lemon or sweet citron. It is used as a root stock.

***Citrus aurantium* L**. (2n=18). Sour or Seville orange.

Plants are relatively tall (10 m), thorn small thin and slender. Leaves alternate, simple, dark green, shiny, ovate to elliptic, large (10x7 cm) broadest in middle, round to short pointed apex, margins crenulated, petiole 2-3 cm long, broadly winged. Flowers are borne axillary, flower large, white, very fragrant (5-10% staminate), stamens 20-25, ovary 10-12 loculed. Fruits usually bright orange-red, very aromatic, globose, rind/peel thick, rough (surface bumpy), pulp very sour to bitter, core generally hollow, seeds borne are many, polyembryonic.

Citrus limon (L.) Burf. (2n=18). Lemon

Lemon plants are small trees (3-6 m tall), thorns stiff, stout. Leaves medium (10x6 cm), simple, alternate, light green, margin slightly serrated, petiole short, narrowly winged with distinct articulation with petiole. Flowering occurs in leaf axils, flowers solitary or in clusters 3-5 cm in diameter, produced in all seasons, calyx 4-5 lobed, petals 4-5, pink in bud, white above, and purplish below, stamens 20-40, style single, ovary 8-10 loculed. Fruit oval oblong (5-10 cm long) with distinct nipple at stylar end, yellowish green (light yellow) at ripening, rind thick, densely dotted with glands, adhering tightly to sour tasty pale yellow pulp/vesicles, seed plump ovoid with greenish cotyledons, polyembryonic. Lisbon, Eureka and Villafranka are the most common and widely grown cultivars. Shows complete nucellar embryony, stock therefore is uniform.

Citrus medica *L.* (2n=18) Citron

Citron plants are shrub or small tree (3 m tall) wood somewhat soft, current growth angular, later becoming circular purple tinged when young, and spine single, stout. Leaves, alternate shiny ovate- lanceolate to elliptic ovate, medium large (8-20 x 3-9 cm), apex pointed or rounded, rounded at base, petiole short, almost wingless and not articulated with lamina. Flowers occur axillary over an extended period in few flowered racemes, flowers are large 3-4 cm across, hermaphrodite and staminate, large proportion being staminate, sepal 5 lobed, petals 5, pink tinged outside, stamens 30-40, style single, thick ovary usually large with 10-13 locules. Fruit ovoid to oblong-ovoid, large sized 10-20 cm long, yellowish coloured, rind/ peel very thick, surface rough very bumpy, segments small, pulp or vesicles greenish, sour in taste. Seeds small, white, polyembryonic.

Citrus sinensis (L.) Osbeck. Sweet Orange 2n=18, triploid and tetraploid occur

Sweet orange plants are evergreen trees (6-12 m tall), crown usually rounded, young twigs angular, often with stout spines (on young seedlings). Leaves are dark green shiny, ovate-elliptic (5-15 x 2-8 cm), rounded at base, apex short pointed, margins sometimes slightly serrated / crenate, petiole small medium (1-2.5cm), narrowly winged articulated. Flowers axillary, borne singly or in few flowered recemes, 2-3 cm in diameter, pentamerous, bisexual and fragrant, calyx 5 lobed, corolla usually whit, stamens 20-25 style single slender with globose stigma, ovary with 10-14 locule. Fruit sub globose 4-12 cm in diameter, peel / rind about half centimeter thick, adhering tightly to juicy sub acidic vesicles, yellow to orange red in colour (often remains green in tropics), central axis solid. Seed nil to many, obovoid, white inside and polyembryonic. Seedling of sweet orange grows up right and are very spiny.

Citrus reticulata Blanco. Mandarin 2n=18

Mandarin plants are relatively small (2-8 m tall), spiny, twigs are slender. Leaves small dark green, shining, green above and pale below, narrow at both apices, narrowly or broadly lanceolate or elliptic with acute base and tip, margin crenate, petiole usually narrowly winged. Flower occur singly or in small clusters in the leaf axils, flowers small

(1.5-2.5 cm diameter), white fragrant, pentamerous, calyx 5, corolla 5, white, stamens 20, style single, ovary with 10-15 locule. Fruit is a depressed globose or sub globes berry, 5-8 cm in diameter, yellow or orange – red when ripe, rind thin, loose separating easily from segments, which are sweet juicy, orange in colour. Seed small, pointed at one end, embryo green, polyembryonic. In some countries mandarins and tangerine are used indiscriminately; however mandarins are used for yellow fruited cultivars and tangerine for deep orange types.

Citrus grandis *(L.) Osbeck*, Pummelo, Shaddock *2 n=18*

Trees are medium tall (5-15 m), spreading and spiny low branching, young twigs pubescent (many persists for year or more) spine prominent large and long (5 cm). Leaves simple alternate, dark green shiny, large (5-20 x 2-12 cm), ovate to broad, elliptic, base rounded to sub-cordate margin entire to slightly / shallowly crenate, apex obtusely acute, sometimes may be slightly notched, under surface pubescent along midrib and veins, petiole broadly winged (7cm broadest amongst all citrus spp.). Flowers are borne axillary, solitary or in clusters of few flowers. Flower white fragrant large measuring 3-7 cm in diameter, penetamerous, sepal 5 lobed, petal 5 cream coloured, stamens 20-25, style one, ovary 11-16 loculed. Fruit very large (largest of all citrus spp.) globose, subglobose or pyriform in shape, 10-30 cm in diameter, yellowish when ripe, rind very thick densely dotted with glands, pulp vesicles also very large, pale yellow or pink well filled with sweet juice (in inferior types vesicles tend to be dry). Seeds are large yellowish and ridged, monoembryonic.

Citrus paradisi **Macf. Grapefruit 2n=18**

Grapefruit plants are large tree (10-15 m tall) spreading, evergreen tree round topped, foliage dense, young twigs angular and sparsly pubescent Leaves, green evergreen, smaller than pummelo and larger than sweet orange, pale green when young, petioles broadly winged (less than pummelo) oblanceolate obovate (7-15 x 4-8 cm) often crenulate. Flowering occurs axillary, solitary or in small clusters, about 4-5 cm across, pentamerous, calyx 5 lobed corolla 5 white fragrant, stamens 20-25 style single, ovary 12-14 loculed. Fruits large, globose borne in clusters, 8-15 cm in diameter, greenish-

yellow coloured, rind thinner, vesicles small (compared to pummelo), adhering to rind. Seed white, smooth, cotyledons white, polyembryonic.

***Poncirus trifoliata* (L.) Raf. Trifoliate Orange**

Plants are small trees with upright growth, densely branched. Young growth smooth angular, dark green thorny, old shoots circular. Thorns very stiff, stout, sharp, 11/2 -2 inches long flattened at base. Leaves trifoliate, deciduous, obovate, central leaflet notched, margin crenate. Flower buds produced singly or in pairs in leaf axils covered by scales and are formed in summer, in spring appear before leaves or on naked shoot. Flowers, short pedicelled or nearly sessile

Anthesis and pollination

Flowering takes place mostly in spring. The lime, lemon, citron and acid group flowers though the year. Mostly of the citrus cultivars self and cross pollinated. The stigma and stamen matures at the same time. The stigma is receptive for 6 to 8 days. Flowers are entomophilous and are visited by bees attracted by white corolla, strong perfume, abundant nectar and sticky pollen. Thrips also visit the flower in great number.

Exercise.4

Study of floral biology of guava and sapota

Botanical Name: ***Psidium guajava***

Class	:	Dicotyledonae
Sub class	:	polypetalae
Serials	:	Calciflorae
Order	:	Myrtales
Family	:	Myrtaceae
Genus	:	Psidium
Species	:	Guajava

Origin – Tropical America or West indies

2n – 21, 22

The Three important spices:

1. *P.cattelianum* / strawberry guava: Sweet and aromatic flavour like strawberry
2. *P. fredrichsthalianum* / chinese guava: Provides resistance to Guava wilt.
3. *P. guinense* / Brazilian guava

Habit: - It is a small tree, spreading, trunk fairly thin, bark is scaly and often multi coloured. The bark is bright and smooth. The erect branches arise from the base of the branch and carries spreading lateral branches.

Leaves: - Small stock and are almost sessile, superimposed and green simple, oval shape sharp shiny. The veins are markedly depressed on the upper surface. Nerve entire with transparent edges. Flowers hermaphrodite, solitary, axillary, some time they also found in two to three together in size. Rarely terminal pedicellate, bracteate calyx tube

completely encloses the flower bud. When the flower matures calyx burst open 4 to 6 irreguler lobe. Shortly pubescent and persistant.

Corolla: 4 o 5 petals, tree spread widely as the flower open, obovate in shape white in colour.

Androecium: Stamens are numerous with long filament and short round anther.

Gynoecium: ovary inferior with four marked carpels ovules many in axile placentation, the long style, extent beyond the stamen and has a long knob like stigma.

Fruit: Berry ovoid or globose, pear shape with persistent calyx at the stylar end within the fruit small yellow seed are embedded in the white or red, pink flesh of mesocarp.

Seed: Seeds are small, reniform, Compressed, light yellow or yellowish brown.

Anthesis & pollination: Floral bud requires 38 to 42 days for full development. Time of anthesis varies from 5 to 8 am. Anther starts dehiscing 15 to 30 min prior to anthesis. Pollen grain of guava is generally triangular in the seedless cultivar. Pollen viability is 84 to 96%, stigma receptivity starts even two days before anthesis and last up to 4th day after anthesis. It is a self pollinated crop.

SAPOTA

CLASS : Dicotyledonae

SUBCLASS : Gamopetalae

SERIES : Inferae

ORDER : Epinates

FAMILY : Sapotaceae

GENUS : *Acharas*

SPEICES : *sapota*

Botanical Name : ***Manilkara sapota , Acharas sapota***

2n = 26

Sapota is a delicious fruit tree. Its origin of growth is tropical America. It is grown for dessert purpose in India. It is commercially exploited in South Mexico for its latex production. The unripened fruit and bark contain milky white latex which solidifies on exposure to air which form the base for making Chicklets. The latex contains 20 to 40% of gum.

Habit: It is an evergreen tree, slow growing to a height of 20m. The milky latex is produced throughout the plant part especially in the bark. Sapota cultivars are grouped into three types based on the nature of the habit (i.e.) based on the branches and the colour of foliage.

I. Trees with erect growing habit.

II.Branches with drooping habit

III.Trees with spreading habit

Leaves: The leaves are glossy, leathery, simple, alternate, petiolate and exstipulate, elliptic to ovate entire and pinnately nerved.

Flowers: Flowers are small densely grouped in leaf axils, tomentose (small hair structure), protogynous.

Calyx: Six sepals in two whorls, outer whorl 3 sepals are united at the base and the inner 3 sepals are free and light green in colour, ovate in shape, obtuse or rounded at the tip, leather like.

Corolla: 6 petals, gamopetalous, single whorl, with corrugated top, tubular or companulate (bell shape), corolla is longer than calyx wide 1/3 of its length is divided into 12 segments. Biseriate, outer series representing the true corolla whereas the inner series consisting of petaloid staminodes.

Androecium: 6 perfect stamens, 6 staminodes, found in between the petals, epipetalous, filaments are short, obliquely erect anthers, ovoid, yellowish brown colour basifixed four celled anthers.

Gynoecium: Protogyny, stigma oblique, ovary superior multichambered, syncarpous with villous ovary, the plancentation is axile

Fruit: It is a berry, persistent calyx at the apex of the fruit, the withered style is present.

Two types are common

1. Round shape
2. Oval shape / Ovoid

The epicarp is thin and rusty brown in colour, the monocarp is yellowish brown, tender, granular, gelatinous material and unripe fruits are astringent and ripe fruits are rich in flavour and sweetness.

Seed: Seeds are upto 12 in numbers some of the ovules may not be fertilized. Sometimes enlarge abort, seeds are hard, black and laterally compressed, shiny and easily separated from the pulp. The seeds are spread out in the central axis like a spoke in the wheel.

Anthesis and Pollination: Flowers open between 4 and 4.30 A.M. Anthers dehisce from 8.00 am to 10.00 pm. The flower remain fresh for nearly two days, stigma was found to be receptive for two days before opening and continue to be receptive for 12 hours, the peak stigma receptively from 8-10 am. Some trees bear flowers continuously in several flushes throughout the year.

Exercise.5

Study of floral biology of grapes and pomegranate

Botanical Name: ***Vitis vinifera***

Class	:	Dicotyledonae
Sub Class	:	Polypetalae
Series	:	Disciflorae
Order	:	Celestrales
Family	:	Vitaceae
Genus	:	Vitis
Species	:	Vinifera

Habit: It is a perennial vine, stem cuttings are normally used for propagation and they generally produce numerous adventitious roots. Shoot has several distinct parts namely growing tip, nodes, internodes, buds, tendrils and laterals

Leaves: The Leaf arrangement on the shoot is distichous and alternate. The leaf consists of petiole, leaf bract and blade. The petiole is cylindrical. Tendrils coil around the support.

Flower: They are borne in clusters, small green in colour usually perfect.

Calyx: 5 sepals, green in colour.

Corolla: 5 petals firmly united at the tip, shed as a little cap at the time of blooming. This cap like corolla is called as calyptra.

Stamens: 5 opposite to each petal anthers are bi-lobed each containing 2 pollen sacs.

Pistil: The ovary is enlarged and contain four ovules.

Anthesis & pollination: Flower opening starts usually between 7-7.30 am and completes by 10.30 A.M. The petals open from base. The cap like calyptra comes out of the flower as cap like structure and fall down at the time of flowering. Pollens are yellow in colour. The fruit set by

1. Stimulative parthenocarpy : Pollination and fruit set occur based on the stimulus from the pollen and produce seedless fruits.
2. Stenospermocarpy: Pollination and fertilization takes place but embryo aborts and thus produces seedless fruits.

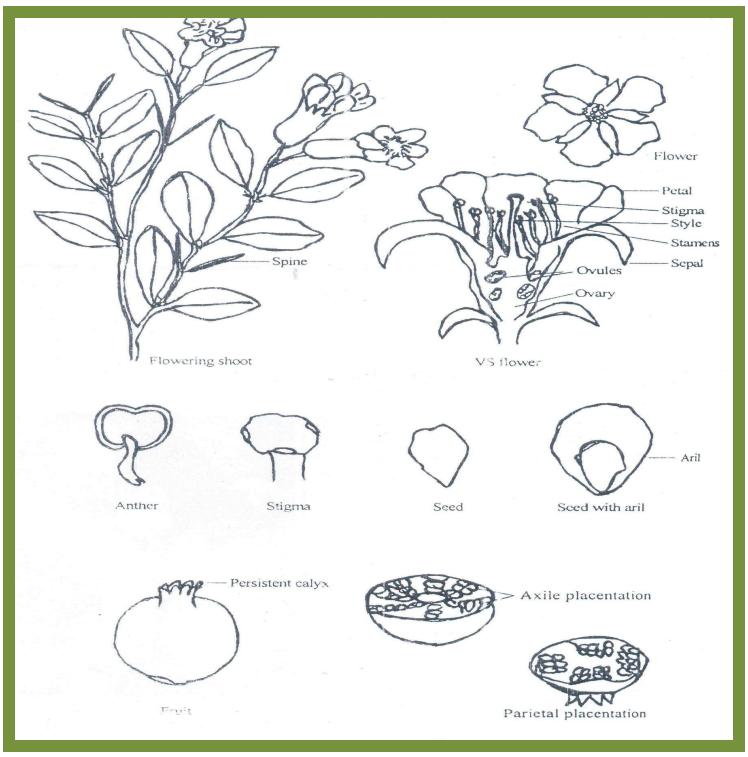
POMEGRANATE

Botanical Name: ***Punica granatum***

Class	:	Dicotyledonae
Sub Class	:	Polypetalae
Series	:	Calyciflorae
Order	:	Myrtales
Family	:	Punicaceae
Genus	:	Punica
Species	:	Granatum

2n = 16, 18

Origin – Iran



It is used for dessert purpose. Juice and jelly are also prepared from the fruit. It is rich in pectin.

Taxonomy: *Punica protopunia* is a wild species

There are two sub species.

P. chlorocarpa

P. porphyrocarpa

Habit: It is a small ever green tree, the trunk is thin branched near the base, the tree is ever green under tropical condition, deciduous under sub -tropical condition.

Leaves: Opposite often densely crowded on small axillary branched, short petioled.

Infloresence: Dichasial cyme, two prominent bracteole at the base of the flower which carry one flower, each in the axile .

There are three types of flowers

1. Male flower

2. Hermaphrodite
3. Intermediary

Male flower has a rudimentary style. Hermaphrodite is perfect flower with long protruding style beyond the staminal column. The intermediary flower has style rearching upto or below the staminal column.

Flowers: Individual flowers are sub sessile, larger, regular, red colour bracts are minute, placed in whorl under flower, receptacle at the base of the flower, above the ovary fleshy thick annular disc is present which is adjacent to the calyx.

Calyx: The segments are 5 to 8 thick mm fleshy gamoseplous and persistent

Corolla: Petals usually as many as sepals are alternating with them wrinkled, falling of after anthesis, dark red colour, pinnately nerved, and imbricate aestivation

Androecium: Numerous stamens inserted irregularly on the disc unequal in length. Filament light red slightly curved at the apex. Anther elliptic & dorsifixed.

Gynoecium: Inferior ovary 3-7 celled, cells 1-3 superposed whorls, ovules in each cells are numerous. Style solitary with a conically thickened base yellowish red stigma depressed globous and faintly grooved.

Fruit: Large glabrous berry known as ‘ Balusta’, 5-12 cm in diameter brownish yellow to red, surmounted by a persistent calyx at the stylar end. Rind coriaceous. Seeds numerous encircled by pink juicy pulp called aril. Seeds are angular, albuminous hard within the outer layer of the testa is thinly fleshy and juicy with a refreshing sour and sweet taste. It is pink yellow or white in colour and edible. **Anthesis and pollination:** Time varies from variety to variety. In Some variety 7 am and in some cultivars by 12 noon. Dehiscense of anthers takes place 3 to 31/2 hrs after anthesis. Optimum temperature 37 to 38˚C.

Exercise.6

Study of pollen fertility in major fruit crops

The science of pollen and spores has demonstrated the utility of palynological studies to the taxonomists and palentologists. Pollen has a very important role in the flow of genes in plants. Especially in plants that are out crossing, pollen which is a carrier of male gametes, composition, morphological structure and their chemical composition, physiological and biological significance. The three domains of pollen grains include exine, intine and nucleus.

The complex exine structures of pollen are storage site for carbohydrate, glycoproteins, lipids, terpenoids and phenolics. The pollen nucleus is rich in chromatin materials and viable pollen stains pink to deep red with acetocarmine, while sterile pollens does not take any stain because of absence of nucleus or non- living nucleus and thus remains almost white or transparent. Pollen viability differs between crops and even in crops like banana, differs between genome groups and within genome groups. Different species and cultivars possess different levels of competency in the production of microspores, which correlated positively with levels of pollen fertility .A viable or fertile pollen is one which after smearing on the stigma of the same plant or other plants of the same variety or species, under normal conditions would start growing a pollen tube and finally discharge its male gametes in the embryo sac effecting fertilization. Pollen fertility status can be determined by using pollen viability tests *invitro* is very important in fruit production in flowering plants. Therefore, the pollen fertility knowledge for any plant species is essential for plant breeders. The pollen viability test in vitro can be done by acetocarmine staining technique. Another method of stain can be used for this purpose are methylene blue.

Preparation of Acetocarmine 1% solution

Take 45 ml of glacial acetic acid

+

Add 55 ml of distilled water

+

Boil it and add 1g of carmine to it

+

Boil for few minute and cool it

+

Filter in whatman filter paper No: 1

The prepared solution will have a clear red colour. To get 2% acetocarmine instead of 1g carmine add 2g of carmine.

Staining of pollens

Take a clean glass slide and allow fresh pollen to fall on the slide by gently crushing and tapping the anthers. Add one drop of acetocarmine and cover it with coverslip. Then watch under microscope. Pollen grains which stain well and look plump and normal are considered to be viable and the shriveled and unstained ones are non-viable.

$$\text{Percentage of pollen viability} = \frac{\text{Number of stained pollens}}{\text{Total number of pollen grains}}$$

The mean pollen stainability of diploids in banana was reported to be more than 66.2%. In wild species the stainability was more than 90%.

Pollen germinability

Pollen germinability is also an another criteria which determines pollen fertility

Procedure for estimation of pollen germinability

Male flowers are collected from newly opened branch 6.30am to 10.00 am. Pollen is dusted onto a cover glass so that a uniform spread is obtained. Three to four drops of the germination medium was placed on a clean glass is carefully inverted on the medium without trapping air. The slides are viewed under a light microscope under 10-40 magnification. For each genotype, two slides are prepared per germination medium and six fields are selected per slide. The slides are placed horizontally on a slide rack that is placed in a moist glass humidity chamber and incubated at room temperature for 24 hr. The number of germinated and non germinated pollen were recorded from the marked areas of each slide after 3 hours and then after 24 hours. The media for pollen germination can be prepared by a mixture of 10 ppm boric acid with 10 per cent sucrose solution

$$\text{Percentage of pollen germination} = \frac{\text{Total germinated pollen}}{\text{Total pollen}} \times 100$$

Practical exercise: Estimate the pollen viability and germinability in the following fruit crops

1. Mango
2. Banana
3. Papaya
4. Sapota
5. Grapes
6. Guava

Exercise.7

Study and practice of crossing technique in major fruit crops

Hybridization refers to mating or crossing of two plants or lines of diverse genotypes to obtain a viable hybrid progeny.

Crossing technique in papaya

There are two major sex forms in papaya

1. Dioecious in which male and female trees are separate
2. Gynodioecious in which female and andromonoecious trees (a tree having male and bisexual flowers) are separate

The knowledge on the presence of variability, floral biology and hybridization techniques are essential for a successful breeding programme.

Crossing technique

Peak anthesis takes places between 5 and 6 AM. Stigma becomes receptive one day before anthesis and remains for to 6 days. Maximum receptivity on the day of anthesis. Anther dehiscence starts in 18 to 36 hrs before the flowers open flowers have to be emasculated one day before anthesis and covered with butter paper bag. After being pollinated with desired pollen, the flower has to be covered again to avoid cross pollination since the stigma is receptive for 6 days.

Preparation of male inflorescence for hybridization

Since papaya is a cross pollinated plant, the bagging of male inflorescence of the desired parents for hybridization about 24 hrs before pollination is necessary, in order to avoid any pollen contamination.

Preparation of female inflorescence for hybridization

Before crossing, flowers of the female parent must be emasculated. This serves two purposes, firstly it prevents self pollination and contamination and secondly it exposes the stigma and facilitates cross pollination.

I. Sibmating in dioecious papayas

Covering the male and female inflorescence one day before sibmating.

(Selection of plants having typical ideo type of the variety is important for both male and female)

↓

Next day morning the male buds that are going to open on that day have to be collected before opening

↓

After removing the cover, transfer the pollen from male bud (petal removed) to female flower.

↓

Three male flowers can be used for dusting one female flower for high seed content

↓

The female flowers have to be covered and proper labeling should be done

II. Selfing in gynodiocioecus papaya

Covering or bagging of bisexual flower is sufficient for getting selfed seeds in gynodioecious varieties (or) it may be sibmated with male flowers of the same population or emasculated bisexual flower or female flowers.

III. Hybridization

The procedure is same as that of sibmation of dioecious varieties but the male parent is the plant of our choice. In gynodioecious varieties, if we use the female parent, just covering of female parent is sufficient. If we use andromonoecious tree, the bisexual flower has to be emasculated and covered with paper bags.

Crossing technique in banana

Flower types

Inflorescence develops from heart of pseudostem, type of inflorescence is spadix. The interesting feature of banana inflorescence is the production of a series of different types of flowers i.e, female, hermaphrodite and male in the same floral stalk.

Type of inflorescence

- Most common type of inflorescence consists of pistillate flowers at basal portion which develop in to the fruits with deciduous staminate flowers (eg) poovan, monthan. Sometimes male bud (heart) continues to produce staminate flowers till the fruit ripen but in Nadan, the heart withers and dries long before the maturity of the bunch.
- Second group of inflorescence does not possess male bud. The whole inflorescence bears pistillate flowers and hence all the flowers develop into fruits (eg) Thatilla Kunan, Ayirankai Rasthali and Moongil.
- In the third type of inflorescence basal flowers develop into fruits followed by persistent male flowers consisting of green rudimentary ovaries with persistent perianth and bracts (eg) Dwarf Cavendish, Nendran.
- In the fourth type of inflorescence basal portions having female flowers developed into fruits followed by persistent male flowers, which is again followed by deciduous male flowers. The bract of persistent male flowers are deciduous (eg) Rasthali and Chakkarakeli.

Crossing Technique

All crosses were carried out between 6.30 AM and 9.30 AM. Unopened anthers should be collected just prior to dehiscence from the inflorescence (preferably 10^{th} to 22^{nd} node) which had entered the male phase after completion of female and neutral phases. The anthers were twist and forced to dehisce; pollens are collected and smeared on the surface of receptive stigma of the female flowers. The crosses flowers were then

covered with brown paper cover and tagged with information regarding date of crossing and male parent used for crossing. The bags were removed after a week.

Crossing technique in citrus

Citrus flowers are large, hermaphrodite, borne solitary and have numerous stamens present in many whorls. Lime and lemons have staminate flowers also. For hybridization, parents with complimentary characters are selected. 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 pervious day evening and 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 or 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.

Exercise.8

Study of polyembryony in certain mango and citrus species

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 embryosac (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 vigour in growth, while the seedling obtained from fertilized embryo will be weak. The greater vigor in polyembryonic nucellar seedlings is probably due to the elimination of viruses.

Polyembryony in mango

In India, majority of the cultivated types are monoembryonic. Surprisingly polyembryonic types were grown only in southern India, especially in coastal parts of Kerala, Karnataka and Goa. Emergence of multiple seedlings from a single seed is referred to as polyembryony. This was observed in 59 families, 158 genera and 239 species. The segregation pattern of individuals originating from selfing of several monoembryonic cultivars and one polyembryonic line indicated that polyembryony in mango was of genetic nature. All the plants originating from monoembryonic cultivars bore monoembryonic fruits. Monoembryonic to polyembryonic segregation pattern was observed at 1:3 ratio among individuals originated from the polyembryonic line, indicating that polyembryony in mango is under the control of a single dominant gene (Aron et al.1996). Polyembryonic mango varieties are chandrakaran, kurukkan, olour, Bapakkai which can be used as rootstocks for propagation for imparting uniformity in the scion since they are of true to type.

Polyembryony in citrus

In citrus, only *C.medica* (Citron) and *C.grandis* (Pumelo) are monoembyonic, while all others are polyembryonic in nature. Though nucellar embryony in citrus is of great value for producing vigorous, uniform and virus free plants, it 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.

Polyembryony constitutes one of the major problems in citrus improvement because it makes difficult to identify the hybrids, particuarly in crosses involving taxonomically closely related parents, despite recently developed techniques for solving the problem, It is well known that the degree of polyembryony of a citrus variety is influenced by the environment, variations are observed from seed to seed, fruit to fruit, and from sector to sector in the same plant and from year to year.

Exercise.9

Study of different sex forms of papaya, their anthesis time

Papaya is a polygamous species; many forms of inflorescence have been reported. In general there are three types of flowers namely staminate, pistillate and hermaphrodite. Storey (1958), however, classified papaya flowers into eight broad categories based on the modifications of sex expression. They are

- staminate
- teratological staminate
- reduced elongata
- elongata
- carpelloid elongata
- pentandria
- carpelloid pentandria
- pistillate

Staminate flower is produced by male plant, while teratological staminate flower is produced by sex reversing male plants. Pistillate flower is produced by female plants. Elongata, reduced elongata, carpelloid elongata, pentandria and carpelloid pentandria are normally produced by hermaphrodite plants.

According to Storey (1958), there are 15 comparable classes found in male plants as well as in hermaphrodite plants. There are 32 heritable sex forms in papaya. Cultivated papayas belong to two major sex forms.

Dioecious form

The seeds of dioecious form when grown segregate into male and female trees in the ratio of 1:1. These types are less influenced by environmental conditions. Occasionally during summer months, certain male trees (teratological staminate) staminate produce bisexual flowers which set fruits having viable seeds. This is called sexual ambivalence and such seeds produce male and female trees in the ratio of 1:2

Gynodioecious form

The seeds of gynodioecious form when grown segregate in the ratio of 1:2. Andromonoecious tree bears bisexual as well as male flowers in one and the same inflorescence. Like teratological staminate trees, andromonecious trees are also influenced by changes in temperature. When temperature falls below 20ºC at flower development, the stamens of the bisexual flowers adhere to the ovarian wall, giving a mis-shapened fruit called cat-faced fruit or stamen carpellody. When temperature goes above 38ºC with low humidity, the flowers and fruits drop off. This phenomenon is called summer-skip. Gynodioecious varieties, are, therefore, not recommended for commercial cultivation for regions having extremes of temperature.

Genetics of sex and sex inheritance pattern

The genetics of sex determination, the hypothetical genes involved and the hypothetical structure of the sex chromosomes have been discussed by Storey, 1953 and Horovitz, 1954.

Genes

The sex determining genes can be symbolized as

$M^{S}m$ -staminate

$M^{H}m$ - hermaphrodite

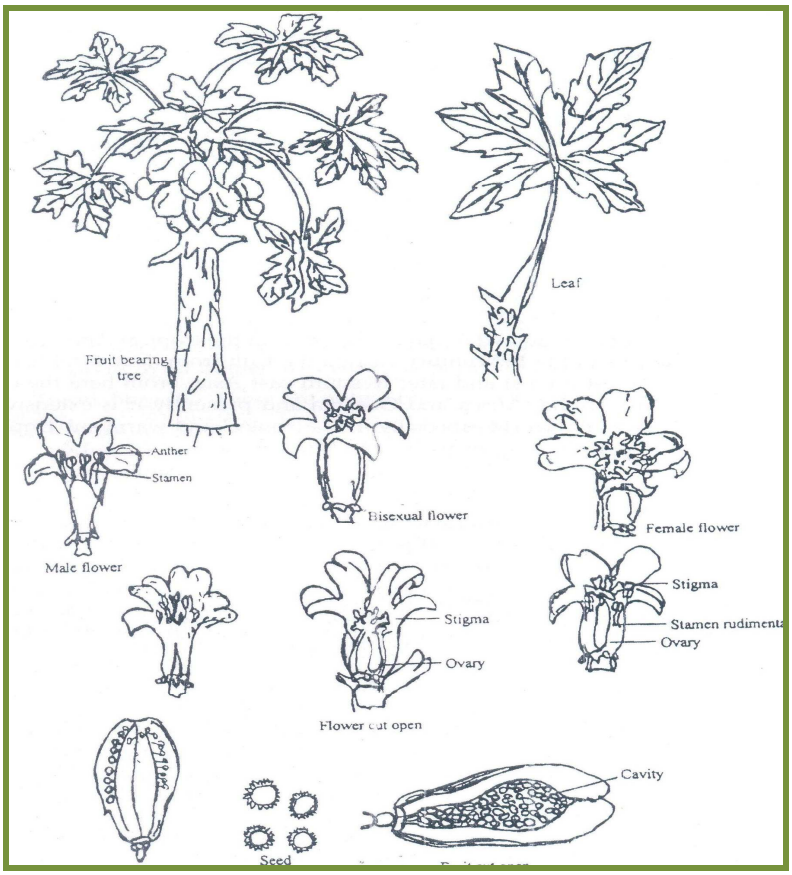
mm - pistillate

Sex inheritance

S.No	Cross/self	Female	0+	Male	Nonviable
1	Mm x M_1m	1mm	-	-	-
2	Mm x M_2m	1mm	$1M_2m$	-	-
3	M_2m x M_2m	1mm	$2M_2m$	-	$1M_2M_2$

4	M_1m x M_1m	1mm	-	$2M_1m$	$1M_1M_1$
5	M_2m x M_1m	1mm	$1M_2m$	$1M_1m$	$1M_1M_2$
6	M_1m x M_2 m	1mm	$1M_2m$	$1M_1m$	$1M_1M$

Anthesis and pollination: It is highly cross pollinated crop. Anthesis occurs between 6.30 am to 8.30 am. Mostly all the flowers will open in the morning. Anther dehisces immediately after anthesis. Wind pollination and pollination through small insects like thrips and ants were noticed. Flower is nocturnally pollinated by moths. Parthenocarpy is also noted.



Exercise.10

Visit to Biotechnology Lab & study of in– vitro breeding techniques

In vitro techniques can be applied in the following areas in fruit breeding and cultivation

1. *In vitro* mass multiplication
2. Zygotic embryo culture to overcome breeding hurdles
3. *In vitro* mutation breeding
4. Genetic transformation

1. *In vitro* techniques for mass multiplication

Shoot tip culture

Uniform plants, uniform flowering, better field establishment, short duration, increased production and productivity are the advantages of tissue cultured plantlets.

Eg: Banana

Zygotic embryoculture

The sterile and parthenocarpic nature of certain plants are the greatest impediment for genetic improvement through hybridization. Even under conditions when sterility barriers are overcome, seed germination and regeneration is still a problem due to factors like dormancy, presence of inhibitors etc. In this context, embryo culture comes to rescue. It is the technique where fully matured embryos or inherently weak, immature, hybrid embryos are regenerated into plantlets in normal MS medium without plant growth regulators

Eg: Grapes- Inter- generic hybrid embryos of papaya

Embryo rescue techniques can be applicable under the following circumstances

- Triploidy nature of the plants
- *In vitro* germination not possible
- Shortening of breeding cycles
- Seed dormancy in banana

- Haploids can be produced
- Ovule culture is possible

Conditions at which embryo rescue is practiced

a. Hard seed coat and seed dormancy in oil palm
b. Haploid embryo could be retrived by embryo rescue
c. Ideal technique for studying the morphogenesis and nutritional requirement of the developing embryo

Embryo /Ovule culture

- It is not possible to obtain hybrid progeny in grape crosses involving seedless parents as female parent
- Embryo culture allows recovery of plants from triploid progenies obtained from diploid and tetraploid crosses
- Ovule culture 45 days of post pollination gave 12% success as compared to 1% success at 40 days old ovule.
- Seedless grape berries developed either through parthenocarpy (ovule fertilization is not required) and stenospermocarpy (ovule fertilization is required)

Embryogenic Cell suspension culture (ECS)

Somatic embryogenesis is aimed at two main objectives – the development of high performance micropropagation and regeneration system useful for transformation. Embryogenesis is considered as a model for testing the totipotency of crop tissues. Although embryogenic cell suspensions are obtained and plants are regenerated from them, it would be an overstatement to say that the production of embryogenic cell suspensions from meristem or immature flowers would be routine and free from problems.

***In vitro* mutation breeding**

Mutation is a sudden heritable change in characters of an organism. Mutation may be the result of a change in a gene, a change in chromosome that involves several genes. Two types of mutations, spontaneous and induced mutations, Macro mutation occurs in large population on single plant basis.

Genetic transformation

The term genetic transformation refers to ability to move DNA into a foreign organism and alter its genotype. This technique plays major role in basic and applied molecular biology.

1. Physical
2. Chemical
3. Biological

Physical method

Biolistic / gene gun particle bombardment, electrophoresis, Micro injection.

Chemical method

PEG – Poly Ethylene Glycol

Biological Method

Agrobacterium mediated transformation of ECS using reporter genes

Different types of genetic transformation methods are available to introduce DNA in to plant cells. Of which, *Agrobacterium tumefaciens* mediated transformation is the most commonl followed method because of its delivery of single copy number. Also it was proved that besides transformation of dicot plants, *Agrobacterium* infects monocots and animal cells. Various types of target tissues are used according to the plants and their regeneration systems for *Agrobacterium* mediated genetic transfer of DNA. For banana, regeneration system using explants like immature male flower bud, suckers etc. The embryogenic cell suspension (ECS) can be developed from immature male flower bud. The ECS are used as target tissues for genetic transformation because of its high regeneration potency and reliability in transgenic recovery.

Biolistic transformation of ECS using reporter gene

In this method, the foreign DNA containing genes to be transferred is coated onto the surface of minute gold or tungsten particles (1-3 micrometers) and bombarded onto the target tissue or cells using a particle gun. Two types of plant tissues are commonly used for particle bombardment namely primary explants and the proliferating embryonic tissues. The coating of DNA with gold or tungsten is achieved by the use of either

calcium components or potassium components. The tungsten coated DNA fragments are purified with the use of alcohol precipitation and finally loaded on to the cartridge. Finally the chamber is vacummed and using helium gas, blasting is done.

Electroporation

It involves a pulse of high voltage applied to protoplasts/cells/tissues to make transient (temporary) pores in the plasma membrane which facilitates the uptake of foreign DNA. The cells are placed in a solution containing DNA and subjected to electrical shocks to cause holes in the membranes. The foreign DNA fragments enter through the holes into the cytoplasm and then to nucleus.

Micro injection

Direct mechanical introduction of DNA under microscopic field. This method is effective for protoplast tissue. A target can be a defined cell a multi cellular structure, embryos, ovules, meristematic cells. By examination with microscope, cell is held in place with gentle suction, while being manipulated using blunt capillary. Fine pipette is used to insert the DNA into cytoplasm and nucleus.

PEG Mediated transfer

This is used for protoplast fusion. This process involves 3 steps.

1. Adhesion of liposomes to protoplast surface
2. Fusion of liposomes
3. Release of plasmid inside the cell.

DNA enters protoplast due to endocytosis of liposomes.

Exercise.11

Exposure to resistance breeding & screening techniques

Resistance breeding involves selection of superior genotypes which are acting as donors for conferring resistance to pests, diseases and nematodes in fruit crops.

Screening techniques for banana nematodes

Nematodes were important pests in banana which cause about 40-60% yield loss. They produce symptoms like stunted growth and slight yellowing of leaves. Root knot nematodes produce yellowing cum margin drying. There are four major nematodes in banana

Burrowing Nematode - *Radopholus similis*

Lesion Nematode - *Pratylenchus coffeae*

Root knot Nematode - *Meloidogyne incognita*

Spiral Nematode - Helicotylenchus muficinctus

Extraction of Nematodes from Cobb's decanting and sieving method (Cobb, 1918)

This method is based on the principle of gravity. Hence the differences in size and specific gravity between nematodes and other soil components are utilized. Heavier particles settle down more easily compared to the lighter ones. Nematodes being light in weight can be separated out from other matters using the set of sieves with specific mesh number for this purpose. The mesh numbers and pore aperture are as follows.

Mesh Number	Pore aperture
20	240
60	250
100	150
200	75
350	45

The step-by step procedure is as follows

1. Mix the soil sample thoroughly and place 250ml of sample using a 250 ml plastic beaker into a 5 liter plastic bucket.

2. Add a litre of water to the plastic bucket and mix thoroughly.

3. Hold the bucket for about 10 seconds to permit the heavy soil particles and stones to settle down. The decant is passed through a coarse sieve (Mesh No.20) into another plastic bucket B. During this process, the nematode is carried to the plastic bucket B along with the water suspension. The plant debris and stones are collected in the 20 mesh sieve which can be discarded.

Extraction of Nematodes from roots and other plant materials

Objective: To extract nematode from plant parts

The contents of the bucket B are mixed again and held for 10 seconds and decant the suspension through a fine sieve (350 mesh) where the nematodes will be retained in the sieve. Repeat the process once again using the same 350 mesh to ensure cent per cent collection of the nematodes in the fine sieve.

The contents of 350 mesh sieve may be washed using a squeeze bottle with a slow jet of water to remove soil as for as possible and transfer the nematode suspension into a plastic beaker.

Identification and Estimation of population Method

I. Direct Extraction

1. Wash the infected plant materials thoroughly and chop into small pieces.

2. Put this material in a petridish containing water

3. Migratory and endo/ semi-endoparasitic nematodes that come out of the chopped material and moving into water can be seen directly under microscope.

4. Alternatively the chopped materials can be processed by modified Baermann's funnel technique.

II. Root incubation method

Procedure

1. Wash the roots to remove the adhering soil particles

2. Place the longitudinally cut wet roots in half of the polythene bag and glass jar.

3. Seal the jar by screwing the lid with a few loose turns or secure the polythene bag with rubber band.

4. Incubate at 15˚C for 72 h.

5. Remove the nematode, which have migrated out of the roots by flushing the roots with water for three times.

Picking of Nematode

1. Take the nematode suspension in a cavity block or petridish and focus the nematode under a low magnification in stereomicroscope.

2. Lift the nematodes to the surface of the water while focusing along floating nematode.

3. Flick the nematode quickly up so that the nematode is pulled out through the meniscus.

After staining and fixing nematodes using lactophenol methods, the nematodes can be counted.

Direct counting

Roots are easily examined when distributed in a small amount of glycerin on a petridish. Making a grid on the pretridish aids in counting the nematode under a stereoscopic microscope.

Extracting Nematodes

Considerable time is required for direct counting of nematodes inside large root systems. Roots may be macerated in warring blends. Nematodes can be separated from the root tissue by sieving. However care must be taken to ensure that the nematodes are not ruptured or destained during maceration.

Screening technique for disease resistance in banana

Screening techniques for Fusarium wilt in Banana

The fusarium wilt of banana caused by *F. oxysporum* f.sp. *Cubense* is one of most destructive diseases of banana in the tropics.

Field evaluation of banana plants for disease tolerance in soils infested with *Fusairum oxysporum* f.sp.*Cubense* (FOC) had been found to be effective. The process is slow as disease expression usually takes 4-5 months, while inoculum concentration, edaphic conditions, temperature and other variables that may affect disease expression are difficult to control. An alternative method of screening seedlings at the nursery stage has been found to be effective.

Plantlets were transferred to the double-container apparatus for hardening and grown in the greenhouse until they attain the desired size. Test plantlets were carefully uprooted and only those with healthy white roots were selected for inoculation by immersion in the appropriate conidia suspension for two hours before being tagged and replanted in the trays for maintenance and observation in the greenhouse.

Plantlets were watered using Hoagland's complete nutrient solution consisting of a) macronutrient and b) micronutrients. Macro-and micro –nutrients were dissolved in 1 litre of sterile distilled water.

Leaf symptoms on susceptible plants were observed within 10 to 14 days. The numbers of leaves that showed disease symptoms were recorded after the first two weeks and again after four weeks. Final evaluation on the 5^{th} week was based on the leaf symptom index (LSI) and rhizome discolouration index (RDI).

Scales of leaf symptom index (LSI) are:

1. No streaking or yellowing of leaves. Plant appears healthy.
2. Slightly streaking and / or yellowing of lower leaves
3. Streaking and / or yellowing of most of the lower leaves. Discoloration of the younger leaves may be just beginning to appear.
4. Extensive streaking and / or yellowing on most or all of the leaves
5. Dead plant

Scales of the rhizome discoloration index (RDI) are

1. No discolouration of tissue of stellar region of rhizome or surrounding tissue.
2. No discolouration of stellar region of rhizome, discoloration at junction of root and rhizome.
3. Trace to 5% of stellar region discoloured
4. 6-20% of stellar region discoloured
5. 21-50% of stellar region discoloured
6. More than 50% of stellar region discoloured
7. Discolouration of the entire rhizome stele
8. Dead plant

After recording LSI and RDI, the overall disease severity index (DSI) for leaf symptoms and rhizome discolorations for each treatment was calculated as follows:

$$DSI = \frac{\Sigma \text{ (number of scale x number of seedlings in that scale)}}{\Sigma \text{ (number of treated seedlings)}}$$

The DSI consists of four designation, namely resistant, tolerant, susceptible and highly susceptible. IF the cultivar is resistant in LSI and tolerant in RDI, the cultivar is considered to be tolerant. If RDI is tolerant and LSI is susceptible, the cultivar is considered to be susceptible. The final status of the cultivar is considered to be resistant if both LSI and RDI for each treatment show resistance. If one of the r esponse is tolerant, the cultivar is then considered to be tolerant.

Translation of DSI scales

DSI Scales for LSI	DSI Scale for RDI	Translation
1	1	Resistant
Between 1.1 and 2	Between 1.1 and 3	Tolerant
Between 2.1 and 3	Between 3.1 and 5	Susceptible
Between 3.1 and 4	Between 5.1 and 8	Highly susceptible

Exercise.12

Practices in mutation breeding

Mutation is a sudden heritable change in a character of an organism. Mutation may be the result of a change in a gene or change in a chromosome that involves several genes of a change in a plasmagene.

Mutation breeding ⟶ 1. Induced Mutation

2. Spontaneous Mutation

Induced Mutation ⟶ Induced artificially

Two types ⟶ Macro mutation

⟶ Micro mutation

Macro mutation occurs in large population on single plant basis.

Micro mutation occurs in population which consists of 30 numbers of plant eg. Quantitative characters like yield.

Spontaneous mutation ⟶ Naturally occurring mutations

Eg. Red Banana, Thatilla Kunnan, Adakka Kunnan, Then kunnan,Veneetu Kunnan

Monthan ⟶ Sambar Monthan, Nalla Monthan, Sambrani, Monthan, Pidi Monthan, Batheesa

Mutagen and Dose

Seeds may be either irradiated or treated with chemical mutagens. But vegetative propagates are more easily irradiated than treated with chemicals.

The dose of mutagen should be such that it induces the maximum frequency of mutations which it causes the minimum killing. Many workers feel that a dose close to LD50 should be optimum. LD 50 is the dose which kills 50% of the treated individuals. LD 50 will vary with the crop species and mutagens used. The dose of a mutagen may be

varied by varying either the intensity or concentration used. The dose of a mutagen may be varied by treatment.

Mutagens ⟶ 1. Physical mutagens
2. Chemical mutagens

Physical Mutagens:

Physical Mutagens ⟶ 1. X rays
2. Gamma rays

They are mainly applied to growing points of vegetative propagalues to induce mutagenesis. Physical mutagens applied in terms of kilo rads as lower doses eg.0.5 KR to 50 KR depending upon the crops.

Radiation:

Radiation ⟶ 1. Ionizing Radiation
⟶ 2. Non-Ionizing Radiation

Ionizing radiations

These radiations produce ionization as well as excitation in the atoms located in their path. When an atom either loses or gains an electron, it becomes positively or negatively charged called ionization. Ionizing radiations may be particulate, consist of atomic particulate or non particulate having no particles but only photons of high energy.

1. **X rays** ⟶ They are electromagnetic radiation produced by electrically accelearated electrons in high vacuum. X rays are non-particulate high energy, sparsely ionizing and most penetrating of the various radiations.

2. **Gamma rays** ⟶ They are similar to X rays in physical and biological properties. Gamma rays are produced from 60 Co radium, etc through radio active delay. Both x rays and gamma rays are commonly used in mutation programmes.

3. **Fast and thermal neutrons**

Fast neutrons are produced during radioactive decay of heavier elements. When graphite or heavy water reduces their velocity, they become thermal or slow neutrons. They are unchanged particulate, highly penetrating and densely lionizing radiations.

Non-ionizing radiation

Such a radiation does not cause ionization but produces mutations. UV radiations are known to induce both frameshift mutations (deletion or addition of bases) and base pair substitutions. Mercury lamps that emit in the range of 250 to 290nm wavelength are the source of UV light in laboratories.

Chemical Mutagens

1. Alkylating agents

Eg. Ethyl methane Sulphonate (EMS)

Methyl Methane Sulphonate (MMS)

Nitroso compounds ⟶ N-Methyl, N nitro – N – nitroso – guanidine

2. Acridine dyes

Eg. Acriflavine, proflavine, acridine orange, acridine yellow, ethidium bromide

3. Base analogues

Eg. 5 bromocracil, 5-chlorouracil

4 Others

Eg. Nitrous acid, hydroxylamine, sodium oxide

Procedure for inducing mutants

Selection of the Variety

Generally, the variety selected for mutagen treatment should be the best commercial variety of the crop. This is particularly so when polygenic traits are to be improved.

Plant part to be treated

In sexually propagated crops, seeds are the most commonly used for mutagen treatment. Pollens grains may be used in some cases. In clonal crops, buds or cuttings are commonly used for mutagenesis. Radiations (except) UV rays can be applied to any part or even whole plants. But chemical mutagens are best used with seeds. However, many workers have used chemical mutagens with vegetative propagates also.

Mutagen treatment

The seeds or vegetative propagates are irradiated with the desirable dose and plant in the field. The seeds to be treated with a chemical mutagen are first soaked in water for a few hours. This initiates metabolic activities, seeds are then treated with desired dose of the chosen mutagen, washed in running tap water to remove the mutagen and planted in the field. The plants produced from mutagen treated seeds constitute the M_1 generation. Selfed or clonal progeny of M_1 plants give rise to M_2 generation and those of M_2 plants constitute M_3 generation.

Handling of M_1 and subsequent generations

In self pollinated species, M_1 plants should be deliberately selfed since they show considerably male sterility which encourages cross pollination. The handling of M_1 and M_2 etc. generations will mainly depend on whether oligogenic or polygenic traits are to be improved. In sexually reproducing crops, both dominant and recessive mutations are utilized for crop improvement.

In sexually reproducing crops, M_1 and subsequent generations are multiplied by asexual reproduction. Only dominant mutations can be used for improvement, recessive mutations can be used only when clone used for mutagens treatment was already heterozygous for the concerned gene.

Mutations usually occur in small sector of the meristem, such a situation is called chimera, chimeras are either lose (or) are recovered as non-chimeric mutations (depending on the type of chimera) in case of sexually reproducing crops. In clonal crops special techniques may be required to maintain some types of chimera which are stable and usable.

Precautions

Avoid crossing out M_1.

Prevent mechanical mixtures.

Achievements

Mango – Rosica from Peruvian

Papaya – Pusa Nanha from local type

Grape – Marvel seedless from delight

Banana - Highgate from Grosmichel, Motta poovan from poovan

Orange – Washington Navel

Grapefruit – Marsh and Thompson seedless

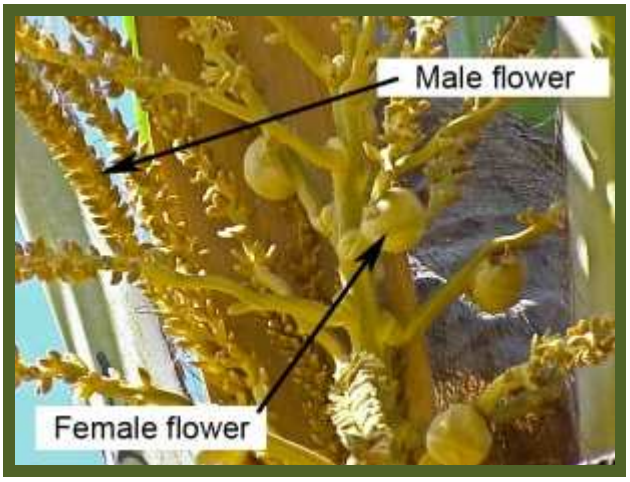
Exercise.13

Botany, floral biology, selfing and crossing techniques for plantation crops

Coconut

Coconut is a monocotyledonous palm belonging to the family palmae. It has only a single species *'nucifera'* in the genus cocos, with the chromosome number of 2n=32. The synonym for *Cocos nucifera* L. is cocos nana. The palms have a robust, cylindrical, erect stem with a single growing point from where the successive leaf production takes place producing a terminal crown with a single apical bud. Palms can grow upto 20-30 meters in tall cultivars and 10-15 meters in dwarf cultivars. Leaves are pinnate and, are called 'fronds', which are generally 4 to 6 meters in length and 1.5 to 2 meters in width. Leaves have a strong rachis to which the leaflets are attached on both sides. Around 200 leaflets are present in a frond. Leaflets are linear-lanceolate. Canopy of coconut ('crown') consists of 28 to 36 fronds at the tip of the stem arranged in circular or ovular or semi circular shapes. Generally one frond is added to the canopy every month and one frond is abscessed from the stem. The inflorescence is protandrous. Unopened inflorescence looks like a spadix within a spathe. It takes 44 months from inflorescence primordial initiation to nut maturity. In a crown one can see all stages of inflorescence. In the 'spadix', the pistillate flowers and staminate flowers are attached to spike like rachillae. As many as 200 to 300 male flowers and only one or a few female flowers are attached to these rachillae. Male flowers are found 1 to 3 together, sessile and pale yellow in colour with three small sepals, three larger petals and six stamens in two whorls. They have a rudimentary pistil. Female flower is solitary, larger than male flowers in size, globose in bud, enveloped by two small scaly bracteoles, three sepals and three petals, ovoid at anthesis sub-oricularm sub-equal, persistant and enlarging in fruit, pistil with large trilocular ovary, three sessile triangular stigmas and three nectaries near the ovary base. Within two to three weeks after the spadix opens pollination takes place. Coconut is mainly a cross pollinated crop. But the 'dwarf' type coconuts are predominantly self-pollinated. It generally takes 12 months from pollination for a pistillate flower to develop in to mature nut. Fruit is a globose, ovoid or ellipsoidal fibrous drupe. Tender coconuts are generally 7 to 8 months old. Fruit(nut) has an outer greenish pericarp, fibrous middle

mesocarp and hard endocarp (shell).Inside the endocarp ,the fruit consists mainly of solid, white endosperm(copra),liquid endosperm (nut water)and a single embryo. Coconut has an adventitious root system, which goes to the depth of only 1.5 to 2 metres but with a horizontal spread of 4 to 5 metres. Decayed roots are replaced regularly due to the formation of new roots.



OILPALM


OILPALM FEMALE FLOWER

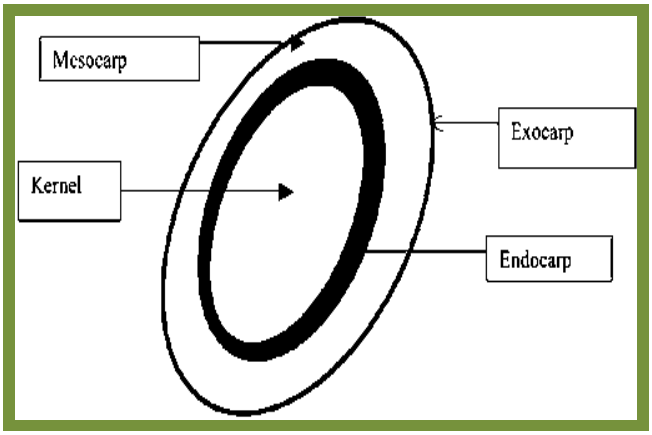
Oil palm is monoecious, with male and female inflorescences produced separately on the same palm. Investigation has shown that each flower primordium is a potential producer of both male and female organs though one or the other almost always remains rudimentary. Rarely hermaphrodite inflorescences are seen. It is a cross-pollinated crop with the female and male inflorescences being produced in alternate cycles (Hartley, 1988). Artificial pollination is resorted to when specific hybrids are to be produced. Inflorescence is a compound spike or spadix carried on stout peduncle. An inner and outer spathe tightly encloses the inflorescence before anthesis. Six to ten long bracts are seen below the lowest spikelets. The female spikelets are thick and fleshy and develop in the axil of a spinous bract. The flowers are arranged spirally around the rachis. An inflorescence

contains about 100 spikelets with over 4000 flowers. Each female flower along with two small male flowers (normally abort) are protected by a bract. The tricarpellate ovary and rudimentary androecium of the female flower are enclosed by a double perianth of six sepaloid segments in two whorls. These in turn lie within two bracteoles. The sessile stigma has three lobes, and hairy. The stigma curves outside at anthesis. The stigmatic lobes are white to pale yellow in colour indicating receptivity.

The male spikelets are non spiny, long finger like structure, bearing 600-1200 male flowers,yellow in colour having aroma and mature from bottom to top. The flowers consist of a perianth of six minute segments,a tubular androecium with 6 or rarely 7 anthers and a rudimentary gynoecium. A single inflorescence produces upto 50g pollen over a period of 2-3 days.


OILPALM MALE FLOWER

The oil palm is almost exclusively wind pollinated. The abundance of pollen attracts a number of insects. They do not however visit female flowers. The main pollinators are *Elacidobius kamerunicus,* E.*subviltatus, Mystrops costaricensia* and Thrips hawaiensi. Fruits ripen within six months after pollination. The fruit is a sessile drupe. It consists of a pericarp, made up of exocarp (skin), mesocarp (pulp) and endocarp (shell) surrounding the kernel. Kernel has a testa (skin), a solid endosperm and an embryo. Shell thickness is of direct relevance to breeding. This is controlled by a single gene (Beirnaert and Vanderveyan, 1941). The homozycote pisifera(sh-sh-)is shell less. Generally, they are sterile, though some plants set fruits and varying degrees of sterility are observed. The other homozygote dura (sh+sh+) has a thick shell. The heterozygote tenera is the only form used for commercial planting because of thin shell and higher mesocarp content.



Arecanut

The arecanut palm is a graceful, erect and un-branched palm reaching to a height of upto 18-20m. The stem has scars of fallen leaves in regular annulated forms. The girth of the stem depends on genetic constiotution, soil condition and plant vigour. The arecanut palm has an adventitious root system. The crown of an adult palm contains 7-12 leaves. The leaves are pinnatisect and consist of a sheath, a rachis and leaflets. The leaf sheath completely encircles the stem. It is about 54 cm in length and 15cm in breadth. The average length of leaf is 1.65m, which bears about 70 leaflets. The leaflets are 30.0 to 70.0cm in length and 5.8 to 7.0cm in breadth depending on the position of the leaf.

Arecanut is monoecious with both male and female flowers occurring on the same spadix. It is cross-pollinated (Bavappa and Ramachander , 1967). The male phase lasts for 25-46 days. Female flowers are cream coloured and turning green within a week. The flowers open between 02h and 10h. The female phase extends upto 10 days. The stigma remains receptive upto 6 days (Murthy and bavappa, 1960a; Sharma Bhat *et al.,* 1962a). Pollen is generally carried by wind.

BETELVINE

Betelvine belongs to genus *Piper* of the family piperaceae which is having about 10 genera and over 1000 species of herbs, shrubs and climbers. About 65 species have been described in genus *Piper*. The species *P.betle* is a perennial dioecious dicotyledonous creeper with semi woody stem which climbs by short adventitious roots. Leaves are 5-20cm long, broadly ovate to slightly cordate and often unequal at the base,

shortly acuminate, acute, entire with often an undulate margin, glabrous, yellowish to dark green, shining on both the surfaces; petiole is stout, 2.0 to 2.5 cm long. The plant produces orthotropic (vegetative) and plagiotropic (reproductive) branches. Growth rates in terms of stem elongation, number of leaves and branch production are higher in vegetative branches compared to reproductive branches. Vegetative branches also produce leaves with higher petiole length and intermodal length (Mithila *et al*., 2000) the reproductive branches bear male or female flower in a plant. The male spikes arising singly from leaf base are long, cylindrical and creamy –white to light orange in colour. The spikes measure 40-55mm in length with a stalk measuring 19-26mm. individual flowers are small, sessile, 5-7 lobed with 3-5 stigmas. During maturation, irregular swellings called nodo sites are formed on the fleshy fruits and their number varies from 5-7. The mature fruits possess 2-20 spherical to oval, smooth surfaced seeds.

RUBBER

H. brasiliencis is a diploid with 2n = 2x = 3 (Majumdar, 194) with the basic chromosome number x=9. An experimental tetraploid (Saraswathyamma *et al.*, 1984) and synthesis of a triploid (Saraswathyamma *et al*., 1980) in the clone RRII 105 were reported from India. A spontaneous triploid (Nazeer and Saraswathyamma, 1987) and a genetic variant with dwarf stature (Markose *et al*., 1981) were also reported from India.

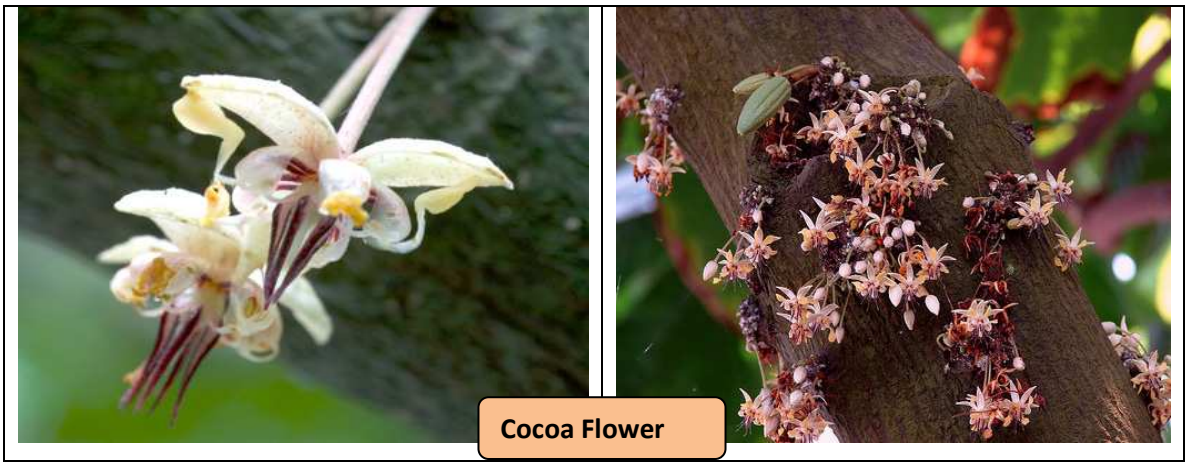
The rubber tree is a sturdy, quick growing, erect, perennial, growing to a height of about 30 m with an economic life span of over 30 years. It has a straight trunk with light gray bark and the branches develope to form an open leafy crown. The leaves are arranged in groups or storeys, each storey with a cluster of spirally arranged trifoliate glabrous leaves and extra floral nectarines is present in the region of insertion of the leaflets.

Hevea is a deciduous tree, which sheds leaves during Dec – Feb (wintering-partial or complete) followed by refoliation and flowering. The plant is monoecious with

unisexual flowers produced in pyramid shaped panicles in the axils of leaves. The panicles bear numerous small male flowers and fewer but bigger female flowers. The female flowers are confined to the tip of the panicles and their branch lets. Ovary is tricarpellary syncarpous, which on pollination develops into a three lobed dehiscent capsule (regma) with three large mottled seeds. Pollination is by insects and fruits ripen in 5-6 months after fertilization. Seeds contain an oily endosperm.

COCOA

The cocoa (*Theobroma cacao*) belongs to the family sterculiaceae. It is a wide-branching evergreen tree, reaching upto 20 -25 feet in height and grows in the shade. It starts bearing after 4 or 5 years but yields most between 15 and 25 years of age. It is an evergreen tree with a typical growth habit, dimorphic with orthotropic vertical stem and plagiotropic fan branches. Small white flowers come into bloom almost throughout the year. Flowers, leaves and fruits can be seen at any time of the year, all together on the same tree. Two peaks of harvests are made yearly. The plant is 'cauliflorous' with flowers (and later fruits) protruding directly from the woody branches and trunk. The fruit, or 'pod', reaches to one foot long and 2-4 inches in diameter. Fruit – indehiscent drupe. Seeds recalcitrant, lacks dormancy.



Cocoa Flower

Flower – bud development is a slow process, taking 21-24 days for a newly emerged flower to mature. The flowers are borne on long pedicels and having five free sepals, five free petals, ten stamens and ovary with united carpels. The petals are very

narrow at the base but expanded into a cup shaped pouch and end in a broad tip or ligule. The ten stamens, which form the androecium or male part of the flower, are in two whorls. The outer whorl consists of five long non-fertile staminodes and inner whorl of five fertile stamens. The stamens bear two anthers, which lie in the pouch of the corresponding petal. The ovary has five parts containing many ovules arranged around a central axis 30 -60 ovules. When a bud matures the sepals split during the afternoon and continue to open during the night. In the following early morning, the flowers are fully opened and the anthers release their pollen. Anthesis commence between 14.00 and 16.00 hrs and complete between 02.00 and 04.00 hrs the next day. Anther dehiscence commences between 4.00 and 6.00 hrs and complete between 08.00 and 10.00hrs. The style matures a little later. Stigma receptivity is high between 12.00 and 14.00hrs and the same day is the best day for pollination and failure of fertilization will cause the flower to abscise the next day.

Exercise.14

Study of pollen viability, emasculation and pollination procedures in plantation crops

Areca nut

General mode of pollination is cross pollination. Overlapping of male phase and female phase leads to self pollination. Pollen travels up to 1.2 kms. Wind is the main agent of pollination. Spray of pollen suspension with sucrose results in 26% fruit set against 12% in open pollination. About 30% of female flowers set fruits (nuts). It takes 8-9 months for the fruits to ripe.

Cashew

Peak anthesis is between 9 am and 11 am, the stigma is receptive as soon as the flowers open and remains receptive for 48 hours from anthesis. The anther dehiscence takes place 1-5 hours after anthesis. Pollination takes place through bees which transfer the sticky pollen to stigma.

Cocoa

Cocoa is cauliflorus – the flowers and fruits are borne on old wood of main stem and fan branches and never on recent flushes. Pollination is effected by various small insects. The most important group of pollinating insects are the midges mostly belonging to the genus *Forcipomyia.* Cocoa flowers are also visited by many other insects such as ants, aphids and fruit flies.

Pollen viability was found to be 97.1% by the acetocarmine staining method, and in vitro pollen germination is 66.25%. Pollination by flying insects result in 25-50% cross pollination of self-compatible trees. Cocoa trees produce large number of flowers but only 1-5% of the flowers are successfully pollinated to produce pods.

Method of Hand pollination

For production of hybrids with specific objectives and to confirm the compatibility reaction hand pollination is being practiced.

- A flower bud which will open the following day, recognized by its whitish colour and swollen appearance, is selected.
- The bud is covered with hood of plastic tube/hose pipe piece (5cm x 1.5 – 2 cm size), which is sealed to the bark using materials like plasticine/ glazeputty.
- The tube is covered with muslin cloth at the top, kept in place with a rubber band. This ensures circulation of air and exclusion of insects.
- Opened flowers are collected from the desired male parent and stamens are carefully taken out by pushing the corresponding petal.
- One entire anther with a part of the filament is deposited on the stigma.
- The style is surrounded by a ring of staminodes and if these are long, removal of two or three staminodes should be done for easy access to style.
- Emasculation is not necessary due to the presence of self-incompatibility. For selfing, hand pollination is done using stamens from the same flower.
- The pollinated flowers are labeled using tin foil pieces fixed in the cushion using ball pins.
- The hoods are removed 24 hrs after pollination and in three to five days, fertilization is confirmed by the visual swelling of the ovary.
- In order to prevent undue shedding and wilting of fruits from hand pollinations, it is usual to remove all the developing fruits on the tree produced by open pollination.
- Developing pods are covered with wire mesh after six to eight weeks to protect them from mammalian pests.
- When flowers are plentiful a good operator can able to make 300 pollinations per day along with marking of pollinated flowers, which will be resulting in 150 pods.
- If unpollinated, the flower abscises within twenty four hours and a conspicuous feature of cocoa tree is the heavy loss of flowers at certain time intervals. A full-

grown tree may produce 10,000 flowers in a year, of which 50 to 100 will develop as mature fruits. 1-50% set observed.

- Most pollination occurs in the morning and artificial pollination should always be done before midday during fine weather.

Coconut

Pollination in coconut is effected through wind and insects. Among insects, bees are major pollinating agents. After pollination, the unfertilized flowers turn to brown colour and fall off from the inflorescence. About 25-40% of the female flowers reach maturity. Pollen grains remain viable for 2-9 days after they are discharged. They can be freeze dried and stored under vacuum for one year or more. Freeze dried pollen grains can be transported at normal temperature and retain their viability for 4 months. Hybridization techniques 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 the mixture using a pollen dispenser. The F_1 hybrid production requires controlled hand pollination using isolation bags.

Coffee

The inflorescence is a condensed cyme arising in leaf axils, on short peduncles and subtended by bracts. Flowers are fragrant and white, appear in axillary clusters 2-20per axil on primary and secondary branches during October – March. Buds remain dormant until stimulated by rain or wetting. Pollination takes place 6 hours after flower opening under bright light and warm windy conditions. Wind, gravity and bees are the agents of pollination. Arabica is self-pollinated while Robusta is cross-pollinated.

Oil palm

Oil palm is a cross pollinated crop. Wind is considered to be the sole agent of pollination until when insect pollinators like *Elaediobius kamerunicus*, *Elaeidobius sulvettatus, Mystrops costaricensia* and *Thrips hawaioensis* are reported. Only *Elaediobius kamerunicus* is available in India, the introduction of which has increased the setting and fruit development and led to substantial increase in yield. Assisted pollination

is done to ensure fertilization of all female flowers. However it is not necessary, if pollination weevil is introduced in the plantation. They congregate and multiply on male inflorescence during flower opening. They also visit female flowers and pollinate them effectively.

Rubber

Inflorescence is borne in the axils of the basal leaves of new shoots that grow out after wintering during December – February, the inflorescence is a many branched panicle, bearing flowers of both sexes. Pollination is mainly by insects like bees, midges and thrips.

Tea

Flowers appear either solitary or in clusters of 2-4 with short peduncles in the axils of scale leave on current season's growth. Sepals and petals are 5-7 with numerous stamens and superior ovary which is 2- 4 loculed. Pollination is carried out by insects. Since tea is virtually self fertile selfing gives a much lower percentage of viable seeds.

Exercise.15

Production of hybrids in plantation crops

Arecanut

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 and combining the dwarf stature.

Coconut

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 hand-pollination using isolation bags.

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 receptive flowers are pollinated.

Cashew

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 (Anakkayam 1), high sex ratio and longer mixed phase, intense branching, high shelling (%) and high nutritive value of kernels are also looked in the parents. Fifteen varieties have been developed through hybridization and selection.

Exercise.16

Visit to research institutes involved in Plantation Crops Research

Exercise.17

Practical Examination

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