

DEPARTMENT OF GENETICS AND PLANT BREEDING

1. Course No. : GBPR 311
2. Course Title : **Breeding of Field and Horticultural Crops**
3. Credit Hours : 3 (2+1)
4. General Objective : To impart knowledge to the students on the botanical description, origin, distribution and various breeding approaches used for the development of varieties / hybrids in various field and horticultural crops
5. Specific Objectives

Theory

By the end of the course, the students will be able to

- i. understand the origin, distribution and different breeding methods to be adopted for the development of varieties / hybrids in various field and horticultural crops
- ii. study about the plant genetic resources, centres of diversity and breeding for resistance to biotic and abiotic stresses
- iii. learn about the influence of Genotype x Environment interaction on yield / performance

Theory Lecture Outlines

1. Introduction – definition, aim, objectives and scope of plant breeding – history and development of plant breeding –contributions of eminent scientists – important concepts of breeding self pollinated, cross pollinated and vegetatively propagated crops
2. Cereals – rice – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
3. Cereals – wheat – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
4. Cereals – maize – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
5. Millets – sorghum – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
6. Millets – bajra and ragi – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties

7. Sugarcane – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
8. Pulses – red gram and soybean – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
9. Pulses – greengram, blackgram and bengalgram – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
10. Oilseeds – groundnut and sesame – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
11. Oilseeds – sunflower and safflower – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
12. Oilseeds – castor and mustard – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
13. Fibre crops – cotton and kenaf – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
14. Fibre crops – mesta, roselle and jute – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
15. Vegetables – tomato, brinjal and chillies – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
16. Vegetables – bhendi and cucumber – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
17. Flower crops – chrysanthemum and marigold – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
18. Flower crops – rose and gerbera – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
19. Fruit crops – mango and guava – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties
20. Fruit crops – banana and papaya – origin – distribution of species – wild relatives and forms – breeding objectives – major breeding procedures for development of hybrids / varieties

21. Plant genetic resources – definition and important features of germplasm – kinds of germplasm – classification of gene pool
22. Plant genetic resources – types of seed collections – germplasm activities – exploration – merits and demerits of exploration and collection of germplasm
23. Plant genetic resources – germplasm conservation – *in-situ* conservation – *ex-situ* conservation – evaluation – documentation – distribution and utilization
24. Plant genetic resources – centres of diversity – types of biodiversity – centres of origin – Law of homologous series – centers of origin – types of centres of diversity – gene sanctuaries – genetic erosion – main reasons of genetic erosion – extinction – introgression – gene banks – types of gene banks
25. Ideotype breeding – main features of ideotype breeding – features of ideotypes of wheat, rice, maize, barley and cotton
26. Ideotype breeding – factors affecting ideotypes – steps in ideotype breeding – achievements
27. Breeding for resistance to biotic stresses – introduction – variability in fungal pathogens – hybridization, heterokaryosis, parasexualism, mutation and cytoplasmic adaptation
28. Breeding for resistance to biotic stresses – disease resistance – mechanisms of disease resistance in plants (disease escape, tolerance, resistance, immunity and hypersensitivity) – causes of disease resistance – genetic basis of disease resistance – sources of disease resistance – breeding methods for disease resistance – achievements
29. Breeding for resistance to biotic stresses – insect resistance – mechanism of insect resistance in plants (non preference, antibiosis, tolerance and avoidance) – nature of insect resistance – genetics of insect resistance – horizontal and vertical – genetics of resistance – sources of insect resistance – breeding methods for insect resistance – problems in breeding for insect resistance – achievements
30. Breeding for resistance to abiotic stresses – drought resistance – mechanisms of drought resistance (drought escape, avoidance, tolerance, and resistance) – features associated with drought resistance – sources of drought resistance – breeding methods for drought resistance – limitations – achievements; breeding for resistance to water logging – effects of water logging mechanism of tolerance – ideotype for flooded areas – breeding methods
31. Breeding for abiotic stresses – breeding for salt tolerance – response of plants to salinity – symptoms – mechanisms of salt tolerance – breeding methods for salt tolerance – problems – achievements; Cold tolerance – chilling resistance – effects of chilling stress on plants – mechanism of chilling tolerance – sources of chilling tolerance – selection criteria –freezing resistance – effects of freezing – mechanism of freezing resistance – genetic resources for freezing tolerance – selection criteria – problems in breeding for freezing tolerance

32. Genotype, environment and their interaction – genotype – environment –micro-environment and macro-environment – classification of environmental variation – genotype X environment interaction – adaptation – types of adaptation – adaptability – stability – models for stability analysis

References

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Lecture No: 1

Definition, Aim, Objectives and Scope of Plant Breeding

Definition :

Plant breeding can be defined “as an art and science” and technology of improving the genetic make up of plants in relation to their economic use for the mankind.

or

Plant breeding is the art and science of improving the heredity of plants for the benefit of mankind.

or

Plant breeding deals with the genetic improvement of crop plants also known as science of crop improvement.

or

Science of changing and improving the heredity of plants

Aim :

Plant breeding aims to improve the characteristics of plants so that they become more desirable agronomically and economically. The specific objectives may vary greatly depending on the crop under consideration.

Objectives of Plant Breeding :

1. **Higher yield** : The ultimate aim of plant breeding is to improve the yield of “**economic produce on economic part**”. It may be grain yield, fodder yield, fibre yield, tuber yield, cane yield or oil yield depending upon the crop species. Improvement in yield can be achieved either by evolving high yielding varieties or hybrids.
2. **Improved quality**: Quality of produce is another important objective in plant breeding. The quality characters vary from crop to crop. Eg. grain size, colour, milling and baking quality in wheat. Cooking quality in rice, malting quality in barley, colour and size of fruits, nutritive and keeping quality in vegetables, protein content in pulses, oil content in oilseeds, fibre length, strength and fineness in cotton.
3. **Abiotic resistance** : Crop plants also suffer from abiotic factors such as drought, soil salinity, extreme temperatures, heat, wind, cold and frost, breeder has to develop resistant varieties for such environmental conditions.
4. **Biotic resistance** : Crop plants are attacked by various diseases and insects, resulting in considerable yield losses. Genetic resistance is the cheapest and the best method of minimizing such losses. Resistant varieties are developed through the use of resistant donor parents available in the gene pool.

5. **Change in maturity Duration / Earliness** : Earliness is the most desirable character which has several advantages. It requires less crop management period, less insecticidal sprays, permits new crop rotations and often extends the crop area. Development of wheat varieties suitable for late planting has permitted rice-wheat rotation. Thus breeding for early maturing crop varieties, or varieties suitable for different dates of planting may be an important objective. Maturity has been reduced from 270 days to 170 days in cotton, from 270 days to 120 days in pigeonpea, from 360 days to 270 days in sugarcane.
6. **Determinate Growth** : Development of varieties with determinate growth is desirable in crops like mung, pigeon pea (*Cajanus cajan*), cotton (*Gossypium sp.*), etc.
7. **Dormancy** : In some crops, seeds germinate even before harvesting in the standing crop if there are rains at the time of maturity, e.g., greengram, blackgram, Barley and Pea, etc. A period of dormancy has to be introduced in these crops to check loss due to germination. In some other cases, however, it may be desirable to remove dormancy.
8. **Desirable Agronomic Characteristics**: It includes plant height, branching, tillering capacity, growth habit, erect or trailing habit etc., & often desirable. For example, dwarfness in cereals is generally associated with lodging resistance and better fertilizer response. Tallness, high tillering and profuse branching are desirable characters in fodder crops.
9. **Elimination of Toxic Substances** : It is essential to develop varieties free from toxic compounds in some crops to make them safe for human consumption. For example, removal of neurotoxin in Khesari – lentil (*Lathyrus sativus*) which leads to paralysis of lower limbs, erucic acid from *Brassica* which is harmful for human health, and gossypol from the seed of cotton is necessary to make them fit for human consumption. Removal of such toxic substances would increase the nutritional value of these crops.
10. **Non-shattering characteristics**: The shattering of pods is serious problem in green gram. Hence resistance to shattering is an important objective in green gram.
11. **Synchronous Maturity** : It refers to maturity of a crop species at one time. The character is highly desirable in crops like greengram, cowpea, castor and cotton where several pickings are required for crop harvest.
12. **Photo and Thermo insensitivity**: Development of varieties insensitive to light and temperature helps in crossing the cultivation boundaries of crop plants. Photo and thermo-insensitive varieties of wheat and rice has permitted their cultivation in new

areas. Rice is now cultivated in Punjab, while wheat is a major *rabi* crop in West Bengal.

13. Wider adaptability: Adaptability refers to suitability of a variety for general cultivation over a wide range of environmental conditions. Adaptability is an important objective in plant breeding because it helps in stabilizing the crop production over regions and seasons.

14. Varieties for New Seasons : Traditionally maize is a *kharif* crop. But scientists are now able to grow maize as *rabi* and *zaid* crops. Similarly, mung is grown as a summer crop in addition to the main *kharif* crop.

Scope of plant breeding (Future Prospects)

From times immemorial, the plant breeding has been helping the mankind. With knowledge of classical genetics, number of varieties have been evolved in different crop plants. Since the population is increasing at an alarming rate, there is need to strengthened the food production which is serious challenge to those scientists concerned with agriculture. Advances in molecular biology have sharpened the tools of the breeders, and brighten the prospects of confidence to serve the humanity. The application of biotechnology to field crop has already led to the field testing of genetically modified crop plants. Genetically engineered rice, maize, soybean, cotton, oilseeds rape, sugar beet and alfalfa cultivars are expected to be commercialized before the close of 20th century. Genes from varied organisms may be expected to boost the performance of crops especially with regard to their resistance to biotic and abiotic stresses. In addition, crop plants are likely to be cultivated for recovery of valuable compounds like pharmaceuticals produced by genes introduced into them through genetic engineering. It may be pointed out that in Europe hirudin, an anti-thrombin protein is already being produced from transgenic *Brassica napus*.

Undesirable effects

Plant breeding has several useful applications in the improvement of crop plants. However, it has five main undesirable effects on crop plants.

1. **Reduction in Diversity :** Modern improved varieties are more uniform than land races. Thus plant breeding leads to reduction in diversity. The uniform varieties are more prone to the new races of pathogen than land races which have high genetic diversity.
2. **Narrow genetic base :** Uniform varieties have narrow genetic base. Such varieties generally have poor adaptability.

- 3. Danger of Uniformity :** Most of the improved varieties have some common parents in the pedigree which may cause danger of uniformity.
- 4. Undesirable combinations :** Sometimes, plant breeding leads to undesirable combinations. The examples of man made crops having undesirable combination of characters are *Raphanobrassica* and Pomato.
- 5. Increased susceptibility to minor diseases and pests :** Due to emphasis on breeding for resistance to major diseases and insect pests often resulted in an increased susceptibility to minor diseases and pests. These have gained importance and, in some cases, produced severe epidemics. The epidemic caused by *Botrytis cinerea* (grey mold) in chickpea during 1980-82 in Punjab and Haryana. The severe infection by Karnal bunt (*Tilletia sp.*) on some wheat varieties, infestation of mealy bugs in Bt cotton.

History and development of plant breeding

- About 10,000 years ago when man is believed to have started agriculture.
- Plant breeding began when man first choose certain plants for cultivation.
- The process of bringing a wild species under human management is referred to as **domestication**
- Domestication may be the most basic method of plant breeding
- All other breeding method become applicable to a plant species only after it has been successfully domesticated.
- Domestication continuous today and is likely to continue for some time in future
- Ex : In case of timber trees medicinal plants, microbes
- During the long period of historic cultivation natural selection has definitely acted on the domesticated species.
- Movement of man from one place to another brought about the movement of his cultivated plant species
- 700 BC - Babylonians and Assyrians pollinated date palm artificially
- 17th century - several varieties of **heading lettuce** were developed in France
- **1717 - Thomas Fair Child - produced the first artificial hybrid, popularly known as Fair Child's mule, by using carnation with sweet William**
- 1727 - The first plant breeding company was established in France by the vilmorins.
- 1760-1766 - Joseph koelreuter, a German, made extensive crosses in tobacco.
- 1759-1835 – Knight was perhaps the first man to use artificial hybridization to develop several new fruit varieties.
- Le couteur and Shireff used individual plant selections and progeny test to develop some useful cereal varieties
- 1873 - the work of Patrick Shireff was first published.
- He concluded that only the variation heritable nature responded to selections, and that there variation arose through 'natural sports' (= mutation) and by 'natural hybridization' (= recombination during meiosis in the hybrids so produced).
- 1856 - Vilmorin developed the progeny test and used this method successfully in the improvement of sugar beets.
- 1900 - Nilson-Ehle, his associates developed the individual plant selection method in Sweden.
- 1903 - Johannsen proposed the pureline theory that provided the genetic basis for individual plant selection.

- The science of genetics began with the rediscovery of Gregor Johan Mendel's paper in 1900 by Hugo de veris, Tshermak and Correns which was originally published in 1866.
- The modern plant breeding methods have their bases in the genetic and cytogenetic principles.
- Numerous workers who determined the various modes of inheritance have contributed to the development and understanding of plant breeding.
- The discovery of chromosomes as carriers of genes has led to the development of specialized plant breeding methods for chromosome engineering.
- The totipotency of plant somatic and gametic cells allows regeneration of complete plants from single cells. This, coupled with the development of recombinant DNA technology, has enabled the transfer of desirable genes from any organism into plants. Crop varieties developed in this manner are already in cultivation in several countries.

History of plant breeding in India

- 1871 – The Government of India created the Department of Agriculture
- 1905 – The Imperial Agricultural Research Institute was establish in Pusa, Bihar
- 1934 – The buildings of the institute damaged in earthquake
- 1936 – Shifted to New Delhi
- 1946 – Name was changed Indian Agricultural Research Institute
- 1901-05 – Agricultural Colleges were established at Kanpur, Pune, Sabour, Llyalpur, Coimbatore
- 1929 – Imperial council of Agricultural Research was established
- 1946 – Name was change to Indian Council Agricultural Research
- 1921 – Indian Central Cotton Committee was established – Notable researches on breeding and cultivation of cotton. Eg : 70 improved varieties of cotton
- 1956 – Project for intensification of regional research on cotton, oilseeds and millets (PIRRCOM) was initiated to intensify research on these crops – located at 17 different centres through out the country
- 1957 – All India Coordinated maize improvement project was started with objective of exploiting heterosis
- 1961 - The first hybrid maize varieties released by the project
- ICAR initiated coordinated projects for improvement of the other crops
- 1960 – First Agricultural University established at Pantnagar, Nainital, U.P.

Scientific contributions of eminent scientists

Name of the Scientists	Contributions
Allard and Bradshaw	- G x E interaction
Recurrent Selection for SCA	- Hull
Recurrent Selection for GCA	- Jenkins
Dominance hypothesis	- Davenport
Gene for gene hypothesis	- Flor
Pureline concept	- Johannsen
Backcross method	- Harlan and Pope
Double cross scheme	- Jones
Cytoplasmic Genetic Male sterility	- Jones and Davis
Ear to row method	- Hopkins
Colchicine	- Blackslee and Nebel
Single Seed Descent Method	- Goulden
Self incompatibility	- Lewis
Vertifolia effect	- Van Der Plank
Centres of diversity, Law of homologous series	- Vavilov
Grater initial capital hypothesis	- Ashby
Progeny test	- Vilmorin
First artificial hybrid	- Thomas Fairchild
Triticale	- Rimpau
Mutation	- Hugo de Vries
Sprophytic System of self incompatibility	- Hughes and Babcock
Bulk method	- Nilsson & Ehle
Raphano brassica	- Karpenchenko
Heterosis	- Shull
Male sterility	- Jones and Davis
Father of hybrid rice	- Yuan Long Ping
Self incompatibility classification	- Lewis
Mechanism of insect resistance	- Painter
Modified bulk method	- Atkins
Components of genetic variance classification	- Fischer
Male sterility in maize	- Rhoades

Microcentre	- Harlan
Chemical mutagen	- Aurbach
Multiline concept	- Jenson
Green revolution in India	- M.S. Swaminathan
Semidwarf rice varieties at IRRI	- T.T. Chang
Forage breeder	- G.W. Burton
Forage breeder	- T.J. Jenkin
Soyabean breeder	- E.E. Hartwig

Some Indian Plant Breeders and their contributions

T.S. Venkatraman	- An eminent sugarcane breeder, he transferred thick stem and high sugar contents from tropical noble cane to North Indian Canes. This process is known as noblization of sugarcane.
B.P. Pal	- An eminent Wheat breeder, developed superior disease resistant N.P. varieties of wheat.
M.S. Swaminathan	- Responsible for green revolution in India, developed high yielding varieties of Wheat and Rice
Pushkarnath	- Famous potato breeder
N.G.P. Rao	- An eminent sorghum breeder
K. Ramaiah	- A renowned rice breeder
Ram Dhan Singh	- Famous wheat breeder
D.S. Athwal	- Famous pearl millet breeder
Bosisen	- An eminent maize breeder
Dharampal Singh	- An eminent oil-seed breeder
C.T. Patel	- Famous cotton breeder who developed world's first cotton hybrid in 1970
V. Santhanam	- Famous cotton breeder

Lecture No: 1a

Concepts of breeding Self pollinated, Cross pollinated and asexually propagated crops

The mode of pollination and reproduction play an important role in plant breeding. Based on this, crop plants are divided into three groups *viz.*

1. Self Pollinated
2. Cross pollinated
3. Vegetatively propagated

Self Pollinated Species:

These are all self fertilizing species. In these species development of seed take place by self pollination (autogamy). Hence self pollinated species are also known as autogamous species or inbreeders. Various plant characters such as homogamy, cleistogamy, chasmogamy, bisexuality etc. favour self fertilization.

Some important features of autogamous species are

1. They have regular self pollination
2. They are homozygous and have advantage of homozygosity, means they are true breeding.
3. Inbreeders do not have recessive deleterious genes, because deleterious genes are eliminated due to inbreeding by way of gene fixation.
4. Inbreeding does not have any adverse effects on inbreeders.
5. In autogamous species, new gene combinations are not possible due to regular self pollination.
6. Inbreeders are composed of several component (homozygous) lines. Hence variability is mostly among component lines.
7. Inbreeders have generally narrow adaptation and are less flexible.

Methods of Breeding in Autogamous Species

1. Plant introduction
2. Pureline selection
3. Mass selection
4. Pedigree method
5. Bulk method
6. Single seed descent method
7. Backcross method
8. Heterosis breeding

9. Mutation breeding
10. Polyploidy breeding
11. Distant hybridization
12. Transgenic breeding

Four breeding approaches viz., recurrent selection, disruptive selection, diallel selective mating and biparental mating are used for population improvement.

Cross pollinated species

This group refers to cross fertilizing species these species produce seed by cross pollination (allogamy) hence, referred to as allogamous species or out breeders. Various plant characters which promote cross pollination which include dichogamy, monoecy, dioecy, heterostylely, herkogamy, self incompatibility and male sterility.

Some important features of out breeders are

1. They have random mating. In such population, each genotype has equal chance of mating with all other genotypes
2. Individuals are heterozygous and have advantage of heterozygosity
3. Individuals have deleterious recessive gene which are concealed by masking effect of dominant genes.
4. Out breeders are intolerant to inbreeding. They exhibit high degree of inbreeding depression on selfing.
5. Cross pollination permits new gene combinations from different sources.
6. In these species, variability is distributed over entire population.
7. They have wide adaptability and more flexibility to environmental changes due to heterozygosity and heterogeneity.

Methods of Breeding Allogamous species

1. Plant introduction
2. Mass and progeny selection
3. Back cross method.
4. Heterosis breeding
5. Synthetic breeding
6. Composite breeding
7. Polyploidy breeding
8. Distant hybridization
9. Transgenic breeding
10. Mutation breeding (rarely)

Three breeding approaches viz., recurrent selection, disruptive mating and biparental mating are used for population improvement.

Asexually propagated species

Some crop plants propagate by asexual means i.e. by stem or root cuttings or by other means. Such species are known as asexually propagated species or vegetatively propagated species. Such species are found in both self and cross pollinated groups. Generally asexually propagated species are highly heterozygous and have broad genetic base, wide adaptability and more flexibility.

Methods of breeding Asexually propagated species

1. Plant introduction
2. Clonal selection
3. Mass selection (rarely used)
4. Heterosis breeding
5. Mutation breeding
6. Polyploidy breeding
7. Distant hybridization
8. Transgenic breeding

BREEDING POPULATIONS

The genetic constitution of plants is determined by mode of pollination. Self pollination leads to homozygosity and cross pollination results in heterozygosity to exploit homozygosity in self pollinated crops and heterozygosity in cross pollinated species, because inbreeders have advantage of homozygosity and outbreeders have advantage of heterozygosity. Based on genetic constitution, breeding populations are of four types viz.,

1. Homogenous
2. Heterogenous
3. Homozygous
4. Heterozygous

1. Homogenous population

Genetically similar plants constitute homogenous populations. Examples of homogeneous populations are pure lines, inbred lines, F_1 hybrid between two pure line or inbred lines and progeny of a clone. Pure lines and inbred lines generally have narrow adoption.

2. Heterogenous populations

Genetically dissimilar plants constitute heterogenous populations. Examples are land races, mass selected populations, composites, synthetics and multilines. Heterogenous populations have wide adaptability and stable performance under different environments.

3. Homozygous populations

Individuals with like alleles at the corresponding loci are know as homozygous. Such individuals do not segregate on selfing. Thus non-segregating genotypes constitute homozygous populations. Examples are pure lines, inbred lines and mass selected populations in self pollinated plants. Thus pure lines and inbred lines are homozygous and homogeneous and mass selected varieties of self pollinated crops and multi lines are homozygous and heterogenous, because they are mixtures of several pure lines.

4. Heterozygous populations

Individuals with unlike alleles at the corresponding loci are referred to as heterozygous. Such individuals segregate into various types on selfing. This includes F₁ hybrids, composites and synthetics. Thus F₁ hybrids are heterozygous but homogeneous and composites and synthetics are heterozygous and heterogenous population. Such populations have greater buffering capacity to environmental fluctuations.

Different types of genetic populations in plant breeding

population	Brief description / definition	Examples
Homogeneous	Genetically similar population	Purelines, inbred line, F ₁ hybrids progeny of a clone
Heterogeneous	Genetically dissimilar population	Land races, composites synthetics and multilines.
Homozygous	Non-segregating populations	Purelines, inbred lines mass selected autogamous varieties and multilines
Heterozygous	Populations segregate on selfing	F ₁ hybrids, composites, synthetics and a clone
COMBINATIONS Homogeneous and Homozygous	Genetically similar and non segregating populations	Purelines and inbred lines
Homogeneous and heterozygous	Genetically similar but segregating on selfing	F ₁ hybrids between inbred lines and progeny of a clone
Heterogeneous and homozygous	Genetically dissimilar but non segregating populations	Multilines and mass selected varieties in autogamous species
Heterogeneous and Heterozygous	Genetically dissimilar and segregating populations	Composites and synthetics

Lecture No. 2

Study in respect of origin, distribution of species, wild relatives and forms and major breeding procedures.

RICE (*Oryza sativa*) 2n = 24

Rice is the world's most important food crop grown in more than hundred countries of the world.

Origin: S.E. Asia

Distribution:

It is grown in humid tropical and subtropical climate and 90 per cent of the rice is produced and consumed in S.E. Asia. Rice producing countries are China, India, Japan, Korea, Pakistan, Bangladesh and other S.E. Asian countries. In India A.P, Karnataka, Tamilnadu, Orissa etc.

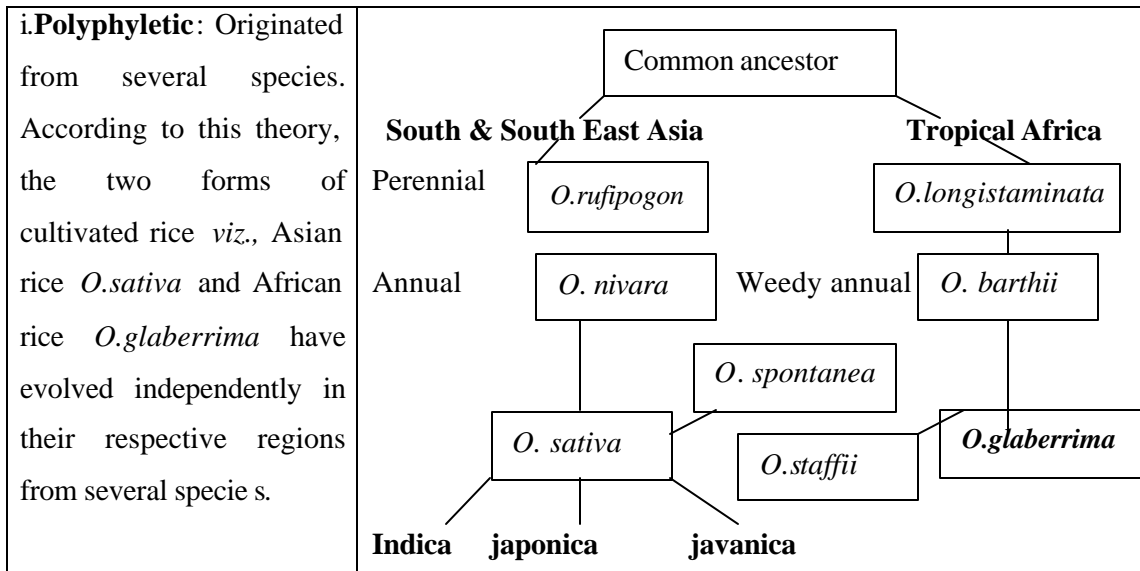
Rice is one of the oldest cultivated crops. The two cultivated species of rice are

- i) *Oryza sativa* - Asian rice
- ii) *O. glaberrima* - African rice.

Origin of cultivated rice.

The views regarding the origin of rice can be grouped in to two classes viz.,

- a) Polyphyletic origin
- b) Monophyletic origin.



<p>ii. Monophyletic : According to this theory both Asian rice and African rice arose from a common parent (<i>O.perennis</i>). This view is the most accepted one because both Asian rice and African rice are similar except in glume pubescence, ligule size and colour of pericarp which is red in African rice.</p>	<pre> graph TD A[O.perennis] --- B[O.glaberrima] A --- C[O.sativa] </pre>
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According to polyphyletic origin the present day rice varieties have originated from several species. According to monophyletic origin a single species has given rise to all varieties of cultivated rice. viz.,

Oryza sativa

Oryza glaberrima

most of the modern rice workers believe that origin of cultivated rice monophyletic. From *oryza perennis* rose the Asian rice in South East tropical Asia and African rice in the upper valley of Niger River in Africa.

CLASSIFICATION

The three sub species or races of cultivated Asian rice (*Oryza sativa*) are

i) Indica

ii) Japonica (Sinica)

iii) Javanica.

S. No.		INDICA	JAPONICA	JAVANICA
1	Distribution	Tropical Ex. Asia India	Sub-tropical to warm temperate Ex. Japan	Intermediate Sub- Tropical Ex. Indonesia
2	Leaves	Broad, Light green	Narrow, Dark green	Broad, Stiff
3	Tillering	Profuse	Medium	Low
4	Height (Stature)	Tall	Short Plant	Tall
5	Grains	Slender-Flat	Short-Roundish	Broad, thick grains
6	Resistant			
a)	Temperature	Sensitive	Resistant	Resistant
b)	Drought	Resistant	Intermediate	Sensitive

Species in the genus oryza:

According to the latest view the genus *oryza* include 20 wild species. Out of these two are cultivated diploids viz. *O.sativa* and *O.glaberrima* and rest are wild species which include both diploid and tetraploid forms.

Botanical name	Chromosome No.	Genome	Origin
<i>O.sativa</i>	24	AA	Asia
<i>O.nivara</i>	24	AA	Asia
<i>O.meridionalis</i>	24	-	Australia
<i>O.longistaminata</i>	24	AA	Africa

<i>O. rufipogon</i>	24	AA	Asia
<i>O. glumaepatula</i>	24	-	America
<i>O. grandiglumis</i>	48	CCDD	America
<i>O. glaberrima</i>	24	AA	Africa
<i>O. barthii</i>	24	AA	Africa
<i>O. australiensis</i>	24	EE	Australia
<i>O. latifolia</i>	48	CCDD	America
<i>O. alata</i>	48	CCDD	America
<i>O. eichingeri</i>	24	CC	Africa
	48	BBCC	
<i>O. minuta</i>	48	BBCC	Asia
<i>O. punctata</i>	48	BBCC	Asia
<i>O. officinalis</i>	24	CC	Asia
<i>O. granulata</i>	24	-	Asia
<i>O. meyeriana</i>	24	-	Asia
<i>O. ridleyi</i>	48	-	Asian
<i>O. longiglumis</i>	48	-	New Guinea
<i>O. brachantha</i>	24	FF	Africa
<i>O. schlechter</i>	-	-	New Guinea

RICE

Related species of rice and their contributing characters in rice improvement.

Species	Genome	Useful traits
<i>O. alata</i>	CCDD	High biomass production
<i>O. australiensis</i>	EE	Drought tolerance, BPH resistance
<i>O. barthii</i>	AA	Drought avoidance, BLB resistance
<i>O. brachyantha</i>	FF	Yellow stem borer and leaf folder resistance
<i>O. eichingeri</i>	CC	BPH, GLH, WBPH resistance
<i>O. grandiglumis</i>	CCDD	High biomass production
<i>O. granulata</i>	unknown	Shade tolerance, adaptation to aerobic soils
<i>O. latifolia</i>	CCDD	High biomass production
<i>O. longistaminata</i>	AA	Drought tolerance
<i>O. meridionalis</i>	AA	Elongation ability
<i>O. meyeriana</i>	Unknown	Shade tolerance, adaptation to aerobic soils
<i>O. minuta</i>	BBCC	BPH, GLH, WBPH, BLB and blast resistance
<i>O. nivara</i>	AA	Grassy stunt virus resistance

<i>O.officina lis</i>	CC, BB, CC	BPH, GLH, WBPH resistance BPH resistance
<i>O.prnetate</i>	BB, BBCC	BPH resistance
<i>O.ridleyi</i>	unknown	Shade tolerance, stemborer, blast and BLB resistance
<i>O.rufipogon</i>	AA	Source of CMS

BREEDING OBJECTIVES:

1. High yield potential
2. Adaptability and stability of yield
3. Maturity early, medium and long
4. Resistance to lodging and shattering
5. Resistant to cold temperature.
6. Resistant to salinity and alkalinity
7. Resistant to diseases like blast, stem rot, Tungro, sheath blight etc.
8. Resistant to pests like stem borer, gall midge, BPH etc
9. Improved grain quality
 - a) Grain shape and size
 - b) Texture of Endosperm and quality of starch in Endosperm
 - c) Aroma & Cooking quality (Basmathi type)
 - d) Colour of kernel
 - e) Milling out turn
10. Breeding for alternate source of dwarfing gene.
11. Breeding varieties suited for direct seeding
12. Breeding varieties for dry lands
13. Breeding varieties for deep water conditions
14. Breeding varieties for export - scented rice
15. Breeding varieties to control wild rice
16. Breeding varieties to suit any other local conditions .

BREEDING PROCEDURES

1. Introduction :

All the IRRI Rice varieties from IR 8 to IR 72. Other Examples are Basmati from Punjab, Ponni (mahsuri) from Malaysia, CR 1009 (Ponmani) from Orissa.

2. Pure line selection :

3. Hybridization and Selection :

a) Pedigree method

i) Inter varietal:

ii) Interracial

Japonica x indica cross ADT 27 (Norin 10 x GEB 24)

Ponni (Mashuri) (Taichung 65 x ME 80)

iii) Inter specific crosses

Co 31 (*O.perennis* x GEB 24) Drought resistance.

IR 34 Complex cross, one of the parent is *O.nivara*

b) Back Cross Method of breeding

4. Mutation breeding:

a) Spontaneous mutation

GEB 24

ADT 41 - Dwarf mutant of Basmati 370.

b) Induced mutation :

Jagannath rice from Orissa. Semi dwarf.

Parbhani - from Maharastra

5. Heterosis Breeding (Rice Hybrids)

APHR – 1 (IR 58025A X Vajram)

APHR – 2 (IR 62829A X MTU9992)

KRH1 (IR 58025A X IR 9761-10-IR)

CORH – 2 (IR 58025A X C 20R)

HYBRID RICE

The utilization of the dwarfing gene (d1) from the mutant variety Dee-Geo-Woo-Gen (DGWG) discovered in Taiwan in 1960s led to the development of Semidwarf, high tillering, nitrogen responsive, high yielding varieties of rice throughout the world. Consequently the yield level of rice in the tropics raised even 8-10 t/ha. Close observation of the yield performance of HYVS had revealed that the realised yield in such varieties are showing a plateauing trend (De Datta, 1990; Pingali *et al*; 1990). Among the various strategies proposed to break the yield plateau in rice productivity, exploitation of heterosis through the development of rice hybrids had been proved to be successful.

Heterosis in rice was reported by Jones in USA as early in 1926 and Ramaiah in 1933. But the research work on hybrid rice was initiated in 1964, in China by Yuan Long Ping (Father

of hybrid Rice). The identification of 'Wild Abortive' or 'WA' type cytoplasmic male sterility in 1970 was a breakthrough in hybrid rice breeding. In 1971 China accepted Hybrid Rice Research as a national cooperative project and in the year 1976, hybrid rice became a reality in China, for the first time in world, by the release of commercial rice hybrids suited for sub-tropical and temperate zones. Since then many of the rice growing countries had accepted the strategical approach of exploitation of heterosis through the development of commercial rice hybrids and as such rice hybrids were released in countries like Vietnam (for subtropical zone), Korea (for temperate zone); besides these countries, research on hybrid rice is progressing in countries like Philippines, Indonesia, Malaysia, Thailand, United States, Egypt, Colombia and Brazil.

Although research on the commercial utilization of heterosis in rice has made tremendous gains during the last 20 years, it is still in its infancy stage because the high yield potential of hybrid rice has not been fully tapped yet. And hence various approaches are adopted in major rice growing countries of the world to maximize the yield potential advancements of hybrid rice production.

Breeding techniques for developing hybrid rice involve the following:

a) Three-line method or CGMS system

This system now a days known as CMS system, involving three lines *viz-* cytoplasmic, genic male sterile line (A), maintainer line (B) and restorer line (R) is the most commonly used method in China and outside. Until 1985, more than 95% of the CMS lines used in the commercial indica rice hybrids, were of CMS-WA type which make the hybrid rice vulnerable to biotic and abiotic stresses. And hence attempts to identify new sources of male sterile cytoplasm led to the identification of CMS system like GA (Gambiac), Di (Disi), DA (Dwarf wild rice), BTC (Chinsurah Boro II) and IP (Ido Paddy 6). Mechanism of male sterility maintenance and hybrid seed production in three-line system given in figure-1.

Many years experience had undoubtedly proved that the CGMS system involving sporophytic and gametophytic male sterility is an effective way of developing hybrid rices and will continue to play an important role in the next decade. However there are some constraints and problems in such a system. The most serious is that yields of existing hybrid rice varieties including newly developed ones, have stagnated (Yuan, 1994). They have already reached their yield plateau, and are unable to increase the yield potential through this approach and hence new methods and materials were adopted. In this regard two-line hybrids are promising ones, to raise the yield ceiling in hybrid rice.

b) Two-line method of rice breeding

Two-line hybrids can be evolved through

- Mechanical means
- Application of gametocides
- Use of cytoplasmic male sterility (CMS)
- Use of genic male sterility (GMS)
- Use of environmentally induced genic male sterility (EGMS)

In rice EGMS system is commonly used. In EGMS systems two kinds of rice lines are made use of *viz.* PGMS (Photosensitive Genic Male Sterility) and TGMS (Thermosensitive Genic Male Sterility) which had been developed successfully in China. In this system male sterility is mainly controlled by one or two pairs of recessive nuclear genes and has no relation to cytoplasm. Developing hybrid rice varieties with these system has the following advantages over the classical CMS system, as given below.

- Maintainer lines are not needed.
- The choice of parents for developing heterotic hybrids is greatly broadened.
- No negative effect due to sterile cytoplasm
- Unitary cytoplasm situation of WA will be avoided.

In this system the exploitation of heterosis can be achieved by developing intervarietal and intersubspecific F_1 hybrids. In 1991, China had released hybrid combinations using this approach, and some of these combinations out yielded the best existing hybrids by 10-20% (Yuan, *et al*; 1994)

Detailed studies about physiological and ecological requirements of EGMS lines had been made in China and Japan. Work is progressing in India and International Rice Research Institute, in Philippines to identify best suited rice hybrids through this approach, for commercial exploitation. TGMS system is considered useful in tropical and subtropical regions where as PGMS system is useful in temperate regions.

Other possible approaches to develop two-line hybrid breeding system includes identification of a genic male sterility system which would revert to male fertility response to application of growth regulators and also the chemical induction of male sterility.

c) One -line method of rice breeding

Rice hybrids can be developed and popularized through the following concepts

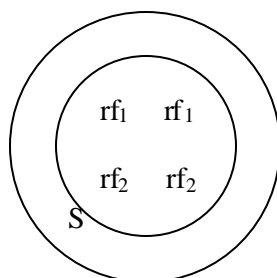
- Vegetative propagation
- Micro propagation
- Anther culture hybrids

- Apomictic lines

Among the above for large scale cultivation, apomictic lines and anther cultured materials will be economical.

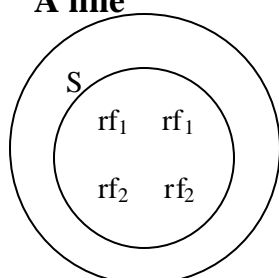
CGMS SYSTEM IN RICE

A line



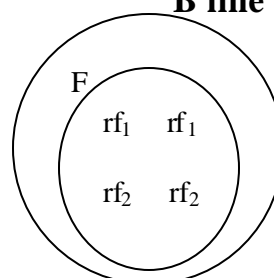
Maintenance

A line



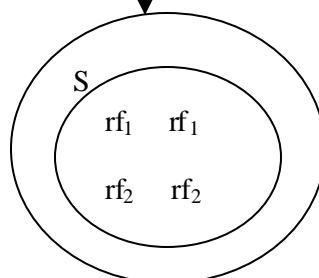
Male sterile

B line



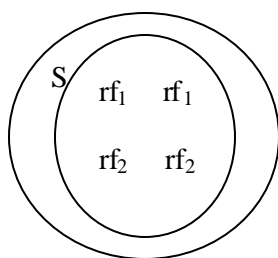
Male fertile

X



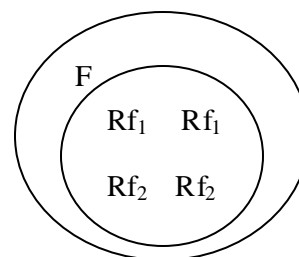
Male sterile A line

hybrid rice production

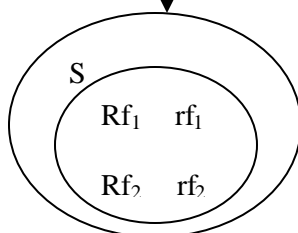


A line

X



R line



Fertile F₁ hybrid rice

Breeding Centers:

- IRRI – International Rice Research Institute Philippines
- CRRI – Central Rice Research Institute Cuttack (Orissa)
- DRR Directorate of Rice Research Hyderabad. (A.P)

Name of the released varieties for different breeding objectives

1.	High Yielding Varieties	Swarna, Vijetha, MTU1000 (Cottondorasannalu) Jaya.
2.	Early maturity	Cottondorasannalu, Tellahamsa, Jagtial Sannalu, IR-64
3.	Resistant to lodging and shattering	MTU 1061 (Indra) MTU 1064 (Amara)
4.	Resistant to cold temperature	Tellahamsa, Erramallelu
5.	Resistant to salinity	Vikas, CSR-30 (Yamini), Swarnamukhi (NLR145 CSR 29) Swarna
6.	Resistant to diseases	Blast NLR-145, Somasila Swathi, Shravani
7.	Resistant to pests	BPH: Vajram, Vijetha Deepti, Krishnaveni Gall midge : Kavya, Surekha Jagtial sannalu
8.	Aroma	Short slender: Chittimutyalu, Kala namak Long slender: Pusa Basmati1, Pusa 1121, Vasumati, Sumati
9.	Red rice	Heera
10.	Deep water	PLA 1100
11.	Dryland conditions	Rasi, MTU 9993 Erramallelu

Lecture No. 3

WHEAT – (*Triticum aestivum*) 2n = 6x = 42

Wheat is the most important cereal in the world, giving about one-third of the total production, followed closely by rice. In temperate regions it is the major source of food. The

chief use of wheat is, the flour for making bread. Wheat is grown in all the continents except Antarctica. It is the staple food of the 1/3rd of the world's population.

Place of origin:

Diploid	(2n=14)	:	Asia minor
Tetraploid	(2n=28)	:	Abyssinia, North Africa
Hexaploid	(2n=42)	:	Central Asia

Distribution:

USA, Canada, Latin America, Europe, China, Japan, Argentina, Mexico, India, Pakistan – Every month of the year a crop of wheat is harvested some where in the world. In India extensively cultivated in North West India, Eastern part, Central plain to some extent Southern peninsular zone.

Classification:

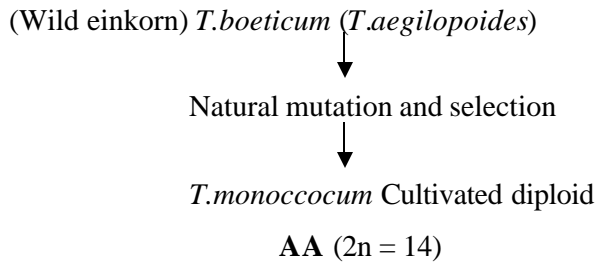
Ploidy level	Species	Common name	Genome
Diploid (2n=14) 2 species	<i>T.boeoticum</i>	Wild einkorn	AA
	<i>(T.aegilopoides)</i>	Einkorn	AA
	<i>T.monococum</i>		
Tetraploid (2n=28) 7 species	<i>T.dicoccoides</i>	Wild Emmer	AA BB
	<i>T.dicoccum</i>	Emmer	AA BB
	<i>T.durum</i>	Macaroni wheat	AABB
	<i>T.persicum</i>	Persian wheat	AABB
	<i>T.turgidum</i>	Rivet wheat	AABB
	<i>T.polonicum</i>	Polish wheat	
	<i>T.timopheevi</i>	-	
Hexaploid (2n= 42) 5 species	<i>T.aestivum</i>	Common or bread wheat	AABBDD
	<i>T.compactum</i>	Club wheat	AABBDD
	<i>T.sphaerococum</i>	Dwarf wheat	AABBDD
	<i>T.spelta</i>	Spelt wheat	AABBDD
	<i>T.macha</i>	Macha wheat	AABBDD

Fourteen species of wheat according to Vavilov:

1. *T.boeoticum*
2. *T.monococum*
3. *T.dicoccoides*
4. *T.dicoccum*
5. *T.durum*,
6. *T.persicum*,
7. *T.turgidum*

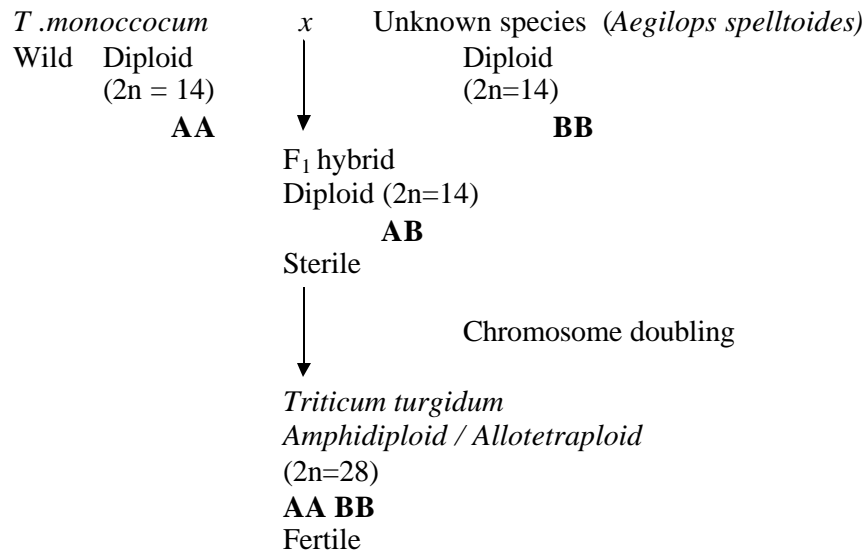
8. *T. polonicum*,
9. *T. timopheevi*,
10. *T. aestivum*,
11. *T. sphaerococcum*,
12. *T. compactum*,
13. *T. spelta*,
14. *T. macha*.

Origin of diploid wheat:

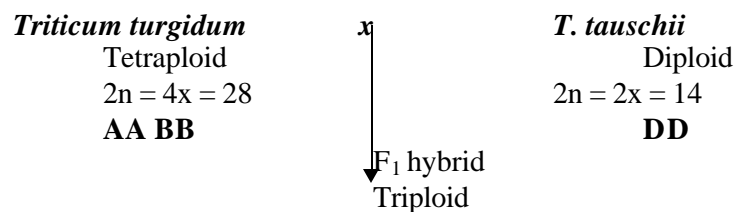


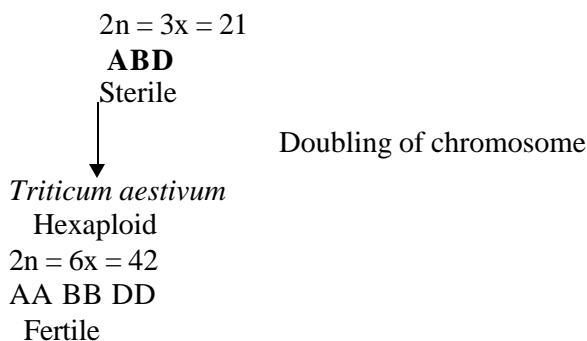
T. boeoticum is probably the ancestor for all the cultivated wheats:

Origin of Tetraploid wheats:



Origin of hexaploid wheat





Breeding objectives

1. High yield

High yield depends on

- The number of heads / unit area
- The number of grains / head.
- The average weight of grain

While breeding for high yielding varieties all the above three components must be looked into. Omitting any one of them may not yield results. Further while breeding for high yield it is necessary to combine into a variety a favourable combination of genes influencing all yield process.

2. Breeding non-lodging varieties:

This is achieved after the identification of dwarfing gene in Japanese variety Norin 10. Most of our dwarf wheats are two gene dwarfs. E.g. Sonara 63, sonara 64, kalyan sona. Emphasis is now on triple gene dwarfs.

3. Breeding for disease resistance

Rust is the major disease. Both stem rust and leaf rust are important ones. There are different races of rust. So while breeding for rust resistance horizontal resistance is to be looked into. Back cross method of breeding and development of multi lines are the methods.

4. Breeding for insect resistance

Hessian fly is the major pest. Resistance in most varieties is thro' Antibiosis.

5. Breeding for quality.

Different wheat varieties vary greatly in their chemical composition which is considerably influenced by environment. The varieties of hard wheat or bread wheat which have higher gluten content. The soft wheat contain lesser gluten content which is suitable for cake making, pastries etc. The durum wheats are unsuited for either cakes or bread but they are suitable for making macaroni.

So depending upon the use the quality breeding objective is to be fixed.

BREEDING PROCEDURES:

1. Introduction :

Semi dwarf wheat from Mexico, Sonara 63, Sonara 64, Mayo 64, Lerma Roja 64

2. Pure line selection :

Earlier varieties like P_4 , P_6 , P_{12} evolved at Pusa institute are result of pure line selection from local population.

3. Hybridisation and selection

a) Inter varietal:

A number of successful derivatives were developed at IARI New Delhi and Punjab. NP 809 - New pusa multiple cross derivative.

However all these varieties were lodging and poor yielder when compared to other countries. Hence the wheat hybridization programme was changed by Dr. M.S. Swaminathan during 1963. **Borloug** was invited to our country and he suggested for introduction of semi dwarf varieties from Mexico. As a result four commercial spring wheat varieties viz., Sonara 63, Sonara 64 Mayo 64 and Lerma Roja 64 were introduced. However they had red kernel hard wheats. These were utilised in our breeding programme and amber colour wheat varieties like Kalyan Sona, Safed Lerma, Sharbati Sonara were released, these are double gene dwarfs.

b) Inter specific crosses

To get Hessian fly resistance. So also for rust resistance.

c) Back cross method of breeding

Rust resistance in Chinese spring from Thatcher.

4. Hybrid wheat :

At Kansas Agri. Expt. Station USA male sterile lines were identified by crossing *T. timophevi* x *T. aestivum* Bison variety By repeated back crossing a male sterile line resembling Bison was evolved. At present USA and Canada are doing work on this.

5. Mutation breeding

Dr. M. S. Swamina than did extensive work on this with gamma rays.

Sharbati Sonara with increased protein content was evolved.

6. Development of multilines

Borlaug developed multilines against rust. MLKS 15 was developed at IARI.

Multiline is a mixture of pure lines which are phenotypically similar but genotypically dissimilar. Each line is produced by separate back cross method of breeding. Each line having resistance against a particular race of a disease.

Breeding centers:

- International Maize and Wheat improvement Centre (CIMMYT) Mexico.
- Directorate of Wheat Research (DWR), Karnal.
- All India Coordinated Wheat Improvement Project (AICWIP) – Karnal (earlier New Delhi)

Practical Achievement:

The semi dwarf varieties of wheat have been developed through the use of Japanese line Norin 10 as a source of dwarfing gene which led to “green revolution” in wheat production. The productivity of Semi dwarf varieties is about two and half times more than old tall growing varieties. More over these varieties are highly resistant to lodging and are highly responsive to fertilizer doses.

:Lecture No. 4

MAIZE (*Zea mays*) 2n = 20

Corn is the queen of cereals and it is the important crop next to rice and wheat with regard to total area and production. It is studied to a much wider range of climatical conditions than rice and wheat, because of its greater adoptability.

Origin: Central America

Distribution: USA, China, Russia, Canada and many south Asian countries

Progenitors: *Zea tunicata*

Z. teosinte

It belongs to the tribe Maydeae of family gramineae.

Wild relative: Teosinte: There are three species of teosinte of which *Zea mexicana* is annual diploid ($2n = 20$) like maize.

Gamma grass another close relative belongs to genus *Tripsacum*

The genes *Zea* characterized by male terminal inflorescences with paired staminate spikelets and lateral female inflorescences with single or paired pistil late spike lets

Genus *Zea* contains four species

1. *Zea mays* ($2n = 2x = 20$) = Corn
2. *Zea mexicana* ($2n = 2x = 20$) = Annual teosinte
3. *Zea perennis* ($2n = 4x = 40$) = Perennial tetraploid teosinte
4. *Zea diploperennis* ($2n = 2x = 20$) Perennial diploid teosinte

Breeding objectives :

1. Yield :

Complex character controlled by polygenes. Attention is to be paid to have ideal plant type. Varietal hybridization as a maize breeding method did not gain popularity. The main reason for this is difficulty in getting superior segregants.

2. Breeding for pest and disease resistance :

Shoot fly, Stem borer, Heliothis are major pests. Mexican varieties are resistant. Downy mildews, leaf blight and helminthosporium are major diseases. Co1, CoH 2 are resistant. Taiwan lines are resistant to downy mildew.

3. Breeding for high protein :

Composed of two fractions. a) Protein in endosperm known as *Zein* which is nutritionally not balanced since it is lesser in lysine and tryptophan. 80% protein found in endosperm.

b) Protein in germ (embryo) 20% balanced one. By increasing the embryo size we can increase protein content.

4. Breeding for increased oil content.

12-15% in germ. By increasing the embryo size we can increase oil content.

5. Alternate sources of cytoplasm

CMS - T. susceptible to helminthosporium, C and S Resistant.

6. High yielding baby corn.

Zea mays. variety *sachharata*, Sweet corn. The green cobs can be eaten as salad. The cobs can be harvested 45 days after sowing. CoBc 1 is latest variety of baby corn.

Breeding methods:

1. Introduction :

Initially the varieties were all introduced one.

Sikkim primitive 1

Sikkim primitive 2.

Mexican line were first introduced during 16th century by Portuguese

2. Mass Selection : Prior to 1945 mass selection was the only method used for maize improvement.

KT 1 - U. P.

RAS 1 - Rajasthan.

By adopting mass selection technique it is possible to get yield increase by 19% per cycle.

3. Ear to Row Selection :

First proposed by **Hopkins** for improving oil and protein content of maize. This method involves selection of a number of phenotypically desirable ears out of a population grown in isolation. The selected cobs are harvested on single plant basis and keeping part of the seeds and remaining sown in rows. Based on the best performing rows during next season the reserve seeds are sown.

This method is suitable for characters having high heritability like oil content and protein content. But it was not helpful to get increased yield.

4. Modified Ear to Row method :

Proposed by **Lonquist**.

- I. Best ear heads from population selected (100 No.) and harvested on single plant basis. And threshed individually.
- II. The single heads harvested are raised in progeny rows in more than one location representing different environment with local checks.
- III. In the main station the progeny rows are used as crossing block. Pollen from best plants are collected, mixed and used for crossing the rows.
Select best five plants from each rows and harvest them separately record the yield.
On the basis of performance of over all locations only top 20% progenies are selected.
These 20% will include the five plants selected.
- IV. The seeds from 5 plants selected are sown in progeny rows and cycle is repeated.

5. Hybridization and Selection

Not popular since isolation of superior recombinants was not made.

6. Heterosis breeding :

Instead of using CGMS lines, detasseling the female inbred line is followed in India. Since use of CGMS line is costlier compared to detasseling it is not followed.

Crossing the inbreds of indigenous x exotic origin resulted in release of best hybrids.

Indian x Indian - 24 to 43% yield increase.

Indian x U.S. dent – 58 % yield increase

Indian dent x Caribbean Flint – 47 to 54 % yield increase

1. Single cross hybrid
2. Three way cross hybrids - Ganga -5, Trishulatha
3. Double cross hybrids - CoH 3
4. Double top cross hybrid - White kernel hybrids - Ganga safed 2, Histarch, Ganga 4.

7. Population Improvement:

Recurrent selection technique was initiated by Dhawan in 1963. The initial synthesis of composites were done from high yielding inter varietal crosses which exhibited minimum inbreeding depression.

Kisan, Jawahar, Vikram, Sona, Vijay, Amber.

VARIETIES / HYBRIDS RELEASED IN MAIZE

Lecture No: 5

SORGHUM (*Sorghum bicolor*) $2n = 2x = 20$

Sorghum is one of the most important food crops in a semi – arid tropics.

Origin: S.E. Africa

Distribution:

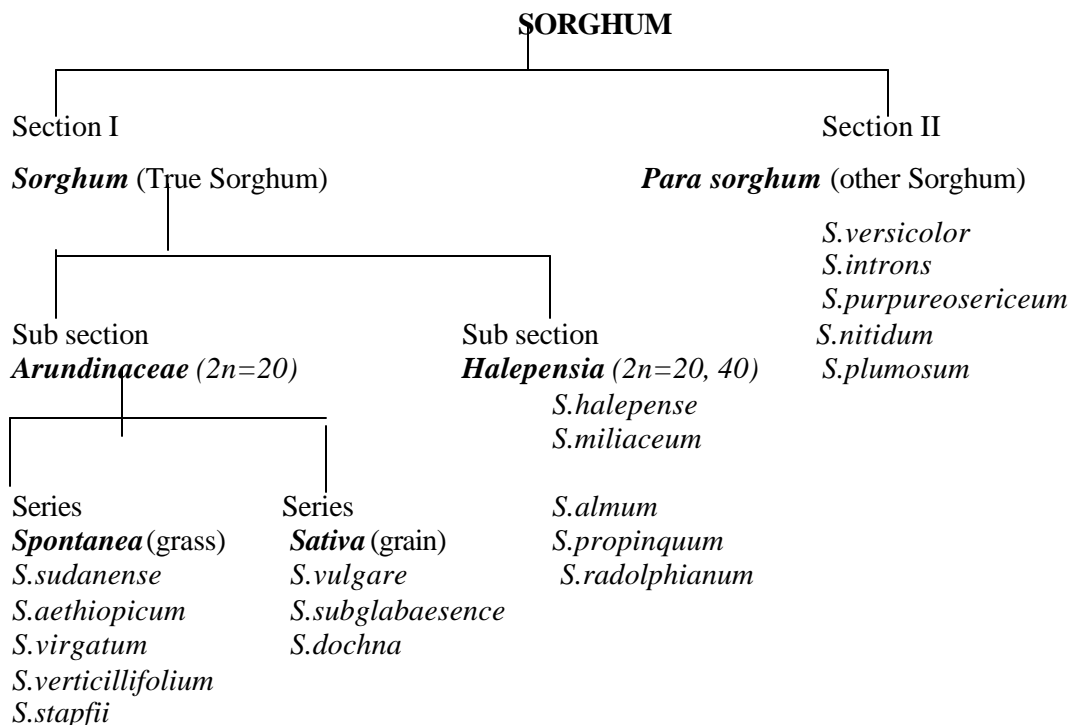
A number of land races, wild forms found in S.E. Africa, says the origin Ethiopia in Africa from there it spread to other parts of world. It is grown in Africa, south and central India, China, Argentina, Australia and south and central plains of US.

Progenitor of sorghum

1. *S.arundinaceum*
2. *S.verticilliflorum*
3. *S.sudanense*
4. *S.aethiopicum*

Classification :

Right from 16th century there were number of classification for the genus Sorghum. The famous among them is **Snowden's** classification (1936) later refined by Garber (1950) and by Dogget (1970).



The latest classification was done by **Harlan and De Wet** (1972).

1. *Bicolor* (B): Grain elongate, glumes clasping the grain which may be completely covered or ¼ exposed.
2. *Guinea* (G): Grains flattened dorso-ventrally.
3. *Caudatum* (C): grains asymmetrical, glumes 1/2 the length of the grain.
4. *Kaffir* (K): Grains symmetrical (spherical), glumes clasping in varying length.
5. *Durra* (D): Grains rounded obovate, wedge shaped at the base and broadest slightly above the middle; glumes very wide.

According to them, the cultivated sorghum *Sorghum bicolor* is divided into five basic races based on the coverage of glume on the grain

Breeding objectives

1. High grain yield
2. High forage yield
3. Breeding for non-lodging sorghums.

4. Dual purpose genotypes with high grain and fodder biomass potential per unit time.
5. Early maturity
6. Resistance to biotic stresses (diseases like grain mold, downy mildew, rusts, leaf blight, leaf spots etc.
7. Resistance / Tolerance to insects like shoot fly, stem borer, gall midge etc.
8. Resistance to abiotic stresses like salinity, drought with resistance to low HCN content
9. Breeding for quality characters like bread making, redgrain for biscuit making protein and lysine content.
10. Breeding for special traits like sweet sorghums and striga resistance.
11. To isolate alternate sources of cytoplasmic genic male sterile lines

Breeding Procedure:

Sorghum is often cross pollinated crop. So to maintain varietal purity isolation distance of 400 meters is necessary. Compared to other often pollinated crop like red gram, maintenance of inbreds is easy in sorghum. By putting brown paper and selfing the genetic purity can be maintained.

1. Introduction : Varieties of milo and kafir sorghum introduced from USA are used in conversion programme to convert the local long duration photo sensitive varieties to short duration, non-photo sensitive lines.

2. Selection : Old varieties like Co1, Co2, Co4 are all selection made from local land races.

3. Hybridization and selection

a) Inter varietal

(IS 4283 x Co 21) x CS 3541, Three way cross derivative Co 25

(MS 8271 x IS 3691) - Single cross derivative Co26

b) Inter specific

Co 27 Sorghum. (Co11 x *S.halapense*)

4. Heterosis breeding :

Use of CMS lines.

CSH 5 2077 A x CS 3541

5. Mutation breeding :

X ray mutant from CSV 5 (148)

Co 19 is a natural mutant from Co 2

6. Back cross method :

By following backcross method of breeding sorghum conversion programme was initiated. The long duration photosensitive germplasm was converted in to photo insensitive short duration sorghums. This was done at USA Similar programme was done at ICRISAT also.

7. Population improvement :

With the use of cytoplasmic genetic male sterility as well as genic male sterility we can go for population improvement. The local land races can be used as pollinators and by half sib family selection, we can isolate lines. We can follow recurrent selection idea to develop superior inbreds.

8. Use of Apomictic lines :

Some apomictic lines have been identified which can be utilised in breeding programme and by vegetative propagation we can fix up heterosis. E.g. R473 from Hyderabad.

B reeder centers:

International sorghum improvement work is carried out by ICRISAT (International Crop Research Institute for Semi Arid Tropics)

In India at Directorate of Sorghum Research (DSR), Hyderabad

Practical Achievements:

Hybrids are developed by using cytoplasmic genetic male sterility combined kafir 60
 Varieties: CSV₁ CSV-2, CSV-4, M35-1, CSV-13
 Hybrids: CSH-1, CSH-2, 3 etc for *kharif* and CSH 7, 12, 13 for *Rabi*

Lecture No. 6

PEARL MILLET (*Penisetum americanum*) (Bajra – Bulrush Millet) (2n=14)

Pearl millet is also known as Bajra, is an important food crop of semi arid tropics. It is also grown as fodder crop

Origin: W. Africa

Distribution:

Africa, India, Pakistan, South East Asia, USA and Europe

Taxonomy : The genus *Pennisetum* is having more than 140 species. Stapf (1954) has divided the genus *Pennisetum* in to five sections viz.,

1. Gymnothrix
2. Eupennisetum
3. Penicillaria
4. Heterostachya
5. Brevivalvula

The cultivated *Pennisetum glaucum* belongs to the section penicillaria.

Progenitors :

1. *Pennisetum purpureum*
2. *P. qumulatum*
3. *P. orientale*

Origin and putative parents.

Stapf included 32 species in *Penicillaria*. Of these 32 species found in Africa, six annuals are considered wild and probable ancestors of the cultivated one. They are

1. *P. perottettii*
2. *P. mollissimum*
3. *P. violaceum*
4. *P. versicolor*
5. *P. adonense*
6. *P. gymnothrix*

The cultivated species of *Pennisetum* is believed to have originated through hybridization with these six species.

Breeding objectives :

1. Breeding for high grain yield

To get high yields the following plant characters are necessary

- a) more number of tillers
- b) well filled, compact, long panicle.
- c) heavy grains.
- d) Uniformity of ripening.

Under irrigated conditions photoperiod insensitivity and early maturity are essential for multiple and relay cropping.

2. Breeding for improved grain quality.

It can be achieved by incorporating yellow endosperm to improve vitamin A content or white endosperm to improve protein content.

3. Breeding for drought tolerance :

This can be achieved through evolving lines having shorter duration so that they can escape drought, lines with more adventitious roots, lines with high leaf water potential and high chlorophyll stability index are to be evolved.

4. Breeding for disease resistance

Downy mildew is the major disease. Ergot and smut comes next. Of late, rust at late stage is also becoming a major problem.

Lines having Local Bellary cytoplasm (732 A) are observed to be downy mildew resistant.

5. Breeding for alternate source of cytoplasm in male sterile lines.

Original Tift 23 A evolved at Tifton, Georgia is highly susceptible to downy mildew. Because of this the HB series went out of cultivation. The indigenous 732 A obtained from Bellary is resistant. Similarly L 111A of Ludhiana is also tolerant. A_1 , A_2 , A_3 and A_4 are there 732 A belongs to A_4 cytoplasm.

6. Breeding for to have high forage value :

The forage cumbu must have following characters.

- a) high sugar content in the stem juice
- b) Increased leaf number with more breadth.
- c) Digestibility.

Breeding Procedures

1. **Introduction** : Hybrid bajra from Punjab.

Tift 23 A from USA

2. **Selection** : Pure line selection : Co 2, Co 3,

3. Hybridisation and selection

Interspecific hybridisation.

Pennisetum glaucum x *P.purpureum*



Cumbu napier hybrids.

4. Heterosis breeding : Hybrid bajra

In earlier days before the identification of male sterile lines utilising the protogynous nature hybrids were released. The hybrids were produced by sowing both parents in the ratio of 1:1.

After the discovery of cytoplasmic genic male sterile line Tift 23A by Burton in Tifton, Georgia led to development of hybrids. Earlier hybrids of India viz., HB1, HB2 to HB5 were produced utilising Tift 23 A. But due to susceptibility to downy mildew they went out of cultivation. Even before the discovery of CGMS lines by Burton it was discovered by Madhava

Menon and his coworkers at Coimbatore. Unfortunately due to failure of publishing it was not recognised.

To overcome the problem of downy mildew male sterile lines L 111A and 732 A were isolated and at present used in breeding programme.

There are number of CMS lines developed by private agencies like Nath seeds, Mahyco, Mahendra.

5. Population improvement :

ICRISAT entry WCC 75 is an example for population improvement. This was developed from world composite by recurrent selection method. It was developed from derivatives of numerous crosses between diverse sources of germplasm and Nigerian early maturing land races known as 'Gero' millets. Another example is ICMV 155 of ICRISAT.

6. Synthetic varieties :

Synthetics are produced by crossing in isolation a number of lines tested for their GCA. E.g. ICMS 7703.

It is a result of crossing between 7 inbred lines of India x African crosses

7. Mutation breeding

At IARI Tift 23 A was gamma irradiated and 5071 A resistant to downy mildew was evolved. With this the hybrid NHB 3 was evolved (5071 A x J 104)

Breeding centers:

International Crops Research Institute for Semi Arid Tropics (ICRISAT,) Hyderabad

All Indian Pearl Millet improvement project (AIPIP) Jodhpur (Rajasthan)

Practical achievements

Varieties: PS B – 8, PSB 15, mukta

Hybrids : HHB 45, HHB 50 from Hissan GHB 30, GHB – 27 from Gujarat

FINGER MILLET (*Eleusine coracana*) (2n = 36)

Ragi

The common name finger millet is derived from finger like branching of panicle – Ragi is derived from Sanskrit word Ragika.

Origin: According to Vavilov – Africa

According to Decandolle – India

Distribution: India, Africa, Pakistan.

Progenitors : *E. indica* is wild in India and Africa

E. stricta is wild only in Africa

Wild relatives :

The genus *Eleusine* comprises of 11 species of which 6 are diploids and 5 are tetraploids.

1. *Eleusine indica*
2. *Eleusine oligostachya*
3. *E. tristachya*
4. *E. poranansis*
5. *E. jaegeri*
6. *E. flacifolia*
(2n = 36)
1. *Eleusine coracana*
2. *E. africana*
3. *E. longipoides*
4. *E. verticillata*
5. *E. cagopoides*

Breeding objectives:

1. Higher yields
2. Early maturity
3. Better quality
4. Resistance to diseases
5. Resistance to pests
6. Resistance to Abiotic stress

Breeding techniques

1. By introduction

Indaf 5 Ragi from Karnataka.

2. By selection

Pure line selection. Earlier varieties were all evolved by pure line selection.

3. Hybridization and selection

The African types are with long fingers, bold grain with stiff straw. Further they are photosensitive and have an even grain maturity. Because of this character they are not recommended for cultivation in India. The Indian types are with short fingers, small grains and photo insensitive. The African types are utilised in hybridization programme, to develop extra long fingered varieties coupled with disease and drought resistance. The Indian African cross derivatives are known as Indaf varieties which are interspecific.

Other state varieties

E.g. Indaf 5 cauvery x IE 929

Indaf 9

4. Heterosis breeding :

Artificial induction of male sterility through use of gametocide, GA3, 24-D are being attempted.

5. Mutation breeding : T20 - mutant from AKP - 7.

Practical achievements:

Varieties saroda, Kalyani, Simhadri, Padmavathi, Ratnagiri, Godavari, Gauthami

Lecture No: 7

Sugarcane (*Saccharum officinarum*) $2n = 80$

Origin: India

The word sugarcane is derived from Sanskrit word 'sharkara' meaning sugar. It includes 3 cultivated species like *S. officinarum*, *S. barberi*, and *S. sinense*.

Wild species

1. *S. spontaneum*,
2. *S. robustum*.

Cultivated species:

S. officinarum ($2n = 80$)

S. sinense ($2n = 118$)

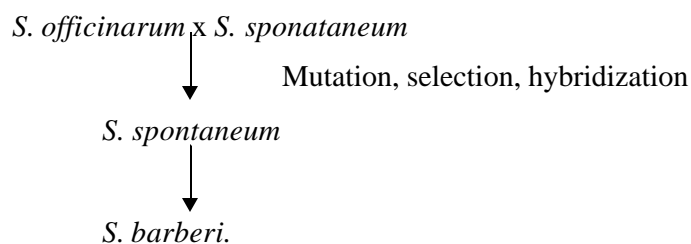
S. barberi ($2n = 82 - 124$)

S. officinarum is also known as noble cane. The term noble was given by Dutch scientists in Java to tall, handsome, large barked and colourful canes of this species. The canes of this species have thick stem, soft rind, low fibre, high sugar content, high cane yield, and resistance to smut.

1. *S. robustum* \longrightarrow *S. officinarum* (New Guinea)
2. *S. officinarum* X *S. spontaneum* \longrightarrow *S. barberi* and *S. sinense* (North India).

Origin of cultivated species:

The wild progenitor for *S. officinarum* is *S. robustum*



Distribution : India, Brazil, Cuba, China, USA, Mexico, France, Germany and Australia. In India, Uttar Pradesh, Maharashtra, Haryana, Andhra Pradesh, Tamilnadu, Karnataka, Bihar and Punjab. India stands first in sugar and sugarcane production in world.

Breeding objectives:-

1. High cane yield / height of stem, thickness, tillering capacity, no of tillable canes / plant and weight of individual cane.
2. Moderate high sucrose content
3. Early to full season maturity
4. Resistance to diseases.
 - a) Red rot
 - b) Smut
 - c) Wilt
 - d) Mosaic
 - e) Ratoon – stunting disease
 - f) Grassy – shoot
5. Resistance / tolerance to insect pests
 - a) Shoot borer
 - b) Cane borer
 - c) Pyrilla
 - d) Mealy bugs
 - e) White flies
 - f) Termites
 - g) White grub
6. Tolerance to abiotic stresses
 - a) Drought
 - b) Salinity
 - c) Flooding
 - d) High temperature
7. Wider adaptability

Breeding procedures:

1. Hybridization: 3 basic types of crosses are made

- i) **Biparental crosses:-** These are the crosses resulting from 2 known parental clones. This is easily achieved by bringing together the two parents in an isolated area or under lanterns
- ii) **Area crosses:** In this system several male sterile female clones are pollinated by one male parent in an isolated area.
- iii) **Melting pot crosses:** Melting pot crosses or polycrosses are made by bringing together arrows of large number of superior / potential parental cultivars in an isolated area. Natural cross pollination is allowed. This procedure allows the evaluation of breeding behaviour of a large number of clones at a minimum expense.

2. Breeding for resistance to diseases:-

1. Red rot:- It is a major problem in sub-tropical countries. The major sugarcane varieties which are found to be resistant to this disease are

Co 1148, 1336, 6304, Co 5659, CoS 698 etc.

Smut: Serious disease in many sugarcane growing countries resistant commercial varieties in India are

Co 449, 527, 853, 1148, 1336.

3. Mutation Breeding:

According to Heinz x-ray - Irradiation to induce mutations in sugarcane were carried out in 1927. Many mutation breeding programmes with x – rays and gamma – rays were started during early sixties in India.

- Mutation breeding in sugarcane aims at creating economic mutants for higher cane yield, non – flowering and resistance to various diseases such as redrot, smut, downy mildew and to various insect borers.
- Gamma-rays as well as chemical mutagens such as EMS are applied mostly on buds.

4. Abiotic stress tolerance / resistance:-

- Common abiotic stresses for sugarcane as in other crops are drought, flooding, salinity, high temperature freezing temperature
- According to Zobel, they are following 3 basic steps for breeding stress resistance cultivars.
 - (i) Identifying and characterizing crop traits that are needed for resistance against a particular stress
 - (ii) Identifying and characterizing the genotypes that are capable of filling the needs are determined under step I above.

- (iii) Manipulating genes to produce an adapted variety that has the required characteristics and fills other specific needs.

5. Biotechnology:

- Regeneration of sugarcane plant from callus has been possible.

Breeding centres:-

1. Sugarcane breeding institute, Coimbatore
2. Indian Institute of Sugarcane Research, Lucknow
3. State sugarcane research stations, such as shahjahanpur (UP), Seorali, (Deoria) (UP), Pusa (Bihar), Padegaon (Maharashtra) and Anakapalli (AP).

Drought	:	Co 285, Co 740, Co 997, Co 1148
Frost	:	Co 1148, N Co 310
Salinity	:	Co 453, Co 62125
Lodging	:	Co 6304, Co 7117, CoS 7918
Water logging	:	Co 1157, Co 975, Co 785, Bo 91, Bo 104, Bo 106, Bo 109
Top borer	:	Co J 67, Co 1158
Inter nodal borer	:	Co C 671, Co 975
Red rot	:	Co 7627, Co J 64, CoR 8001.

Lecture No: 8

PULSES

The pulse crops in general give lower yields than the cereals. Pulses are rich in protein and it takes more energy weight for weight to synthesise protein than carbohydrates. When you compare the energy requirement of various metabolic pathways. one gram of glucose can give rise to 0.8g of carbohydrate but on an average only about 0.5 g protein and even less of oil.

The protein from pulses are incomplete. Legumes are good source of lysine, tryptophan and theonine but are low in sulphur containing amino acids *methionine*, *cystine* and *cystene* which are adequate in cereals. So a mixture of cereals and pulses are recommended for food. Many grain legumes contain toxic inhibitors which are removed while cooking.

Further maintenance of nitrogen fixation in roots require prolonged use of photosynthate and thus may reduce the energy available for storage in seeds.

Main reasons for low yield compared to cereals

1. Indeterminate growth habit

2. Long continued natural selection
3. Cultivation on poor soils
4. Inadequate use of fertilizers
5. Inadequate plant protection measures
6. Rainfed cultivation
7. Photo sensitiveness

RED GRAM (*Cajanus cajan*) (2n = 22)

Pigeon pea / Red gram is an important pulse crop next to chickpea in India. India is a largest producer i.e. 90% of the world's production

Origin: Africa and India

Distribution: India, Uganda, Kenya, West Indies, Burma etc. In India, Maharashtra, Uttar Pradesh, Madhya Pradesh, Karnataka, Gujarat and Andhra Pradesh and under irrigated belt in Punjab, Haryana and Rajasthan.

Progenitor: *Cajanus cajanifolius*

Atylosia lineate

Genus *Cajanus* and *Atylosia* and have many similarities. *Cajanus* has more than 30 species. The view is that *Cajanus* arose from *Atylosia*. In western ghats, West Bengal and Orissa, *Atylosia* species are known as wildtur. Now this genes has been included in *Cajanus*.

Breeding objectives:

1. Evolution of long duration high yielding variety suitable for rainfed to replace the local land races :

SA1 - Released during 1940

2. To evolve short duration (105 days) varieties suitable for irrigated / mixed crop with ground nut.

ICPL 87 - ICRISAT

3. Breeding for bold grain type with desirable seed coat color

HY 3C long duration variety with dull white seed coat and bold grains.

4. Breeding for vegetable type

Green pods with bold seeds are used as substitute for green peas in some areas are perennial types

5. Breeding for resistance to pests.

Heliothis is the major pest, terminal cluster types are highly susceptible. All our varieties are highly susceptible.

6. Breeding for disease resistance :

Sterility mosaic, root rot, blight are important diseases. Wild species *Cajanus scaraboides*, *C.lineata* are having resistance.

7. Breeding for high protein content and quality

Mean protein content 23%. The wild species have 27% to 29% , Red seed coat contains more polyphenol (Tannin) than white seed coat. So preference is towards white seed coat. Red grain contains lesser amount of sulphur containing amino acid. When we increase protein content there will be lesser amount of these amino acids. So care is to be taken to increase them.

8. Breeding high yielding perennial redgram suitable for bund cropping

Breeding procedures

1. Introduction :

E.g. Prabhat short duration variety from IARI, ICPL 87 from ICRISAT.

2. Pure line selection

Earlier breeding work was based on the assumption that Redgram is a self pollinated crop. However it was later found to be often cross pollinated crop.

3. Hybridization and selection :

Inter varietal : VBN 1 (Prabath x NY 34) (T.12 x 102)

Inter generic : *C. cajanus* x *Cajanus lineata*

C.cajanus x *C. scaraboides* are being attempted

4. Mass selection :

5. Population improvement :

Using male sterile line and recurrent selection methods.

Two populations are used, one is seed parent and the other is pollen parent. The seed parent must have one or two easily identifiable recessive character and the pollen parent more dominant genes. The seed and pollen parents are sown in alternate rows so as to maximize natural cross pollination.

The F_1 's and selfed ones are identified in S_0 generation. The identified F_1 s are space planted in the next generation S_1 . In S_2 generation they are yield tested in 3 environments and best ones are either recycled or taken to conventional breeding programme.

6. Mutation breeding

LRG-30 variety was susceptible to wilt was irradiated and wilt resistant variety was developed as ICPL-270

7. Heterosis breeding

Red gram Ideal plant type

a) Long duration:

The genotype that have steady rate of growth and have a moderate harvest index.

High seed weight

Long pods

Increased number of pod bearing branches.

b) Short duration :

Dwarf in nature with erect branches having high dry matter production

High seed wt.

Long pods.

Increased no of seeds / Pod

Less flower dr op.

c) Breeding centers:

International Crop Research Institute for Semi Arid Tropics (ICRISAT) Hyderabad

Practical Achievement:

Varieties: Prabhat, Vishakha, Sharada, ICPL – 87

Hybrids: ICPH – 8

SOYBEAN (*Glycine max*) $2n = 40$

One of the important oil yielding crop of world it is miracle crop giving 42 – 45 per cent protein and 19-20 per cent oil it belongs to family leguminoseae

Origin: China

Distribution: USA, Brazil, China, Argentina and India.

Progenitors: *G. usuriensis*

G. tomentolla

G. tabacina

G gracilis

Glycine max is originated from *G. usuriensis* and *G. tomentolla*

Breeding objectives:

1. Breeding for short duration high yielding varieties

The yield of soy bean plant is determined by size, number of seeds per pod and number of pods / plant. The number of pods/ plant is determined by number of nodes / plant, number of pods / node. Each of the above components of yield are polygenic in inheritance and so it is complex.

The duration is also determined by multiple genes. Maturity is correlated with height of the plant.

Early varieties will be short is stature.

2. Breeding varieties suitable for rice fallows

Short plants 65 -70 days duration. Suitable for inter cropping also in banana and sugarcane.

3. Breeding for quality

a) Seed coat color and quality – Yellow, Black, Brown Green

b) Oil content and quality

c) Protein content

a) Seed coat color:

May be yellow, green, black, brown or combination of all the above colours. For oil extraction yellow color is preferred because of high oil content where as black seeded varieties are low in oil content but high is protein content.

b) Oil content and quality:

Oil content is greatly determined by environment :

Yellow seed coat varieties are rich in oil. Complex character determined by poly genes.

c) Protein content and quality:

Ranges from 35 to 50%, protein content is negatively correlated with oil content so while breeding for high protein content a compromise is to be made.

4. **Breeding for vegetable type**

AVRDC, Taiwan has evolved vegetable types

5. **Breeding for forage type of soybean**

6. **Breeding for non-shattering type**

E.g. Lee, Co2

7. **Breeding for YMV resistant lines**

Co 2

Breeding Methods:

1. **Introduction :**

EC 39821 from Taiwan - released as Co1

2. **Pure line selection**

Co1

3. **Hybridization and selection**

Clark,

4. **Mutation breeding.**

Breeding centers:

- Asian Vegetable Research and Development Centre (AVRDC) Taiwan
- International Institute of Tropical Agriculture (IITA) Nigeria
- In India National Research Centre for Soybean (NRCS) Indore (M.P)

Practical Achievements:

Varieties: Bragg, Clark 63, Hardee, MACS 13 etc.

Lecture No: 9

GREEN GRAM (*Vigna radiata*) $2n = 22$

Also known as mung bean

Origin: India

Distribution : India, Pakistan, Bangladesh, Srilanka, Philippines, Taiwan, Thailand, Nepal and Southern Asian countries. In India, Maharashtra, UP, MP, Karnataka, Gujarat A.P, Tamil Nadu and Rajasthan.

Progenitor: *Vigna radiata* var: *sublobata*

Breeding objective:

1. High yield, medium duration dry land varieties

2. High yielding, short duration irrigated varieties :

Lines having rapid growth rate or dry matter increase associated with high harvest index.

3. Breeding for rice fallows

4. Breeding for disease resistance, YMV, Leaf crinkle virus, Tarai local Lm 214 - resistant

5. Breeding for quality

- a) Mung bean has highest digestibility among grain legumes from 83 to 90%. Varieties having bold seeds to use as sprouts is the aim.
- b) Transfer of high methionine content from black gram to green gram.
- c) High dal recovery - 80% and more
- d) Less hard seed.

Breeding Methods:

1. Introduction - Pusa baisaki

2. Pure line selection - Co1

3. Hybridisation and selection

Inter Varietal :

Inter specific - To transfer high methionine content from black gram to green gram.

V. radiata x *V.umbellata* rice bean to transfer resistance to bean fly crossing with *V.radiata* var. *sublobata* resistance to bruchids

5. Mutation breeding

Co4 - mutant of Co1

6. Embryo culture :

Green gram x Black gram

Ideal plant type

- 1. 60 - 65 days duration with determinate habit for irrigated conditions
 - 2. 80 days duration with indeterminate type for dry land condition
- Plants with more pods and seeds, increased branches podding from base of main stem with synchronised maturity non - shattering habit.

Varieties:

Jawahar – 45, WGG-2, LGG-127

Black gram (*Vigna mungo*) $2n = 22$

Origin: India

Distribution: India, Pakistan, Srilanka, and South Asian countries. In India, Maharashtra, UP, MP, Karnataka, Gujarat A.P, Tamil Nadu and Rajasthan.

Progenitor: *Vigna mungo* var *silvestris*

Vigna radiata var *sublobata* – common progenitor of green gram and black gram.

Breeding objectives

1. Evolving medium duration high yielding varieties for dry land cultivation.
2. Evolving short duration high yielding varieties suitable for irrigated conditions

This can be used as mixed crop in cotton, turmeric Short duration varieties are Co2, Vamban 1, 2 and 3.

3. Evolving short duration varieties suitable for rice fallow conditions

4. Breeding varieties resistant to diseases

YMV is a serious disease. Leaf crinkle virus, powdery mildew.

5. **Pest** : White fly vector for YMV and leaf crinkle, leaf eating caterpillar

6. Breeding for better quality

24% protein. There are lines having 27% protein. These can be utilized.

Quality of black gram is determined by

- a) Protein content
- b) Methionine content 1.17%
- c) cooking quality - Time
- d) % of hard seeds.
- e) Dal recovery 70%

Breeding methods

1. **Introduction** :
2. **Pure line selection** :
3. **Hybridization and selection**
 - a) **Intervarital**
 - b) **Inter specific** :

Vigna mungo x *V.mungo* var.*silvestris* - Pantnagar. YMV resistant lines obtained. but pod shatters. More number of back crosses suggested.

Vigna mungo x *V.radiata* for increasing pod length, digestibility. Sterility is the main problem. Few plants obtained revert back to parental form.

- 4) **Mutation breeding**

- 5) **Embryo rescue** - Attempted in inter specific crosses.

Ideal plant type

For irrigated and Rice fallows

Determinate type, short duration, high dry matter producing with 30cm plant ht.

Photo insensitive.

For rainfed condition .

Semi determinate with pod setting from base of the main stem; higher pod length and more number of seeds / pod.

Breeding centers:

ICRISAT, - Hyderabad

ICARDA, - (International Crops for Agricultural Research in Dryland Areas) – Syria

AVRDC - (Asian Vegetable Research and Development Centre)

IIPR - (Indian Institute of Pulse Research), Kanpur

Varieties:

Black gram : T9, T27, LBG-17, LBG-402

Bengal Gram – Chickpea (*Cicer arietinum*) $2n = 16$

The most important pulse crop India is the largest producer of chickpea in the world.

Origin: According to Vavilov (1926) – S.W. Africa and Mediterranean region

Later, Vander Maesun (1984) – Turkey and Syria

Distribution: India, Pakistan, Mexico, Turkey, Ethiopia, Burma and Maynmar. In India M.P.

U.P. Rajasthan, Haryana accounts 75-80% of the India's production other states are Maharashtra, Bihar, West Bengal and Andhra Pradesh.

Progenitors :

Cicer bijugum

C. echinospermum

C. reticulatum

Genus *Cicer* has 49 species, out of these nine are annual and forty are perennial

Breeding Objectives:

1. Increased seed yield
2. Increased biomass, tall, erect and compact cultivars
3. Resistance to diseases like A, blight, *Fusarium wilt*, Root rot, Botrytis grey mold.
4. Resistance to insect pests – Pod borer
5. Tolerance to stress environments
 - a) Cold
 - b) Heat
 - c) Drought
 - d) Saline and Alkaline.

Plant type in chickpea

1. Compact plant type
2. Medium tall are preferred
3. Optimum number of primary and secondary and minimum number of tertiary branches
4. Photo thermo sensitiveness
5. Determinate growth habit for harvesting uniform produce
6. Well developed nodules

Breeding procedures:

1. **Pedigree method:** for resistance breeding (disease, insect, nematode, orobanche spp)
2. **Modified bulk method :** for stress situations (drought, cold, heat, iron deficiency)
3. **Back cross method:** for interspecific hybridization. Limited backcross (one or two) for desi x kabuli introgression and also for resistance breeding. Resistance to fusarion wild can be easily transferred from desi to kabuli type
4. **Somaclonal variation:** through plant tissue culture appears to be a potential tool for generation and exploitation of useful variability.

Lecture No: 10

GROUND NUT (*Arachis hypogcaea*) ($2n = 40$)

It is important oil seed crops in India, grown in subtropical and warm temperate zone also called as peanut or monkey nut. It contains 45-55 per cent oil and 25-30 per cent protein.

Origin: Brazil

Distribution:

India, China, USA, Africa, South and South East Asia In India, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu Maharashtra, Madhya Pradesh, Rajasthan Uttar Pradesh, Punjab.

Progenitor:

Arachis monticola

A – prostrata

A – silvestres

Putative parents and origin of cultivated ground nut.

The cultivated ground nut is a Allotetraploid having A and B genomes. The genus *Arachis* is sub divided into 7 sections. The cultivated ground nut comes under section *Arachis*. This section includes 12 species of which *hypogaea* is the only cultivated species having $2n = 40$. The other one is *A. monticola*. The rest ten species are diploids.

Groundnut an unpredictable Crop

Ground nut is popularly known as unpredictable legume. Since the pods are borne below ground positively geotropic we cannot predict its performance before harvest as in the case of other crops. Further Ground nut is highly influenced by environment.

If there is no favourable environment yield alone will not be affected but also the quality characters.

Less boron means low shelling % and more of immature seeds **moisture stress** leads to lower yield as well as reduction in well developed kernels. Oil percentage is also influenced by environment.

Excess moisture leads to more vegetative growth and reduction in yield. Compared to any other crop here. G x E interaction is more pronounced.

Besides abiotic stress, biotic stress also play a major role rust and leaf spot in diseases, red hairy caterpillar and leaf minor in pests cause major havoc.

Seed multiplication ratio is 1:5. This is also one of the bottlenecks in the spread of improved varieties.

Classification :

The genus *Arachis* is subdivided in to the following seven sections. (Gregory and Gregory, 1973)

Arachis

Erectoides

Rhizomatasae

Extranervosae

Triseminate

Ambinervosae

Caulorhizae.

1. Arachis 2n*Arachis villosa* 20*A. batizocoi* 20*A. cardinassi* 20*A. chacoense* 20*A. monticola* 40*A. hypogaea* 40**2. Erectoides***A. tuberosa* 20*A. paragurensis* 20**3. Rhizomatasae***A. glabarata* 40*A. hagen beckii* 40**4. Extra nervosae***A. villosulicarpa* 20*A. marginata* 20**5. Triseminate***A. pusilla* 2n = 20**6. Ambinervosae**

none, named

7. Caulorhizae*A. repens* 2n = 20

In hybridization programme intersectional hybridization is not successful but intra sectional hybridization is successful keeping wild species as female is more successful.

According to Smart 1961 *A. hypogaea* has been sub divided in to two sub species

viz. A. hypogaea subsp. *hypogaea*

A. hypogaea subsp. *fastigiata*

According to this hypogaea the first two nodes bear vegetative branches then next two branches bear inflorescence

fastigiata : Inflorescence are borne on second and subsequent nodes of primary branches.

Karpavickas (1968) recognised two other botanical varieties in each of the sub species.

A. hypogaea subsp. *hypogaea*

var. *hypogaeae*. *Virginia type* spreading

var *hirsuta hirsuta* type semi spreading.

A. hypogaea sub. sp. *fastigata*

Var. *fastigata* (Valencia type)

subsp var *vulgaris* Spanish bunch.

In India the cultivated types are grouped into

i) Bunch type Valencia Spanish bunch

ii) Semi spreading - *Virginia* bunch

iii) Spreading - *Virginia* runner.

Breeding objectives:

1. Breeding high yielding bunch ground nut with dormancy suitable for dry land conditions

The dry land bunch type sown during June - July often caught up in early N.E. monsoon rains which results in germination of varieties. So it is necessary to breed varieties having dormancy. Semi spreading varieties are dormant TMV 7 slightly dormant varieties, BSR.1, ALR 2 dormant for 15 days.

2. Breeding varieties for quality

a) High shelling percentage > 75%

Thin shelled varieties have high shelling percentage.

b) High oil content > 50%

TMV 10 the semi spreading variety is having 52% oil. Oil content is highly influenced by environment.

ALR. 2-52% oil

c) High sound mature kernel (SMK)

Which is also influenced by environment. Increased boron application results in high shelling percentage and high SMK %

d) Table purpose varieties

Hand picked kernel for export market. Valencia types are suitable for this.

3. Breeding disease resistance varieties.

Rust and leaf spot are causing major damage. If the onset of rust is in initial stage it results in total failure. Late leaf spot hinders harvest of crop due to foliage loss.

Tomato spotted wilt virus or Bud necrosis of late gaining importance. NCAC 17090 - resistant

4. Breeding for pest resistant varieties

Red hairy caterpillar, leaf miner are major pests.

5. Breeding short duration (85 days) varieties suitable for irrigated conditions

Breeding Methods:

1. Introduction:

All the ground nut lines are introduced ones.

2. Selection:

a) Pure line selection

TMV 2 - Selection from local Gudiyatham bunch.

b) Mass selection

JL 24 from Taiwan variety.

3. Hybridization and Selection

a) Inter varietal

Bunch x Bunch - VRI 2 (Co2 x JL 24)

SSP x Bunch - VRI 3 (R 33-1 x Ah selection)

b) Inter specific

For transfer of disease resistance.

Arachis sp :

A.hypogaea x *A.batizocoi*

2n = 40 ↓ 2n = 20 (Resistant)

Triploid sterile

doubled

Hexaploid

Reduced to tetraploid.

A. chacoense

$2n = 20$

A. monticola - for thin shelled conditions

Extranervosa sp.

A. villoullicarpa for increased number of pods.

5. Mutation breeding

Gregory in USA extensively adopted and released varieties.

Co2 EMS from POL 1

TMV 10 Natural mutant from Argentina local.

TG 1 to TG 6 (Vikaram) from BARC Trombay.

GNLM - Gujarat Narrow Leaf Mutant.

6. Embryo rescue technique :

A. puscilla x *A. hypogaea* crosses. But not much successful. Cotyledon culture is a success.

7. Transgenic plants

Transgenic plants for disease resistance. Transfer of a particular gene from wild species thro' use of medium of carrier (plasmid) micro projectile bombardment direct transfer. Transfer of disease resistance gene from wild species through plasmid is a success.

Breeding centres:

ICRISAT, Hyderabad

NRCG, (National Research Centre for Ground Nut Junagarh)

Practical Achievements

Varieties: Kadiri-3, JL-24, Tirupathi 1, 2, 3, 4 TMV – 2, J11, Vemanara, Jagtia-88

SESAME (*Sesamum indicum*) (2n=26)

It is an ancient oil seed crop of tropics and warm sub-tropics. It is also called as gingelly.

Origin: India, and Ethiopia (Africa)

Distribution: India, Pakistan, Africa, China, Mexico, Iran, Iraq etc.

Progenitors: *Sesamum angustifolium*

S. radiatum

S. alatum

Wild species utilised in breeding programme

1. *S. alatum* 2n = 26

Resistant to phyllody *S. alatum* x *S. indicum* alatum is having dormancy.

2. *S. malabaricum* (2n = 26) Occurs in Travancore of Kerala. It freely crosses with cultivated gingelly. Oil content is low 32% It is utilised to induce male sterility in cultivated sesame.

3. *S. laciniatum* 2n = 32

Tolerant to phyllody, drought and jassid resistant.

Fertile auto allopolyploid produced by crossing *S. indicum* x *S. laciniatum*

Sterile, Double.

4. *S. prostratum* occurs in S.India (2n = 26)

Tolerant to drought.

Breeding objectives

1. Breeding high yielding varieties tolerant to drought.

2. Breeding white seeded varieties

Finest quality of oil is obtained from white seeded lines.

3. Development of mono stemmed varieties.

By this more population per unit area and yield can be increased. Monostemmed varieties are low yielders.

4. Development of multicapsule / axil and multicarpellary varieties.

5. Rice fallow varieties :

Shorter in duration.

6. Non-shattering varieties

African lines.

7. Resistant to disease

Powdery mildew;

Phyllody - transfer from wild species.

Breeding Methods :

1. **Introduction** : African lines.
2. **Pure line selection.**
TMV6 - Andhra local.
3. **Hybridization and selection.**
 - a) **Inter varietal**
 - b) **Inter specific** : Male sterile lines evolved by crossing with *S.malabaricum*.
4. **Population improvement**
5. **Poly ploidy breeding**
6. **Heterosis breeding**
Epipetalous nature makes emasculation and crossing easier
Use of CMS lines is also being attempted.
7. **Embryo rescue technique.**
Varieties Gouri, Madhavi, Rajeshwari, Swetha

Lecture No: 11

SUNFLOWER (*Helianthus annuus*) (2n=34)

It is an important oil seed crop. Oil content ranges from 46-52 per cent and is of high quality having non-cholesterol properties.

Origin: America

Distribution: USSR, Romania, Canada, USA In India this crop is introduced in 1969 from USSR. In India it is cultivated in Tamil Nadu Karnataka, Maharashtra and Andhra Pradesh, Punjab and Haryana

Progenitors: *Helianthus petiolaris*
H. gigants

Wild species: *H hirsutus*
H rigidus

The genus *Helianthus* comprises of 67 species. Two species *H .annuus* and *H. tuberosus* are cultivated as food plants genus has basic chromosome number of 17 and diploid, tetraploid and hexaploid species are found.

Cultivars of sunflower:

a) **Giant types:** 6 - 14 feet tall. Late maturing, Large heads 12 - 30" in diameter, seeds large, white or grey or with black stripes. Oil content is very low. E.g. Mammoth Russian.

b) **Semi dwarf varieties :**

Medium tall - 4 ½ to 6 feet, Early maturing. Heads 7 - 9" in diameter. Seeds smaller, black, grey or striped. High oil content 35%. E.g. Jupiter, Pole star.

c) **Dwarf types**

2 to 4½ feet tall. Early maturing. Head size 5½ - 6½ " diameter. Small seeds, high oil content 37%.

E.g. Sunrise, Morden, Co1, Co2

Breeding objectives

1. **To develop short duration varieties suitable for dry land and irrigated conditions .**
Dryland successful in black soils only. In red soil under rainfed it is not successful.
2. **Breeding varieties with high oil content :**
Ranges 38 to 48%. Complex character yield and oil content are negatively correlated. To increase oil content the shell must be thin.
3. **Breeding for self fertile lines.**
Protoandry and self incompatibility mechanism operates in sunflower. Hence hand pollination is necessary. To avoid this self fertile lines can be evolved.
4. **Breeding for disease resistance.**
Maharastra hybrid susceptible to powdery mildew. Hence ban is there. Powdery mildew, rust, charcoal rot, *Alternaria*. Wild species like *H.hirsuta* are moderately resistance to *Alternaria*.
5. **Resistant to pests**
Heliothis , Grass hopper Jassids.

Breeding Methods :

1. **Introduction :** Morden from Canada.
2. **Mass selection:**
Ec 68414 from Russia. Co1 mass selection from Morden. Useful for characters which are highly heritable. E.g. Plant height, disease resistance.
3. **Hybridization and selection**
 - a) **Intervarietal :**

b) **Interspecific :**

Wild species of North American origin and best Soviet varieties were crossed and number of varieties were evolved.

They are resistant to *Verticillium* wilt also

4. **Mutation**

Co3 (Mutant from Co2 thro' gamma rays)

5. **Head to row and remnant seed method**

Developed by **Pustovoit** in Russia. By this method oil content is increased. In this method the following are the steps:

- a) From open pollinated type a large no (10,000 to 12,000) plants are selected based on Head size.
- b) The selected lines are analysed for oil content and high oil content lines are isolated (1000 plants).
- c) Part of the seed reserved and the part is sown in progeny rows along with check to estimate yield.
- d) Second season testing is also done. The best lines are identified.
 - a. The remnant seed of elite plants which give high yield were raised in isolation and multiplied for crossing *interse* next season.
 - b. The multiplied lines also tested for oil content and high yielding high oil content lines were raised in isolation and crossed *interse*.

6. **Population improvement**

By mass selection, recurrent selection and use of male sterile lines population can be improved and utilised for breeding.

7. **Heterosis breeding :**

Development of inbred lines and crossing them to harness heterosis was first done as early as 1920 in Russia. During 1970 cytoplasmic genic male sterility was identified in wild types and obsolete cultivars. Now this system is being extensively used for production of hybrids.

First hybrid

BSH 1

APSH – 11

A number of CGMS lines were bred by Government as well as private seed growers and are utilised now.

Male sterility can also be inducted by GA 100 ppm.

Steps

1. Development of inbreds.
2. Evaluation of inbreds for combining ability.
3. Conversion of inbreds into CGMS lines and R lines.
4. Production of hybrids.

Breeding centre:

Directorate of oil seed Research (DOR) Hyderabad.

All India coordinated sunflower improvement project (Bangalore)

Practical achievements

Varieties EC 68414, EC 68415, Mordern, Co-1, surya

Hybrids BSH-1, KBSH-1, LSH-1, APSH-1 LDMRSH-1, 3

SAFFLOWER (*Carthamus tinctories*) (2n=24)

Safflower is an important oil seed crop of India. The oil is edible but best used in industry particularly in the manufacture of paints and varnishes. It is also used for its reddish dye called carethamine extracted from florets oil is excellent source of unsaturated fatty acid. Oil content is 32 per cent of which above 72 per cent is Linoleic the factor which reduces the blood cholesterol. It belongs to the family compositeae

Origin: Africa and Afghanistan

Distribution

Afghanistan, India, Pakistan, USA, Egypt middle east in India, Maharashtra, Andhra Pradesh, Karnataka together accounts for more than 90 per cent of country's area

Progenitor *Carthamus oxycantha*
C. lunatus

Related species : The wild species *Carthamus oxycanthus* is found in many parts of Punjab. It is a dwarf bushy plant, very spiny, forming small achenes. The oil content is 15 to 16 percent

Classification of safflower :

Safflower can be grouped in to two broad categories.

1. The outer involucral bracts spinose, lanceolate mainly cultivated for oil. Flowers yellow in colour.
2. Involucral bracts moderately spined or spineless which are cultivated mostly for the dye than the spiny types. Flowers orange in colour.

Breeding objectives :

1. Breeding for high oil content :

Normal oil content is 32% of which 72% is linoleic acid, the factor which reduces blood cholesterol. Oil content is negatively correlated with yield. Wild species of *C.oxycanthus* having 28% oil were utilised in hybridization programme to increase yield and oil content but success was not achieved.

2. Breeding for non-spiny varieties with high oil content.

A very limited success was achieved in safflower

3. Breeding varieties having thin shell

Thin shelled varieties have high oil content.

4. Breeding varieties for dry land conditions.

Under dry land conditions the spiny nature will be more pronounced. How ever dry land varieties with less pronounced spines were evolved. E.g. K.I.

5. Breeding varieties resistant to pest and diseases :

Pests like Prodenia and Heliothis are important pests. The wild species *C.oxycanthus* is moderately resistant to pests. This is being utilised in breeding programme.

Breeding methods:

The breeding methods are similar to that of sunflower.

It is an oil seed crop. It belongs to the family Euphorbiaceae. Its oil is mainly used as a lubricant in industry or for medicinal purposes. It requires a warm climate.

Origin: Africa

Distribution: African countries (Egypt), China, India, Middle East etc. In India Andhra Pradesh, Karnataka, Maharashtra

Classification: Monotypic, all varieties of castor from giant perennials to short internode dwarf have the same chromosome number.

Zugovosky (1962) has described three species in the genus *Ricinus*

1. *R. communis*
2. *R. macrocarpus*
3. *R. microcarpus*

But this is not accepted by Botanists.

There are subspecies which are considered to be ecological extreme varieties i.e. polymorphic of cultivated type. They are

R. communis subsp. *persicus* (Persian)

ssp. *chinensis* (Chinese species)

ssp. *zanzibarensis* (Zanzibar)

ssp. *sanguinens* (Crimson species)

ssp. *africanus* (African)

ssp. *mexicanus* (Mexican)

Red castor varieties (Popova 1930)

Subsp. *gibsoni*

subsp. *cambogenesisis*

Breeding objectives :

1. **Long duration varieties for dry lands**
2. **Short duration high yielding varieties suitable for irrigated mixed cropping conditions**
3. **Breeding non shattering spineless varieties**
Baker variety of USA Non - Shattering.
4. **Breeding for insect resistance**
Semi looper, jassid. Hopper burn - serious in dry land varieties.
Triple bloom - TMV 5. - Triple bloom condition gives resistance.
5. **Breeding varieties with low ricinin content**

Breeding Methods:

1. Introduction

Hospet varieties.

Russian lines.

2. Selection

a) **Pureline selection**

b) **Mass selection**

3. Hybridization and selection

TMV 6. (VP 1 x RC 962)

4. Population improvement

By using recurrent selection technique.

5. Mutation breeding Aruna castor

SA2 Natural Mutant from TMV 1.

6. Heterosis breeding

GAUCH - 1

100 % pistillate lines.

Geneic male sterility

Temperature plays a major role.

GCH 4

MUSTARD (*Brassica nigra*) (2n=16, 18, 20, 22, 36)

Important oil seed crop grown in cool season sub tropics, higher elevations and winter crops. Seeds contain 40 – 45 per cent oil and 38-41 per cent protein.

Origin: India

Distribution:

China, Canada, India, Europe, Pakistan, collectively contribute 90 per cent of the global production. In India Uttar Pradesh, Rajasthan, Punjab, Assam, Bihar and West Bengal.

Progenitor: Exact progenitor is not known.

The genus *Brassica* contains more than 3000 species of which 40 are of economic importance. Cultivated *Brassica* can be broadly divided in to two distinct types viz.

Vegetable type : cabbage, cauliflower, turnip

Oil seed type - rape seed and mustard.

Taxonomy :

Harberd (1972) examined 85 species of *Brassica* and grouped species of the genus into cytodemes. These cytodemes are composed of different species with the same chromosome number and which are cross fertile and other having species with different chromosome number and cross infertile. According to him most important agricultural species are four diploids, three allopolyploids, each belong to a separate cytodeme.

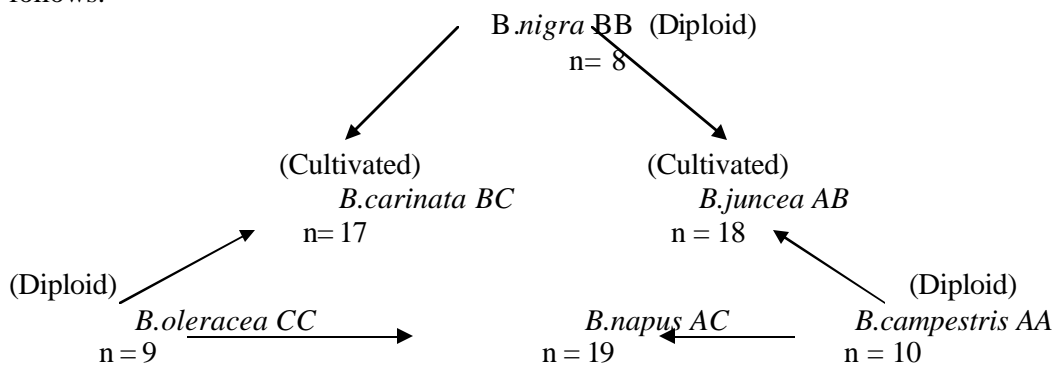
Four diploids are :

1. *B.nigra* - Black mustard
2. *B.oleracea* - Cabbage
3. *B.campestris* - Rape seed.
4. *B.tourne frotii* - Wild turnip

Three allopoly ploids

1. *B.napus* - Rape seed of Europe
2. *B.juncea* - Indian mustard
3. *B.carinata* - sthipplam mustard (veg / oil seed)

The genetical relationship between the oilseed brassicas are diagramatically represented as follows.



B.napus will cross readily with *B.campestris* but with extreme difficulty in case of *B.oleracea*.

Botanical name	2n	Economic characters
Rape seed	20	Indian Rape Seed. Self sterile in nature. Important oil seed crop of North India. 3 Cultivated types.
1. <i>Brassica campestris</i>		<i>B.campestris</i> var. Brown sarson <i>B.campestris</i> var. Yellow sarson <i>B.campestris</i> var. toria
2. <i>B.napus</i>	38	European Rape Seed. Self fertile.
Mustard		
1. <i>B.nigra</i>	16	Black mustard : Native of Eurasia. 28% fixed oil. Used as medicine pungent due to glucoside sinigrin.
2. <i>B.alba</i>	24	White mustard : Young seedling used as Salad, yellowish seed 30 % oil.
3. <i>B.juncea</i>	36	Indian mustard. RAI 35% oil. Leaves used as herb contains sinigrin.

Breeding objectives :

1. **Seed yield** : Yield is the end product of many biological processes which are under control of complex polygenic systems. An ideal plant type is having increased branch number, pods per plant, seeds per pod and seed size. Further yield increase could result from increase in biomass and harvest index. Increased biomass can result from reduced photo respiration and increased light saturated rate of photosynthesis.

2 **Early maturity** : For use in various multiple cropping sequence.

3. Resistance to abiotic factors

Frost resistance is needed to prevent yield losses. Winter hardiness is very important.

4. Resistance to biotic stress

Powdery mildew

Black leg

Sclerotinia rot, alternaria blight

mustard aphid - so far no resistance source identified.

5. Herbicide resistance : (Atrazine, simabine)

A few sources of resistance is available.

6. Shattering resistance

B.napus - highly shattering

B. juncea - tolerant. Introgressive breeding done.

7. Increased oil content and quality

High oil content 45% yellow seed varieties > oil.

For industrial purpose > Erucic acid.

Development of low erucic acid cultivars for edible purpose.

Reduced linolenic acid content is also desirable.

8. Meal quality

Meal having less Glucosinolate content.

Breeding methods :

1. Introduction - Regina from Sweeden

2. Simple selection

3. Hybridization and selection

Intervarietal

a) Bulk method

b) Pedigree method

c) single seed descent

Inter specific

4. Back cross method

5. Population improvement

Recurrent Selection, mass selection

6. Heterosis breeding

CMS lines

7. Mutation breeding

8. Tissue culture technique for production of homozygous diploids

Saline resistance screening. Induction of mutation in haploids.

9. Embryo rescue technique for inter specific crosses.

Breeding centres:

National Research Centre for Mustard (NRCM) – Bharatpur (Rajasthan)

Coordinated project at Bharathpur.

Practical Achievements

Varieties Kranti, RLM 198, Krishna, Varun, Pusa Kalyani etc.

$2n = 4x = 52$

Cotton is grown in tropical and sub-tropical regions of more than 80 countries of the world.

Origin: Central Africa

Distribution: China, USA, India, Pakistan, Egypt. In India Rajasthan, Maharashtra, M.P. Gujarat, A.P. Karnataka and Tamil Nadu.

Progenitors: *Gossypium africanum*

G. raimondii

Gossypium africanum – reached India by traders and travelers and differentiated into two species *G. herbaceum* and *G. arboreum*

Cultivated Species:

I. Asiatic cottons or old world cotton (Diploid cotton – $2n = 26$)

1. *G. arboreum* –
2. *G. herbaceum* –

II. New world cotton (Tetraploid cottons – $2n = 52$)

3. *G. hirsutum* – American / upland cotton
4. *G. barbadense* – Egyptian / sea island cotton

G. hirsutum is predominant species which contributes about 90% to the current world production. Besides cultivated species there are about 46 wild species India is the only country where all the 4 cultivated species are grown for commercial cultivation.

Breeding objectives:

1. High yield (more bolls, bigger bolls and high lint percentage)

$$\text{Lint \%} = \frac{\text{weight of fibre}}{\text{weight of cotton}}$$

$$\text{Lint index} = \frac{100 \text{ seed weight} \times \text{lint \%}}{100 - \text{lint \%}}$$

2. Early maturity
3. Superior fibre quality
4. Better plant type
5. Resistance to diseases like fusarium wilt, rots etc.,
6. Resistance to insects like boll worms, Jassids, Thrips etc.,
7. Resistance to abiotic stresses.

Breeding Procedures:

1. Introduction : **Cambodia cotton** in South India, **MCU- 1**

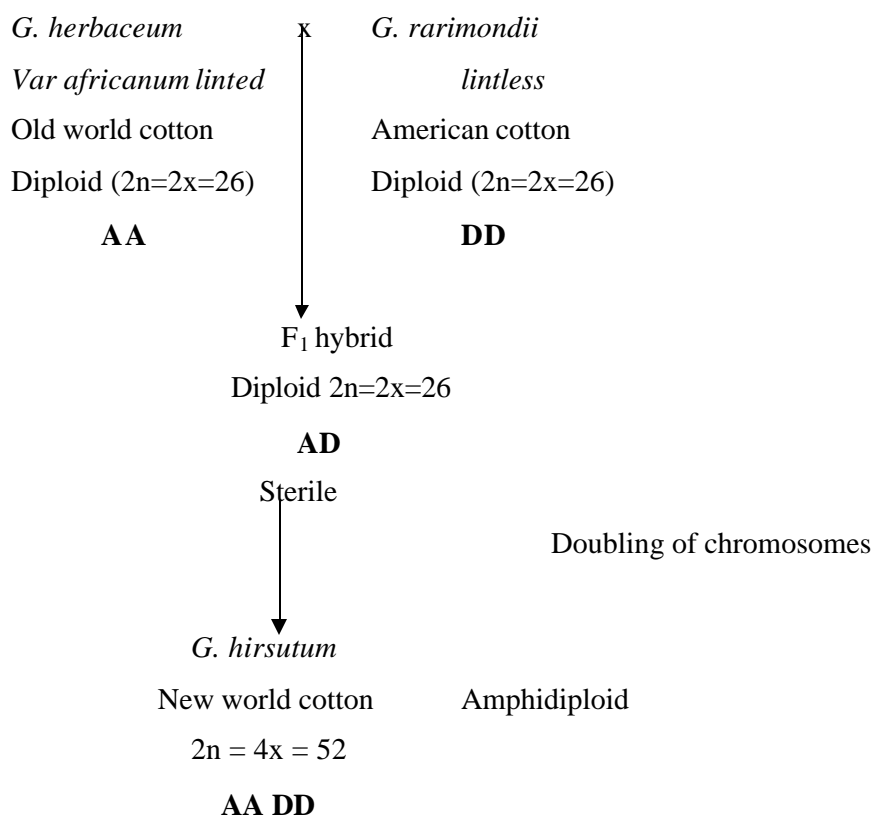
2. Selection : **K1** cotton reselection from SRT - 1

3. Hybridization and selection

- a) Inter varietal : **MCU 5** - Multiple cross derivative
MCU 6 - Multiple cross derivative
MCU 9 - (MCU 5 x MCU 8)

b) Inter specific hybridization

African linted species (*G. africanum*) reached America through pacific ocean and after crossing with American lintless wild diploid species *G. rarimondii* gave birth to tetraploid cotton. The chromosome doubling took place in nature resulting in the development of fertile amphidiploids



4. Heterosis breeding

India is the first country in the world to release first commercial hybrid in cotton. Both intraspecific and interspecific hybrids are evolved in cotton.

- a) Intraspecific : *G.hirsutum* x *G.hirsutum* Shankar (H4) cotton of Surat
(Gujarat 67 x American nectariless)
- b) Interspecific hybrids : Varalakshmi (Laxmi x SB 289E)
(*hirsutum*) x (*barbadense*)

4. Mutation breeding

MCU 7- Xray irradiated mutant of L 1143

MCU 10 - Gamma irradiated mutant of MCU 4

Indore – 2

MCU – 5

Rasmi

5. Population improvement followed in USA

- a) Recurrent selection : Pima S₁ Pima S₄ of *G.barbadense*
- b) Synthetic variety : Deltapine 15 developed at konyvllwer USA.
- c) Composite : Pima 17 of *G.barbadense*.

6. Biotechnology has helped in developing transgenic cotton with resistance to Helicoverpa. The resistant gene has been transferred from bacteria *Bascillus thuringiensis* into cotton plant by Monsanto Seed Company in U.S.A.

Breeding centers:

- International Cotton Advisory Committee (ICAC)
- Central Institute of Cotton Research (CICR) Nagpur
- All India Coordinated Cotton Improvement Project (AICCIP) Coimbatore

Varieties: MCU – 5, MCU – 10, K9, K10

Hybrids:

Interspecific hybrids	-	Varalakshmi, HB 224
Intraspecific hybrids	-	Dhanalaxmi, H4, H6
Desi cotton	-	DH 7, DH9
Male sterility based hybrids	-	Suguna, PKVHY3, ARDH- 7

JUTE

Corchorus sp (2n=14)

Tiliaceae

The genus *Corchorus* includes about 40 species. In India only 8 species occur. Two cultivated species are

C.capsularis : White jute 50 races occur in this

C.olitorius : Tossa jute 8 races occur in this.

Both the species are not crossable. Among the two *olitorius* yields more fibre/unit area. The fibre is finer, softer, more, lustrous and less rooty than *capsularis*. *Olitorius* occupies about 25% of jute area in India. One of the draw backs of **Tossa** jute is pre mature flowering if the varieties are sown earlier in March-April in early monsoon rains. The pre mature flowering leads to profuse branching and deterioration in fibre quality.

Capsularis strains are characterised by a single flush of flowering at the end of single vegetative period. Based on maturity, the varieties in *Capsularis* are divided in to

Early - Flowering in July

Medium - August

Late - September.

Breeding objectives:

1. Breeding for high yielding short duration jute varieties.

Early varieties are generally low yielders whereas late varieties are high yielders. So to combine high yield with earliness is one of the main objectives. Yield is positively correlated with plant height, basal diameter of stem, fibre-stick ratio. Higher photo synthetic capacity with increased lamina length, breadth, petiole length and leaf angle at 40° also contribute to yield.

2. Breeding for quality fibre

In jute quality is negatively, correlated with yield. The quality characters are

- a) Fibre length.
- b) Fibre strength
- c) Fibre colour
- d) Lustre
- e) Percentage and quality of retting

Environment plays a major role in quality. Alternate and fluctuating bright sunshine, humidity and temperature and rainfall at minimal level are favourable for improved quality.

Further retting in clear and slow running water gives good quality fibre. The tall and thick plants in general gives inferior fibre than that in short and thick plant.

3. Breeding for pest and disease resistant varieties

In pests, stem borer and aphids cause greater damage and in diseases *Macrophomena* is major. Though resistance sources are available in other related species, the crossability barrier prevents transfer.

4. Breeding varieties for high seed yield :

Since jute is cut for fibre at 50% flowering stage, it is essential to reserve some plants for production of seeds. The fibre obtained from seed crop will be poor in quality. Hence it is necessary to breed varieties specially for high seed production with out loosing quality characters.

5. Breeding for *olitorius* varieties having non-shattering habit coupled with non-pre flowering habit.

JRO 524

JRO 7885

Sudan green x JRO 632

Breeding Methods :

1. Germplasm building and Utilisation

Central Jute Technological Research Institute, Calcutta is maintaining the Jute collections. This shows wide range of variability thus offering a great scope for improvement by selection and hybridisation.

2. Introduction : Introduced short duration varieties are Jap green, Jap red, Jaichung sudan green.

3. Hybridization and selection

a) **Inter vareital:** Multiple crossing and selection are followed both in *olitorius* and *capsularis* improvement.

In *olitorius* improved varieties are JRO 524, JRO 7885.

In *capsularis* JRL 412, JRL 919

Since yield and quality are negatively correlated a balance must be struck in breeding for improved varieties.

b) **Inter specific cross:**

So far not successful. Attempts were made by straight cross mixed pollen method, Stigmatic paste method, self anther paste method, stigma cut method polyploidy breeding. But none of them proved successful. Difference in embryo endosperm growth is the reason

4. *Mutation breeding* : Using x rays useful jute mutants were obtained at Calcutta JRC 7447 and Rupali two varieties.

MESTA, KENAF

BIMLI JUTE, DECCAN HEMP

Hibiscus cannabinus (2n=36)

ROSELLE / JAMAICAN SORREL

Hibiscus sabdariffa (2n=36, 72)

Both the species are important jute supplements and show wide adaptability unlike jute. At present both the species are known as **Mesta**.

Place of origin :

H.cannabinus have its possible origin in Africa and *H.sabdariffa* - Asia.

Kenaf is used for making ropes, twines, fishing nets and also in the paper pulp making from kenaf stalks especially fine paper, structural boards.

H.cannabinus : **mesta**

Compared to jute mesta is of inferior in quality in respect of fineness, lusture, and colour. Mesta varieties show poor performance in spinning because the fibre is coarse, stiff, brittle and irregular in cross section mesta alone cannot be spun in jute machines unless it is mixed with jute in some proportion.

H.sabdariffa var.*altissima* (**Roselle**)

Roselle is an useful substitute to jute. It is also called as *Siamijute* two types are available.

- i. Tall non branching types cultivated for fibre.
- ii. Dwarf, bushy wild type used as green and edible calyx as pickle.

Breeding objectives :

1. Breeding of high yielding short duration mesta varieties

(Similar to Jute)

2. Breeding for quality fibre

(Similar to Jute)

3. Breeding for pest and disease resistant varieties.

Breeding Procedures:

Same as Jute.

Tomato is one of the most important vegetable crops grown throughout the world.

Origin: Peru and Mexico

Distribution: Europe, USA, India, Japan and China. In India it is grown in all the states

Other species:

<i>L. pimpinellifolium</i>	-	Fusarium wilt, early blight resistant
<i>L. peruvianum</i>	-	Leaf curl virus resistant
<i>L. cheesmanii</i>	-	Salt resistant
<i>L. hirsutum</i>	-	Fruit borer resistant
<i>L. pennellii</i>	-	Drought tolerant

Breeding objectives

1. Breeding for earliness
2. Breeding for increased fruit yield
3. Fruit quality like large round, uniform size, deep red colour and increased shelf life etc.
4. Breeding for disease resistance like (Fusarium wilt, late blight anthracnose, bacterial wilt).
5. Breeding for insect resistance (fruit borer, whitefly etc).
6. Breeding for Abiotic Stresses (cold tolerant, drought tolerant, salt tolerant, low temperature tolerant, herbicide tolerant.
7. To breed varieties for prolonged storage and transportation e. g, flavr Savr
8. To breed varieties suitable for processing

Breeding procedures:

1. **Introduction:** Seeds of improved varieties are introduced from one ecological area to another and evaluated. *E.g.*, “Marglobe”.
2. **Pureline selection:** Arka vikas, Arka saurab.
3. **Back cross method:** is commonly utilized in wide crosses or in interspecific gene transfer for resistant to diseases.
4. **Pedigree method:** has the most common method in tomato. In this method single plant selection is initiated in F₂ and is continued through successive generations till pure lines are obtained (up to F₆ generations)
5. **Single seed decent method**
6. **Heterosis breeding**
7. **Mutation breeding**

8. Biotechnological methods: Breeding for resistance to abiotic stress tomato is sensitive to low and high temp from the stage of germination to ripening. *E.g.*, Transgenic variety “Flavr Savr” was developed for long shelf life and transportation.

Practical Achievement

Varieties, Sioux, Marglobe, Pusa Ruby, Pusa early dwarf, Fire ball, Best of all Arka vikas, Arka saurab.

Chilli (*Capsicum annuum*) (2n=24)

Chillies are also called as pungent pepper grown all over the world except in colder climates. Bell peppers are constituents of many foods, add flavour, colour, vitamin C and pungency.

Origin: Tropical America

Distribution: Mainly cultivated in Brazil, Mexico, Spain South and Central America China and India. In India, Andhra Pradesh, Maharashtra, Karnataka, Tamilnadu and H.P etc.

Five major cultivated species in the Genus Capsicum

1. *Capsicum annuum*
2. *C. frutescens*
3. *C. chinense*
4. *C. pendulum*
5. *C. pubescens*.

Classification of chilli type based on fruit characters

1. *C. annuum* var *acuminatum* (Nepal pepper): Fruits long thin, pendulous and pungent
2. *C. annuum* var *longum*: Long chilli the fruit are long and stout with a very broad base
3. *C. annuum* var *grossum*: Big chilli sweet pepper, bell pepper, fruits large and bell shaped turn, bright red on ripening, little pungent, used as vegetable
4. *C. annuum* var *ceraciferma*: very small chilli fruits, and round, slightly pungent.
5. *C. fruitiscens* var *minima*: Bird pepper with white and long pedicel, fruits small and highly pungent e.g., Golconda Mirapa, Seema mirapa

Breeding objectives:

1. Earliness
2. Desirable fruit shape and size (obovate and round fruit in bell pepper and long fruits in chilli)

3. Superior fruit quality (pleasing flavour, high sugar / acid ratio, high pigment content and vitamin C in bell pepper and high capsaicin.
4. Resistance to diseases (fruit rot, Cercospora leaf spot, powdery mildew, bacterial leaf spot, phytophthora root rot, root knot, common TMV)
5. Resistance to insects (thrips, mite, aphid, fruit borer)
6. Resistance or tolerance to abiotic stress (heat, water stress, salinity etc).

Breeding methods:

1. **Pure line selection:** This method is applicable to land races or local cultivars being grown by farmers. *e.g.*, G₁, K₁, Co₁, Sindhu.
2. **Pedigree method:** involves selection of superior plants following hybridization between superior cultivars. *e.g.*, Andhra jyothi, Pusa jwala
3. **Backcross method:** Used to transfer single gene or few genes from primitive cultivars or wild forms to leading cultivars.
4. **Heterosis breeding:** F₁ hybrids are popular in USA and Europe and gaining popularity in India after the initiation. The first hybrid in India was **Bharat** developed by Indo American hybrid seed company, Bangalore (1973) followed by several companies
5. **Mutation breeding:** Found to be effective and efficient breeding tool in pepper.
6. **Biotechnological methods:**

Brinjal / Egg Plant (*Solanum melongena*) (2n=24)

Brinjal is an important commercial vegetable crop grown in India.

Origin: Indo-Burma

Distribution: India, Japan, Indonesia, China, Bulgaria, Italy, France, USA and African countries. In India all the states grow brinjal

Wild species:

- Solanum torvum*
- S. nigrum*
- S. indicum*
- S. mamosum*

Breeding objectives:

1. High yield
2. Earliness
3. Fruit shape, size and colour as per consumer's preference
4. Low proportion of seed
5. Soft flesh
6. Lower Olanine content
7. Upright study plant free from lodging.
8. Resistance to diseases like bacterial wilt, blights.
9. Resistance to insects like shoot and fruit borer, jassids etc.

Breeding methods

1. **Introduction:** This method may be useful in other countries but not to India.
2. **Pure line selection:** *e.g.*, Pusa Purple long, Co.1
3. **Pedigree selection:** Many varieties have been developed through hybridization and subsequent pedigree selection. *e.g.*, Pusa Kranti
4. **Heterosis breeding:** Many F₁ hybrids have been developed and released for commercial cultivation. *e.g.*, Arka Navneet
5. **Hybridization for resistance breeding:** Resistance is not available in the cultivated varieties. Wild varieties like *S. incanum*, *S. anthocarpum* are reported to be resistant and used in hybridization programme. However the inferior quality of the fruits of wild species associated with resistance are often expressed in the hybrid progenies.

6. Backcrossing: is normally follow to transfer genes conferring resistance to disease like bacterial wilt resistance which has been shown to be under a single dominant gene.

7. Mutation Breeding:

8. Biotechnological Methods: *e.g.* Bt. Brinjal

Varieties: Pusa purple long
Pusa kranti
Arka navneet

Lecture No: 16

OKRA Lady's finger (*Abelmoschus esculentus*) (2n=130)

Okra is a common vegetable crop grown in warmer climate,

Origin: India

Distribution: Asia, Europe, Africa and United States and Brazil. In India it is grown in Gujarat, Maharashtra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Haryana and Punjab.

Species of *Abelmoschus*

Abelmoschus angulosus

A. crinitus

A. ficulneus

Breeding objectives:

1. High pod yield
2. Dark green, tender, thin, medium long smooth with 4-5 ridged pods
3. Pods free from conspicuous hairs
4. Early and prolonged harvest
5. Short plant with more number of nodes, short internodes
6. Optimum seed setting ability
7. Pods suitable for processing industry and export market.
8. Resistance to diseases (yellow vein mosaic virus, (YVMV) Fusarium wilt)
9. Resistance to insects (fruit and shoot borer, jassids and white fly)
10. Tolerance to Abiotic stresses.

Breeding methods

1. **Introduction:** A cultivar from Africa (Ghana) known as *A. manihot* sp. manihot introduced into India has been successfully used as a source of resistance to YVMV.
2. **Pure line selection**
3. **Pedigree Method**
4. **Mutation Breeding**
5. **Heterosis breeding**

Varieties: Pusa makhmali, Pusa swani, Co-1 etc.

Cucumber (*Cucumis sativus*) (2n=14)

Cucumber is one of the Asiatic species and member of the cucurbitaceae which has 90 genera and 750 species.

Origin: India – It is considered as home of cucumber

Distribution: China, USA, Africa, Europe. In India it is grown in north and south and lower as well as higher hills

Breeding Objectives

1. Early fruiting
2. High female to male sex ratio
3. Attractive green or dark green fruits with smooth surface and without prominent spines or prickles.
4. Uniform long cylindrical shape without crook neck
5. Fruits free from carpel separation without hollow spots
6. Fruits free from bitterness
7. Less seeds at edible maturity
8. Resistance to diseases (powdery mildew, downy mildew, anthranose, cucumber mosaic virus)
9. Resistance to insect pests
10. Resistance to abiotic stresses.

Genetics of sex

Different sex types in cucumber

- | | | |
|-----------------------|---|----------------------------------|
| a) Monoecious plants | - | Staminate and pistillate flowers |
| b) Androecious plants | - | Only staminate flowers |
| c) Gynoecious plants | - | Only pistillate flowers |

- d) Hermaphrodite plants - Only hermaphrodite flowers
- e) Andromonocious plants - Staminate and hermaphrodite flowers.

Chemical regulation of sex expression

Increasing female tendency

- (i) Auxin
- (ii) Ethylene
- (iii) Acetylene
- (iv) 2-chloroethylphosphonic acid

Increasing male flower promotion

- (i) GA₃
- (ii) GA₄
- (iii) GA₇
- (iv) Silver nitrate
- (v) Silver thiosulfate

Breeding Methods:

1. **Pedigree method:** This includes selection of single plant segregates in segregating generations F₂, F₃ etc. derived from crosses between desirable parents
2. **Backcross method:** This is useful for transferring characters governed by single genes, e.g., disease resistance or quality traits from donor lines to more stable recurrent parents.
3. **Use of sex inheritance and chemicals in breeding methods:** In this system gynoecious lines are treated with AgNO₃ to stimulate production of staminate flowers and such lines are allowed inter pollination to build up a source population with wide genetic variation. The gynoecious lines treated with AgNO₃ pollinate a mixture of same lines which have been sown about 2-3 weeks later and rouged from any staminate flowers segregates. A gynoecious population emerges from the harvested seed and serves as a gene pool for carrying out further selection of desired genotypes and lines.
4. **Population improvement and extraction of inbred lines:** This method is based on recurrent selection and aims at long term gain for the characters having low to moderate heritability.
5. **Hybridization:** Hybrid varieties of cucumber are becoming predominant day by day. Their number is continuously increasing in India also
6. **Biotechnology methods:**
 - a) Introduction of somaclonal variation and its application in breeding
 - b) *In-vitro* mutagenesis on haploids and diploids.

- c) *In-vitro* selections for disease resistance and cold resistance etc.
- d) *In-vitro* fertilization
- e) Production of transgenic plants
- f) Embryo rescue technique

Varieties:

Japanese long green

Poinsette

Pusa Sanyog

Lecture No: 17

CHRYSANTHEMUM (*Chrysanthemum moniliformin*) (2n=36)

Florist's chrysanthemum (*Chrysanthemum morifolium*, Ramat) ranks second among commercial flowers in the world. In India it occupies third position, with jasmine and rose standing first and second. It is grown in wide range of environment, suitable for various purposes e.g. pot culture, field culture, for garland making or cut flowers or simply bedding purpose, long post harvest life, predictable response to environment and amenability to different attractive training methods or styles. However, the most important of all factors is the immense number and diversity of shape, size and colour displayed by its cultivars. Breeding has played a pivotal role in augmenting this diversity during the long history of its evolution.

Origin: China

Distribution: China, Japan, France, USA, Australia, Europe, and Asia. In India all the states.

Species of chrysanthemum

Genus *Chrysanthemum* belongs to the family Compositae which is second largest family among flowering plants comprising about 20,000 species, largest being *Orchidaceae*.

1. *Chrysanthemum morifolium*
2. *C. sinense*
3. *C. indicum*
4. *C. japonicum*
5. *C. arnatum*
6. *C. satsumense*
7. *C. boreale*

Indigenous species

C. indicum– Native to India, Florist chrysanthemum

Wild species

1. *C. stilliszakai*, *C. rkhtsria*, *C. atkinsoni* and *C. leucanthemum* as wild species in the Indo-Tibetan border.

Introduced species / Exotic species

1. *C. caronanium* (Garland chrysanthemum)
2. *C. carinatum* (Tricolour chrysanthemum)
3. *C. rubellum* (for hardiness)
4. *C. sagetum* (Corn marigold (or) pot plant)
5. *C. boreale* (Evolution of florif, chrysanthemum)
6. *C. cinerarifolium* (Used as insecticide)
7. *C. coccineum* (Perennial, seed propagated)
8. *C. manifoldium* (Florist chrysanthemum)

Breeding objectives

1. Cultivars with low temperature requirement
2. Rapid growth habit with small to medium size of leaves to enable close planting.
3. Pollen – free cultivars have been reported to be desirable as pollen spoils the appearance and also induces allergy reactions during handling.
4. Uniform response to environment,
5. Long storage life
6. Compact and dwarf
7. Easy to root cutting
8. Cultivars with no vernalisation requirement are preferred for year around production.

Breeding Methods:

1. Introduction: Scrutiny of names of cultivars grown in this part of the country show their Australian, English, French, Japanese or American origin in addition to those originating within the country. In South India on the other hand only a few yellow or white small coloured cultivars are grown for use as loose flowers which are probably of Indian origin. Introduction of exhibition types seems to have started in East India, particularly in Calcutta and Sikkim during British period. Most introductions till two decades back were done by resourceful individuals or nurserymen in these two places or through some embassies in New Delhi.

Names of some well known cultivars grown in India have been given below along with the name of country wherefrom they were introduced into this country or where it originated:

Country from which introduced / or originated	Name of cultivar
Australia	'J.S. Lloyd', 'Louisa Pockette', 'William Turner' and 'T.W. Pockette'
France	'Gloria Deo', 'S.L. Andre Raffaud', and 'Sancho'
Japan	'Ajina Purple', 'Kenroku Kangiku', 'Kiku Biori', 'Taiho Tozan', 'Tokyo', 'Shin Mei Getsu', 'Senkyo Emaki' and 'Otome Zakura'.
New Zealand	'Gusman Red', 'Lcicles', 'Jane Sharpe', 'Orange Fair Lady', and 'Nancy Ferneaux'.
United Kingdom	'Alfred Wilson', 'Alfred Simpson', 'Balcombe Perfection', 'Beatrice May', 'May Shoesmith', 'Maurice White', 'Leviathan', 'Pink Cloud', 'Princess Anne' and 'Woolman Centruy'.
United States	'Cassa Grande', 'Mountaineer', 'Nob Hill', 'Snow Ball, Potomac' and 'Peacock'.

The realization of this fact led to introduction of 80 cultivars from Japan in 1972 at National Botanic Gardens, Lucknow (Kher, 1977). These introduced cultivars formed the basis for filling the gaps mentioned above by hybridization or mutation breeding at the institute.

2. Selection:

Most of the outstanding spray and loose flower type cultivars evolved in India, namely Birbal Sahni, Apsara, Kundou, Jaya, Shard Singer, Co1, Co2. The drawback of this method include unknown parentage, need for raising a very large number of seedling population. Failure of the improved double long and tabular ray florets to set seeds etc. Single plant selection method is followed.

3. Hybridization

The aim of hybridization is improvement which assumes different meanings depending-upon the purpose for which a new cultivar is intended. A cultivar suitable for pot-culture may not be fit for growing as cut-flower. Similarly, a cultivar may be suitable for cut-flower purpose but not for garland making. The desirable characters in cultivars intended for pot-culture, cut-flower and garland purpose have been enumerated for the benefit of breeders at the 5th workshop of the All India Coordinated Floriculture improvement project held in New Delhi in 1983 (Report of AICFIP, 1982-83), as given below.

Parameters for good pot variety: Profuse branching, uniform spread of plant, dwarfness, compactness, simultaneous blooming to give carpet like appearance, attractive colour retention, storage framework to withstand bloom weight and healthy leaves.

Parameters for good cut flower variety: Attractive colour, normal spray with high central bloom, long erect stem, quick growth from late stem cuttings, easy to root cuttings, uniform bloom opening with 5-6 blooms per 32.ray, tough florets, long vase life and healthy leaves.

Parameters for good garland variety: Yellow or white colour of bloom, diameter of bloom about 5cms, fluffy blooms, disc absent or not visible, good quality of recovery from pressure, high yield (15 m. tons/h or 150 gms. per plant), good colour retention in the field, storage life more than 3 days, long blooming season, smooth bloom-periphery, profuse branching and sweet scented blooms are preferred.

4. Mutation breeding:

Pioneering work on induction of somatic mutation in chrysanthemum by using a Co 60 radioactive gamma irradiation source has been done at N.B.R.I., Lucknow, resulting in the development of about 40 mutant cultivars strikingly different from their parents. The main advantage of this method lies in changing one or few characters of an otherwise outstanding cultivar without altering the remaining, and often unique, part of the genotype.

Examples:

Basanti, Pusa centenary, pusa anmol, usha kiran

Sports

A good number of outstanding chrysanthemum cultivars in the world have arisen a natural mutants commonly called sports. examples:

S. No.	Original cultivar	Sport
1.	Mahatma Gandhi	Kasturba Gandhi
2.	Snow Ball	Sonar Banla Bangla
3.	Sharad Shobha	sharada

MARI GOLD (*Tagetes erecta* L.). (2n = 24)

Introduction

Marigold (*Tagetes erecta* L., Asteraceae) is grown as an ornamental crop for loose flowers and as a landscape plant, as well as source of pigment for poultry feed. Flowers are sold in the market as loose or after making into garlands. Other than loose flowers, it can also be used as cut flowers. Marigold especially is used for beautification and also in landscape plans due to its variable height and colour of flowers. It is highly suitable as a bedding plant, in a herbaceous border and is also ideal for newly planted shrubbery to provide colour and fill spaces. French marigold is ideal for rockeries, edging, hanging baskets and window boxes.

Origin: Mexico

Distribution: USA, Europe India etc. In India Maharashtra, West Bengal, Karnataka, Tamil Nadu and Andhra Pradesh.

Species, Types and Cultivars

Species: There are about 33 species of the genus *Tagetes*. The characters of important species (Bailey, 1963) are given below:

***Tagetes erecta* (African marigold):** The plant is hardy, annual about 90 cm tall, erect and branched. Leaves are pinnately divided and leaflets are lanceolate and serrated. Flowers are single to fully double and large sized with globular heads. The florets are either 2lipped or quilled. Flower colour varies from lemon yellow to yellow, golden yellow or orange.

***Tagetes patula* (French marigold):** A hardy annual, about 30 cm tall, forming a bushy plant. Foliage is dark green with reddish stem. Leaves are pinnately divided and leaflets are linear lanceolate and serrated. Flowers are small, either single or double, borne on proportionately long peduncles. The flower colour varies from yellow to mahogany-red.

***Tagetes tenuifolia* (Syn. *Tagetes signata*):** It is an annual with a branching habit. Leaves are pinnately divided into 12 oblong, linear, sharply serrated segments. Flowers have 5 rays, yellow, roundish and obovate. *Tagetes signata* cv. *Pumila* is a dwarf, bushy and grows less than 30 cm. Flowers are bright yellow and small but numerous.

***Tagetes lucida* (Sweet scented marigold):** The plants of this species are tender, perennial. Leaves are sessile, small and lanceolate. Flowers usually are 2-3 rayed, produced in dense, terminal corymbs. The flowers have much more agreeable odour than other species.

***Tagetes lacra*:** It was discovered in California. The plant grows upto 120-150 cm in height and flowers profusely. Flowers are yellow in colour.

***Tagetes lemmonii*:** It is a shrubby plant, grows up to 60-70 cm. Leaves are slender, opposite; leaflets about 2-3 cm long. Flowers are showy and 2-3 cm in diameter.

The other species grown in gardens are *Tagetes minuta*, *Tagetes pusilla* and *Tagetes corymbosa*. In India, however, the cultivation of *Tagetes erecta* and *Tagetes patula* dominates.

Breeding objective:

1. Compact and dwarf growth habit
2. Uniform response to environment
3. More flower yield.
4. Free from diseases and pests

Breeding Methods:

1. Introduction :

A wide array of germplasm was collected At N.B.R.I., Lucknow and Punjab Agricultural University, Ludhiana from exotic sources. In African marigold, 5 varieties, namely Alaska, Doubleloon, Fire Glow, Golden Jubilee and Yellow Fluffy were recommended for loose – flower production, whereas eight varieties viz., Geradine, Golden Climax Giant, Orange Fluffy, Orange Mums, Sovereign, Sun Giants, Super Chief Double and Yellow Climax were found suitable for cut flower purpose at N.B.R.I. Lucknow, PAU, Ludhiana recommended 2 varieties like Giant Double African Orange and Climax of African marigold and 3 varieties Rusty Red, Butter Scotch and Red Brocade of French marigold for loose flower production and 3 varieties, namely, Valencia, Sussana and Tetraploid for bedding purpose.

2. Selection: A large number of varieties of African marigold were collected at IARI, New Delhi. Since, most of the varieties were in heterozygous condition, single plant selections were made in the basis of desirable attributes. As a result of these efforts, few promising selections have been developed, which are in pre-release stage.

3. Hybridization: Hybridization between distantly related types is the most effective and commonly employed tool to induce variation so as to improve the existing cultivars and evolve new, high yielding and better quality of genotypes. Different principles of breeding have successfully been used in marigold, which resulted in new cultivars and present day F₁ hybrids.

Inter-Varietal Hybridization: In well-planned breeding studies, Singh and Swamp (1972) observed appreciable heterosis. Attempts were made to develop F₁ hybrids in marigold because F₁ hybrids are considerably uniform and capable of producing large blooms with high yield potential. In addition, they are characterized by their semi-tall nature with excellent large full double flowers. For the last 20 years, F₁ hybrid seeds of *Tagetes erecta* are available. Climax was the first F₁ hybrid to be released. A number of other F₂ hybrids are also available in the market.

InterSpecific Hybridization: The inter-specific hybridization between *Tagetes erecta* x *Tagetes tenuifolia* and *Tagetes erecta* x *Tagetes jaliscensis* has been done by Towner (1961, 1962). Recently, inter-specific hybridization between *Tagetes erecta* x *Tagetes patula* has been carried out which finally led to evolution of Red and Gold hybrids. These hybrids are dwarf-like French marigolds but produce bigger flowers like that of African marigolds in large number.

4. Pedigree Breeding: A large number of single crosses were made involving genetically diverse inbred lines / open pollinated varieties. Selections started from F₂ generation onwards till they attained homozygosity. As a result of these studies, a few very promising improved lines have been developed, which are in pre-release stage.

5. Polyploidy: Studies on the nature and the limit of polyploidy in marigolds were carried out at N.B.R.I., Lucknow. Interspecific crosses between *T. erecta* (2n=24) and *T. patula* (2n=48) were attempted and interspecific triploid hybrids (2n=36) were produced. It was inferred that hexaploidy may not be successful in marigold as the highest ploidy level in about 50% of the species of the genus *Tagetes* is tetraploidy.

6. Male sterility: Male sterility in marigold is of two kinds: (1) apetalous, and (2) double-flowered. Apetalous sterility is preferred to full double flowers because the latter type is prone to break down and it gives rise to a few disc florets at later stages which may be due to either age of plants or environmental factors. However, apetalous flowers are less attractive to pollinating insects. Male sterility is governed by a recessive gene and is incorporated into the seed parent. It is maintained by crossing the heterozygous plants with the sterile ones.

African marigold (hybrid seed production)

In African marigold, genic male sterility system is being used for F₁ hybrid seed production. There are two types of male sterility in marigold, that is, apetalous form (with no stamens) and true double form (produces no anthers in the disc florets). Apetalous type of male sterility has greater liability and is being used for the production of F₁ hybrid seeds on a commercial scale in the U.S.A., U.K., Holland, France, etc. The apetalous type of male sterility is controlled by recessive alleles. Thus, a male sterile plant has a genetic constitution of ms (homozygous recessive), while male fertile plants may be of Ms Ms or Ms ms genotypes. The heterozygote ms ms will segregate to give 1 Ms Ms:2 Ms Ms ms:1 ms ms, the usual ratio for a single gene, but both homozygous Ms Ms and ms ms) will, of course, breed true (except that the latter will produce no pollen to allow to breed further).

Therefore, for use as a parent in F₁ hybrid production, the male sterile line is perpetuated by back-crosses of double recessive (ms ms) male sterile by heterozygous male fertile (Ms ms) maintainer. In the subsequent generations, 50 per cent of the progeny will be male fertile Ms ms,

while the other 50 per cent will be male sterile $ms\ ms$. Male sterility phenomenon can be incorporated into standard varieties through five or six generations of back-crossing.

For the actual production of F_1 hybrid seed in the field, the back cross generation is inter-planted with the other parental lines (which is a normal male fertile inbred) and heterozygous male fertiles occurring in back-cross generation should be removed as soon as identification is possible, thus leaving male sterile plants only. The male sterile plants can be identified in the early stage by the shape of sunflower buds as these plants have pitcher type of flower buds, whereas the male fertile plants have normal flower buds.

To summarise, the mechanisms of using genetic male sterility for F_1 hybrid seed production under open field conditions require (1) a normal fully fertile inbred line and (2) an inbred line which is maintained by crossing together known heterozygous ($M_s\ m_s$) and male sterile ($m_s\ m_s$) plants. Seeds should always be harvested from $m_s\ m_s$ plants. The cross of $m_s\ m_s \times M_s\ m_s$ should be repeated in every generation, as it will segregate in 1 fertile 1 Sterile ratio. A ratio of male sterile to pollinating fertile line is dependent on the size of hybrid block, but a ratio of 3 male sterile line 1 male fertile has proved to be the optimum.

Lecture No: 18

ROSE (*Rosa indica*) $2n = 14$

The rose is the world's most favourite and popular romantic flower. History and symbolism, colour and fragrance, and sheer elegance of form all combine to give the rose its pre-eminent position. Even the thorns have romantic associations. The rose is one of the important crops grown for its cut flowers. It belongs to the family Rosaceae and all species of this flower, with minor exceptions, belong to the genus *Rosa*. The genus *Rosa* comprises 120 species and there are more than 30,000 cultivars which are extensively distributed in the temperate and subtropical parts of both the hemispheres.

All the present day remarkable changes in growth habit, flowering and flower shape, form, colour, size and fragrance of modern roses have been due to chance crossing, selective crossing, bud sports, induced mutations, molecular breeding and selections.

Origin: Europe

Distribution: Extensively grown in colder parts, Canada, America, Russia and Japan. In India extensively grown in all northern states. To a little extent in southern states.

Species / Cultivars

R. glantheria syn. *R. rubiginosa*: Sweet Brier

R. foetida syn. *R. lutea*, *R. eglanteria*: Austrian Briar rose
R. gallica syn. *R. rubra*: French rose
R. gigantean syn. *R. odorata* var. *gigantean*: Manipur Tea rose
R. hugonis: Father Hugo rose, Golden rose of China
R. kordesii (*R. rugosa* x *R. Wichuraiana*)
R. laevigate: Cherokee rose
R. moschata : Muse rose
R. multiflora

Breeding objectives:

1. Continuous blooming – free flowering or recurrent blooming
2. Brilliant and fragrant flower
3. Uniform flower shape, form and size
4. Growth should be vigorous – Improved appearance of plant
5. Floriferous nature
6. Winter hardiness
7. Evergreen plant type and foliage attractiveness
8. Long shelf life with less petal shedding.
9. Resistance to pests and diseases (powdery mildew, black spot, scale insect)
10. Thornless nature
11. Developing blue and purple coloured varieties as they are in great demand.
12. Heat tolerance *i.e.* breeding varieties for tropical conditions.

Breeding methods:

1. Natural crossing and selection

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

2. Hybridization

Cross-breeding is one of the most powerful classical methods for developing new varieties. Artificial crossing is necessary to develop varieties with desirable selection of parents.

Although a good amount of present day cultivars have arisen through hybridization, no systematic work has been done by geneticists to explore the scientific basis of rose breeding. The abnormalities, poor seed set, low seed germination, etc. These are the major constraints in rose breeding in obtaining the desired results. Our modern hybrids carry the genes of many ancestors and it is practically impossible to predict the result of any specific cross. The tip to hybridizing is to find good seed and pollen parents that will donate their characteristics. Most hybridizers have a special goal and are looking for a specific type of rose or characteristics. The principal method of creating new rose varieties is growing progenies from seeds of planned crosses and making selections from them. The larger the population of seedlings, the greater is the chance of finding the desirable combinations of characters one seeks. It is very easy to produce a new rose from seedlings but very difficult to produce a really good new rose. It is very important to identify parent varieties that appear to have the best potential for contributing the characters which one seeks to combine in the hybrid offspring. Another consideration is to select the parents for crossing on the basis of their fertility status, which varies with the cultivars.

With the advancement of knowledge, rose breeding is becoming more and more scientific. However, the experience gained through numerous studies conducted worldwide suggested the possibility of directed breeding for desired objectives.

Ex: Anurag, Chandrama and Chandrika

Breeding for disease resistance

Black spot is a major foliar disease of roses that causes severe losses to commercial and home gardens. The breeding lines 'Spotless gold' (Floribunda, F₃ selection: Goldlocks x *Rosa rugosa*), 'Spotless Yellow' (Floribunda, F₃ selection; Goldlocks x *Rosa rugosa*) and 'Spotless Pink' (Floribunda, F₃ selection: Chic x *Rosa rugosa*) have been released for use as resistant parents in breeding programmes. Some resistant varieties have been developed through complex hybridization, like 'A Mackenzie', 'Charles Albart', 'Champlan', 'William Baffin', etc. resistance to black spot and Mildew.

Breeding for Better Red Rose

Cyanidin imparts red colour to flower petals. But two more pigments have been identified, 'Chrysanthemins' and 'Paeonins' which produce a red much more brilliant and much less prone to fade than cyanidin. The breeder may select varieties containing large quantities of these pigments in a breeding programme to produce the perfect red rose. Climbing rose varieties 'Francois juraville', 'Dorothy Perkins' and sports have been an important source of variation because of the ease with which they can be isolated and vegetatively propagated. The rate of

spontaneous mutation in nature is very slow, but it has played an important role in the evolution of many new cultivars of roses.

One most important bud sport is the climbing habit in Hybrid Teas. Some more important climbing bud sports are available in 'Crimson Glory' and "Mrs. Sam McGredy, Climbing Blue Moon, Climbing Cinderella.

3. Induced mutation:

Mutation breeding has now become one of the most powerful complementary methods for developing new varieties. The mutation breeding technique has been successfully utilized for the development of many new ornamental varieties. This technique has also been successfully used in roses for the development of new varieties. More than 30 induced mutant rose varieties have been commercialized. Physical mutagens (radiations) like x-ray, gamma ray, different chemicals (chemical mutagen) like ethyl methane sulphonate (EMS), methyl methane sulphonate (MMS), N-nitroso-Nmethyl Urethane, sodium azide and colchicines have been widely used for evolving new cultivars.

4. Polyploidy Breeding:

Among the horticultural classes, early miniatures were diploid but some later ones are tetraploids. Hybrid Teas and Floribundas are generally tetraploids but occasionally triploids. An example for evolution of tetraploid variety is "Eva". The cultivar 'Eva' had been subsequently utilized to develop the modern roses 'Fashion', 'Bonn', 'Berlin', etc., Artificially, polyploidy has been induced through colchicines treatments of buds.

Molecular Breeding

Traditional breeding continues to be the principal source of new cultivars and varieties for the ornamental market. Its success is evident in the huge array of products available to the consumer. In spite of its success, traditional breeding has several limitations, the most obvious being the limited gene pool contained within a species. For example, it is not possible to breed for a blue rose or chrysanthemum or marigold because the gene(s) required for this colour is/are not present in the gene pools of these plants.

Molecular biology is expected to overcome the above mentioned breeding problems

Genes conferring desirable traits, such as blue pigmentation, potentially can be transferred to species where these genes previously did not exist. Recent advances in recombinant DNA and allied techniques may permit additional opportunities for plant improvement. In recent years, several centres have started work on genetic engineering, using recombinant DNA technology, which offers unique possibilities of direct manipulation of specific – plant gene(s).

One of the most exciting developments of molecular biology is the synthesis of the blue gene with special reference to synthesis of the blue rose. Rose cannot synthesis the blue pigment delphinidin due to a deficiency of the enzyme dihydrokaempferal 3 and 5 hydrolyze. Calgens pacific company at Melbourne. Suntory limited Japan and Petunia genetics group at the national del 1 Recherche Agronomique France have jointly successfully isolated the blue gene using petunia.

They have standardized the technique to transfer the blue gene to rose.

- Genetic engineering in used to enhance fragrance to a variety of plants.
- Post harvest longevity by genetic engineering strategies to control senescence (phytohormone ethylene).

GERBERA (*Gerbera jamesonii*)

Gerbera commonly known as Transvaal Daisy, Barbeton Daisy or African daisy. It is highly suitable for beds, borders pots and rock gardens. The wide range of colours and the attractive shape of flowers suit very well in flower arrangements. The cur blooms have long vase life.

The breeding of gerbera started in 1887 when R.I. Lynch crossed *Gerbera jamesonii* and *Gerbera viridifolia*. The hybrid was named *Gerbera contabrigensis* known today also as *Gerbera hybrida*. Majority of the present commercial cultivated varieties originated from crossing the progenies of these two species.

Breeding Objectives:

Taking into account the importance of Gerbera as a cut flower and for garden purposes the following objectives are suggested in breeding of Gerbera.

1. Uniformity and compactness of growth of plants
2. Earliness in flowering
3. More number of flowers / plant
4. Development of double coloured flowers
5. Uniform long and sturdy stalks
6. Yield, period of flowering
7. Vase life and
8. Resistance to pests and diseases.

Breeding Methods:

Since Gerbera can be propagated both sexually (seeds) and asexually (Suckers). The breeding methods suitable for both types can be followed they are

- 1. Clonal Selection**
- 2. Synthetic variety**
- 3. Polyploidy**

4. Hybridization:

Numerous cultivars of Gerbera that are known today have been developed through hybridization. For breeding purposes the flowers can be divided into two groups based on ray floret width namely florets narrower than 5 to 55 mm and those wider than 55 mm. Breeding for flowers with fine rays is done within the first group. For wide rays crossing is done within the second group (or) hybridization between the second group and the less narrow types of the first group.

5. Mutation Breeding:

X-ray irradiation (20 GY) was tried on plants propagated *in-vitro*. Flower shape and size and foliage characters were affected but changes in flower colour were rare. Ethyl methyl sulphate (EMS) was better than sodium hydrazide in inducing gene mutation.

Lecture No: 19

Mango (*Mangifera indica*) (2n=40)

Origin: Tropical Himalayas

Mango is described as king of all fruits according to Decandole Mango is in cultivation for the last 4000 years supposed to be originated from Himalayas in the areas of Burma, China and Malayan Peninsula. The number of varieties grown in India are about one thousand. Every variety has its own distinct taste, flavour, pulp consistency and yield potential.

Distribution:

It is extensively cultivated in India, Indo-China warm parts of Australia, Philippines, Pacific Islands, Himalayas. In India Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Maharashtra, West Bengal and Gujarat.

Breeding objectives

All the commercial varieties have some demerits, which need improvement by breeding. Qualities of an ideal mango variety have been outlined as follows:

1. Dwarf tree growth habit,
2. Precocity and regularity in bearing,
3. Attractive and good quality fruits
4. High productivity and resistance to major diseases and pests
5. Good transport and processing qualities
6. Varieties suitable for export market

Allied species in Mango:

<i>M. sylvatica</i>	- India, Burma
<i>M. caloneura</i>	- Burma
<i>M. pentandra</i>	- Burma
<i>M. odorata</i>	- Malaya
<i>M. zeylanica</i>	- Ceylon
<i>M. cochinchinensis</i>	- Cochinchina
<i>M. monandra</i>	- Philippines

- M. andamanica* - Andaman Islands
M. macrocarpa – Malaya
M. foetida - Malaya

Breeding methods

1. Introduction
2. Selection
3. Hybridization
4. Mutation breeding

1. Introduction:

Name of the variety	Country from where introduced
Sweet	Thailand
Sensation	USA
Tomy Atkins	Brazil
Early Gold	USA

2. Selection:

a. Chance seedlings:

Mango was previously propagated through seeds and hence the old orchards in India were mostly of seedling origin. Some seedling progenies gave rise to varieties such as 'Chinnaswarnarekha' and 'Mundappa'. The popular, salt tolerant rootstock (13-1) was identified in Israel by this technique.

b. Clonal selection:

- Extensive survey of Dashehari orchards around Maliabad in Uttar Pradesh has resulted in the isolation of best clone *viz* Dashehari -51 with higher yield and regular bearer.

3. Hybridization:

Since a large number of male and perfect flowers are borne on a mango panicle, it requires a special crossing technique.

The panicle should be bagged with a muslin bag (60 cm x 30cm) fully stretched and fixed with two rings and a rod made of spliced bamboo. A piece of thick iron wire can also be made into a good frame for stretching the muslin bag

Staminate flowers of the selected panicle to be used as female parent should be removed daily before dehiscence. Panicles of the variety selected as male parent should also be bagged before their flowers begin to open. freshly dehisced male flowers should be carried in a small

petridish lined with a filter paper and covered with another petridish to protect the flower to avoid contamination with foreign pollen carried by insects.

The conventional method of pollination is time consuming, cost intensive and inefficient because of tallness and difficult to handle trees poor fruit set. 'Caging technique' for crossing, developed at IARI following the discovery of self incompatibility in Dashehari, Langra, Chausa and Bombay Green, involves planting of grafted plants of the self incompatible varieties along with those of male parents enclosed in an insect proof cage and allowing pollination by freshly reared house flies and thus getting away with the tedious hand pollination.

In hybridization on mango, 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. Few of these such as 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. The average size Sindhu fruits has been reported to be 215 g.

It may be observed that the parents used in hybridization programme were of the best commercial varieties, superior in most of the traits but lacking in few qualities, which may be available in the other parents. Though in some cases (e.g. the hybrids at Sangareddy), the parents were the same the hybrids were differently named, due to the heterozygous nature of parents resulting in heterogeneous hybrid population.

The constraints encountered in mango hybridization are:

1. High fruit drop: In early stages, many young fruits drop after pollination and fertilization.
2. Only one seedling can be obtained from one fruit (since the varieties are monoembryonic).
3. The heterozygous nature and cross fertilization makes it difficult to predict the qualities of the hybrids.
4. Complex nature of panicle and flower and excessive fruit drop.
5. Large area of land is required for hybrid seedlings.
6. Polyembryony - Difficulty in accurately identifying the zygotic seedling: polyembryonic varieties in Israel show that weight of zygotic seedling is higher than the nucellar seedling. Use of polymorphic enzyme systems (isozyme) has been used to identify zygotic seedling since the nucellar seedlings have the same isozyme alleles as in the maternal parent.

7. Longjuvenile phase - Mango hybrids usually take 4-5 years to come to bearing and stability in yield could be assessed only after 10-15 years.

4. Mutation Breeding:

No variety has been developed so far by mutation breeding. Some attempts at IARI, New Delhi using physical mutagens showed that the LD so for Neelum, Dashehari and Amrapali was between 2 and 4 Kr of gamma rays. LD so values has been found to be around 2 to 3 Kr for Neelum and Alphonso at Coimbatore.

New Mango cultivars / hybrids

Institute	Cultivars	Parentage	Major characters
IARI, New Delhi	Mallika	Neelum x Dashehari	Semivigorous, regular bearer, fruit attractive, large with good keeping quality
	Amrapali	Desehari x Neelum	Dwarf, precocious, highly regular and good cropper
CISH, Lucknow	M1	Ammpali x Janardhan Pasand	Attractive skin colour, firm flesh and high TSS
FRS, Sangareddy	Au Rumani	Rumani x Neelum	Regular and prolific bearer
	Manjira	Rumani x Neelum	Dwarf, regular and prolific bearer
TNAU, Periyakulam	PKM.1	Chinnaswamarekha x Neelum	Regular bearer; fruit large, sweet and bearing in clusters
	PKM.2	Neelum x Mulgoa	Large frits (650 -700g) good quality of fruits.
IIHR, Bangalore	Arka Aruna	Banganapalli x Alphonso	Dwarf, regular -bearing; large Alphonso and attractive fruits free from spongy tissue
	Arka Puneet	Alphonso x Banganapalli	Attractive colour, good keeping quality, free from spongy tissue and regular bearer.
	Arka Anmol	Alphonso x Janardhan Pasand	Regular bearer, free from spongy tissue, good keeping quality.
	Arka Neelkiran	Neelum x Alphonso	fruits attractive with red flesh, pulp deep yellow, regular bearer, late season
West India			
FRS, Paria, Gujarat	Neelphonso Neeleshan Neeleshwari	Neelum x Alphonso Neelum x Baneshan Neelum x Dashehari	Dwarf with superior quality TSS and vitamin C content.
FRS, Vengurla, Maharashtra	Ratna Sindhu	Neelum x Alphonso Raina x Alphonso	Early. Free from spongy tissue Virtually seed less and free from spongy tissue

GUAVA (*Psidium guajava*) (2n=22)

In guava, most of the commercial varieties are reported to be diploids, the chromosome number being $2n=22$, while the seedless varieties are triploids.

Origin: Tropical America / West Indies

Distribution: America, Canada, Australia, India, Burma, Indonesia, Bangladesh etc. In India Uttar Pradesh, Andhra Pradesh, Maharashtra, Karnataka etc.

Breeding objectives

1. Development of seedless variety
2. Less pectin content for edible purpose
3. More pectin content for processing
4. Uniform ripening
5. High keeping quality
6. Resistance to tea mosquito bug and wilt.

Breeding methods

1. 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 character such as spreading or erect growth habit of the tree. Improvement work for the first time was initiated during 1907 at Ganeshkhind Fruit Experimental 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 Lucknow49, which is a popular variety throughout India.

At Horticultural Research Station, Saharanpur, evaluation of seedling types resulted in a superior selection, S-I, having good fruit shape, few seeds, sweet taste and high yield. 11w w -

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.

2. Hybridization

At IIHR, Bangalore, by hybridization among Allahabad Safeda, Red Flesh Chittidar, Apple Colour, Lucknow-49 and Banaras, 600 FI hybrids were raised. One hybrid viz Arka Amulya has been released recently. It is a progeny from the cross Allahabad Safeda Triploid. Plants are medium vigour and spreading type. Fruits are round in shape. Skin is smooth and

yellow in colour. Fruits on an average weigh about 180-200g, Flesh is white in colour and firm. TSS is around 12° Brix, soft seeded, weight of 100 seeds is 1.8g. Keeping quality is good.

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

a) 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 fruit quality. The fruits are bigger in size with good quality and few soft seeds.

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

Haryana Agri. University, Hisar 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 Surkha'. Of the pink fleshed hybrids, it is ideal. 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 of ascorbic acid. Yield is 94 kg/tree/year.

3. 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 the IARI, New Delhi, between seedless triploid and seeded diploid variety Allahabad Safeda. Of the 73 F₁ hybrids raised, 26 were diploids, 9 trisomies, 5 double trisomies and 13 tetrasomics. Distinct variation in tree growth habit and leaf and fruit characters were observed.

Lecture No: 20

Banana (*Musa paradisica*) – Fruit variety
(*Musa sapientum*) – Vegetable variety
(2n=22, 33, 44)

Origin: Tropical Asia

Distribution: USA, Canada, Europe, Brazil, India, Pakistan, Bangladesh, Indonesia, Burma and China. In India Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa and West Bengal.

The edible cultivated parthenocarpic bananas belong to the section 'Eumusa' which are derived from *Musa acuminata* and *M. balbisiana*. They have 22, 33 or 44 chromosomes; the basic number being $n=11$ so that these cultivars are respectively diploids, triploids and tetraploids. Triploid cultivars are generally the most numerous, diploid somewhat less and tetraploids are very rare. Simmonds and Shepherd (1955) devised a method of indicating the relative contributions of these two wild species to the constitution of a cultivar. This involves a scoring technique using 15 morphological characters and applying the derived information to distinguish the *M. acuminata* types from those of *M. balbisiana*.

Depending upon the contribution of these parents to the constitution of the progeny and their chromosomal status, the naturally occurring edible bananas fall into seven groups; two diploids (AA, BB), three triploids (AAA, AAB, ABB) and two tetraploid (AAAA, AAAB).

(i) **Principal clones:** There is a wide range of diversity in the clonal cultivars ranging from edible diploid *M. acuminata* (AA) types, nurtured only in sheltered and humid environments, to the hardy hybrid triploids (ABB) which can tolerate seasonal monsoon as well as dry conditions prevailing in most part of the country. There are many synonyms and the classification of the Indian AAB and ABB groups is exceedingly complex. With possible exception of Dwarf Cavendish, all the important clones are of Indian origin. The important clones are given below.

AB Group : Ney Poovan, Thaen Kunnan, Kunnan, Adakka Kunnan, Nattu Poovan

AA Group : Anaikomban, Matti, Sanna Chenkadali, Kadali, Surya Kadali, Namarai, Pisang Lilin, Tongat

AAAA Group : Bodies Altafort

ABBB Group : Klue Teparod, Sawai (synthetic hybrid)

AAA Group : Amritsagar, Gros Michel, Cavendish, Giant Cavendish, Robusta, Lacatan, Wather, Red Banana, Chakkarakeli, . Manoranjitham

AAB Group : Poovan, Rasthali (Silk), Sugandhi, Pachanadan, Rajapuri, Virupakshi, Nendrapadthai, Nendran

ABB Group : Nalla Bontha, Monthan, Karibontha (S), Ney Vannan (S), Peyan (S), Karpuravalli, Bhimkol, Enn Beman (S), Kallu Monthan (S)

Breeding objectives

1. Dessert varieties for export

At present, the entire dessert banana export industry is dependent on Cavendish cultivars, all of which are genetically similar with respect to response.

The characteristics sought by the banana breeder for export varieties are:

- » Yield equal to Cavendish varieties.
- » Quality, especially finger length, finger curvature and finger pedicel strength as in Cavendish varieties.
- » Flavour, ripening and carrying qualities similar to present varieties.
- » Pseudostem height similar to 'Grand Nain' or at least less than in the Cavendish varieties such as 'Valery', 'Poyo', 'Robusta' or 'Giant Cavendish' .
- » Foliage characteristics and production efficiency not inferior to 'Grand Nain'.
- » Resistance to all known races of Fusarium wilt.
- » Resistance to black Sigatoka and similar leaf spot diseases.
- » Tolerance to nematodes.

It is most unlikely that all these characteristics could be incorporated into one variety.

2. Dessert varieties for local use

In many parts of the tropics, dessert bananas of the 'Silk' and 'Pome' clones (AAB) are preferred to the Cavendish clones (AAA). Unfortunately, 'Silk' is highly susceptible to Panama disease and the 'Pome' variety is attacked by Panama disease in some situations and is somewhat susceptible to the common Sigatoka. In addition to disease susceptibility, the AAB varieties are very low yielders (6-12 tons/ha) in comparison to the Cavendish varieties (40 -50 tons/ha per year). Therefore, the main objective of a breeding programme for AAB dessert varieties is to produce disease resistant, high yielding varieties having the flavour and texture of the 'Silk' and 'Pome' cultivars.

3. Cooking varieties: Cooking varieties of the AAB plantain group and AAB and ABB cooking bananas have several major defects. All plantain cultivars are susceptible to black Sigatoka. Some of the ABB cooking bananas are susceptible to Race 2 of Panama disease and to Moko diseases. All, however, are relatively low yielders in comparison to the Cavendish varieties. Most of them are tall with consequent high losses from wind. In addition to disease resistance, good culinary traits and modest increase in yield should be the main objectives of breeding new cooking varieties.

Breeding methods

1. Hybridization

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.

Seed germination in banana is found to be very poor, the percentage ranging from 0.003 to 0.60. The seeds are soaked in water for a week before sowing in seed pan kept in mist chamber. The time taken for seeds to germinate ranges from 24-101 days, sometimes even 6 months. The seeds of wild bananas germinate in 24 days. Under better conditions (hot days and cool winter), the germination improves (25-70%).

Evaluation of hybrid progenies from seedling 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 I 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:

- » 3N x 2N superior diploids; there is no chromosome reduction in the egg cells thus yielding tetraploids;
- » 4N bred tetraploid hybrids x 2N superior diploids producing 'Natural triploids' .
- » 2N meiotic restituting clones x 2N superior diploids producing 'Natural triploids'.

Method (1) has been used extensively and method (2) has been tested relatively to a lesser extent. Method (3) has shown no promise thus far. One other method not evaluated is production of unreduced triploid egg cells from selected seeded triploids from 4N x 2N crosses. When crossed with diploids, the tetraploids produced would have three introductions of diploid parents in the pedigree.

2. Developing new diploid male parent

In many banana growing countries, initially wild diploid bananas (AA) were utilized as male parents 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 synthesise 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 meriting mention are SH 3142 for

nematode resistance and SH 3176 evolved through multiple crosses for resistance to black Sigatoka with desired horticultural traits.

In India, the banana breeding goal has been set to develop malefertile, parthenocarpic diploids with resistance to Sigatoka disease, burrowing nematode and Fusarium wilt, along with high yield, longer fruits and better bunch hang. Dwarf stature is desirable for developing resistance against wind damage. The basic approach has been oriented primarily towards improving the diploid male parents.

3. Mutation breeding: Bud mutation in Indian banana is very common perhaps due to spontaneous rearrangement of chromosomes in somatic meristem and structural reassortment. 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. Clonal propagation and selection have helped in perpetuation of these mutants continually adding to these changes.

Large number of mutants is reported from the cultivated clones of banana in South India. In Nendran variety alone, 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.

Dwarf Cavendish itself is a mutant of an important clone and is known to have given rise to many clones. A semi -tall mutant known as Pedda Pacha Arati in Kumool district of Andhra Pradesh and Harichal or Bombay Green of Maharashtra have assumed commercial status. More than six clones have been isolated from Basrai based on robust growth of pseudostem and large bunch size. Ambalakadali and Erachi Vazhai are mutants of Red Banana. The superior table variety, Rasthali in which the male bud is aborted giving rise to many number of fruits in a bunch. This variety is popularly called 'Ayirankai Rasthali', meaning tooo-fruited Rasthali. The Kunnan variety of Malabar has provided a few mutants known as Thattilla Kunnan (male phase absent), Vennettu Kunnan, Adakka Kunnan and Thaen Kunnan.

A number of sports have been recognized in cv. Monthan, viz., Sambal Monthan, Nalla Bontha Bathees, Sambrani Monthan, pidi Montha and Thellatti Bontha. In Puri district of Orissa, Monthan banana is largely cultivated and more than 5 bud sports have been identified which are under commercial cultivation. The sports differ with respect to plant size, colour and shape of finger. From Poovan cultivar, Motta Poovan (absence of prominent nipple at distal end of the fruit) has been developed as a bud sport. These are some of the outstanding mutants recognized mainly in south India.

Induced mutations have now been used in banana breeding.

b. Iso/ation of somaclona/ variants: In vitro production of crop plants has resulted in substantial variability called "somaclonal variation". A wide range of stable variants involving dwarfism, leaf shape, pigmentation of foliage and pseudostem and bunch characteristics was also observed. Few somaclonal variants isolated in cv. Robusta at TNAU, Coimbatore is reported to be dwarf in stature.

FATOM- I, an early flowering mutant derived from *in vitro* gamma irradiated meristem culture of cv. Grand Nain has been released in Malaysia.

It is a selection from $M_1 V_4$ generation, which flowers within 9 months, as against 15 months in the parent material. It yields a bunch weight of 26 kg! plant as against 23 kg/plant in cv. Grand Nain.

Papaya (*Carica papaya*) (2n = 18)

Papaya (*Carica papaya*) belongs to the family Caricaceae and genus *Carica* have about 40 species. Only *Carica papaya* produces edible fruits. Among the other species, only six have been utilized in breeding programme to induce resistance to virus diseases and frost. *C.cauliflora* is resistant to viruses while *C.candamarcensis* and *C.pentagona* are resistant to frost. Papaya is a polygamous plant and has many sex forms. There are 3 basic sex types - staminate or male, hermaphrodite and pistillate or female. Of these, only female is stable whereas flowers of hermaphrodite and male vary in sex expression under different environmental conditions. Inheritance of sex has been studied extensively and the following Mendelian symbols have been proposed:

Genes

M_1 = dominant factor for maleness

M_2 = dominant factor for hermaphroditism, and

m = recessive factor for femaleness

Genetic constitution

$M_1 m$ = Staminate plant.

$M_2 m$ = Hermaphrodite plant, and

mm = Pistillate plant

Sex in papaya cannot be identified unless they flower but the ratio can be predicted provided it is control pollinated. The sex inheritance in different cross combinations is as follows:

Cross of self	Female plant	Hermaphrodite plant	Male plant	Non-viable
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mm x M ₁ m	1 mm	-	1 M ₁ m	-
mm x M ₂ m	1mm	1 M ₂ m	-	-
M ₂ m x M ₂ m	1 mm	2 M ₂ m	-	1 M ₂ M ₂
M ₁ m x M ₁ m	1mm	-	2 M ₁ m	1 M ₁ M ₁
M ₂ m x M ₁ m	1 mm	1 M ₁ m	1 M ₁ m	1 M ₂ M ₁

Breeding objectives:

1. More fruit yield
2. To develop dwarf stature trees.
3. Uniform ripening
4. High keeping quality
5. Resistance to frost and other abiotic stresses
6. Resistance to pests and diseases

Breeding methods

1. 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 S₁ 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 of 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.

1. CO. 1 : A selection made at Coimbatore from cultivar Ranchi, plant dwarf, fruit round to oval with orange-coloured flesh.
2. CO.2: Selected from local strain, plants medium tall, fruits large, ovate in shape, a high papain yielder.
3. CO.5: Inbred selection from Washington type, high papain yielder.
4. CO.6: Inbred selection from a giant papaya, dual purpose variety.
5. Pusa Giant: Vigorous and sturdy plant, good fruit size, tolerant to strong wind.
6. Pusa Dwarf: Dwarf plant, fruit oval, and medium size preferred by consumers.

Breeding for gynodioecious lines may be followed by selfing regular and prolific bearing hermaphrodite and/or crossing (sibmating) the female with hermaphrodite. The main advantage of this method is that all the plants are productive. Suitable hermaphrodite plants which do not vary with climatic changes are selected for breeding. Selfing is to be continued in selected

hermaphrodite plants for at least 3 generations for uniformity of characters. As regards sibmating, desired types of female plants are selected and sibmated with hermaphrodite plant. Seedlings raised from S_1 inbred are screened and desired female and hermaphrodite plants are selected for further sibmating. This process is to be continued for 7-8 generations till the homozygosity is achieved. In this method, the progenies will be female and hermaphrodite. As a result of inbreeding and selection for 8 generations during 1966-1982, following varieties were developed.

1. Pusa Delicious: Gynodioecious line, heavy yield, fruit very sweet with good flavour, medium tall plant
2. Pusa Majesty: Gynodioecious line, high papain yielder, better keeping quality fruit, tolerant to virus and nematode.

2 Hybridization:

a) Using Dioecious lines

It has been established that female plants are more productive than hermaphrodite ones. Due to the crossing, most of the cultivars are highly variable. Hence it is considered appropriate to sibmate the selected female and male plants so as to bring homozygosity. Hence, 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. This process is to be continued for 7-8 generations to achieve uniformity of a group of characters.

b) Using gynodioecious lines

It involves selfing regular and prolific bearing hermaphrodite and or crossing (sibmating) the female with hermaphrodite. Suitable hermaphrodite plants, which do not vary with climatic changes, are selected. Of the various types of the flower produced by a hermaphrodite plants 'elongata' and 'pentandra' types are selected for selfing. Selfing is to be continued in selected hermaphrodite plants for atleast three generations for uniformity of characters. In the case of female and hermaphrodite plants, sibmating between desired types of female plants are selected and sibmated with hermaphrodite plant. Seedling raised from S_1 inbred is screened and desired female and hermaphrodite plants are selected for further sibmating: This process is to be continued for 7-8 generations till homozygosity is achieved.

Crossing between two or more parents and selecting the derived progenies with good attributes in the advanced generations has been employed as a method to develop new cultivar. CO.3 is a hybrid derivative between CO.2 x Sunrise Solo. Similarly, CO.7 is a gynodioecious

cultivar developed from the crosses of CP.75 (Pusa Delicious x CO.2) x Coorg Honey Dew. Fruits are with red flesh and very sweet in

c) Heterosis breeding

At IIHR, Bangalore, an F_1 hybrid namely Surya (Sunrise Solo x Pink Flesh Sweet) was released recently. It is gynodioecious in nature and produces about 75-80 fruits of medium size weighing about 600-800 g. The flesh is red in colour, firm, sweet to taste with a TSS of 14° brix.

d) Mutation breeding

A Dwarf mutant was isolated in ~ generation by treating the seeds with gamma rays. Repeated sibmating among the dwarf plants had resulted in the establishment of homozygous dwarf line, named as Pusa Nanha. The first bearing height is about 106 cm from the ground level.

Lecture No: 21, 22 & 23

Plant Genetic Resources

The sum total of genes in a crop species is referred to as genetic resources.

or

Gene pool refers to a whole library of different alleles of a species

or

Germplasm may be defined as the sum total of hereditary material i.e., all the alleles of various genes present in a crop species and its wild relatives.

Also known as gene pool or genetic stock or germplasm or genetic resources.

Germplasm or gene pool is the basic material with which a plant breeder has to initiate his breeding programme.

Important features of plant genetic resources are

1. Gene pool represents the entire genetic variability or diversity available in a crop species.
2. Germplasm consists of land races, modern cultivars, obsolete cultivars, breeding stocks, wild forms and wild species of cultivated crops.
3. Germplasm includes both cultivated and wild species or relatives of crop plants.
4. Germplasm is collected from the centres of diversity, gene banks, gene sanctuaries, farmers fields, markets and seed companies.
5. Germplasm is the basic material for launching a crop improvement programme.
6. Germplasm may be indigenous (collected with in country) or exotic (collected from foreign countries)

Kinds of Germplasm

The germplasm consists of various plant materials of a crop such as

- | | |
|------------------------|------------------------------------------------|
| (1) land races | (4) advanced (homozygous), breeding materials, |
| (2) obsolete cultivars | (5) wild forms of cultivated species |
| (3) modern cultivars | (6) wild relatives |
| | (7) mutants |

These are briefly discussed below :

1. Land races

These are nothing but primitive cultivars which were selected and cultivated by the farmers for many generations without systematic plant breeding efforts.

- Land races were not deliberately bred like modern cultivars. They evolved under subsistence agriculture.
- Land races have high level of genetic diversity which provides them high degree of resistance to biotic and abiotic stresses.
- Land races have broad genetic base which again provides them wider adaptability.
- The main drawbacks of land races are that they are less uniform and low yielders.
- Land races were first collected and studied by N.I. Vavilov in rice.

2. Obsolete Cultivars

These are the varieties developed by systematic breeding effort which were popular earlier and now have been replaced by new varieties. Improved varieties of recent past are known as obsolete cultivars.

- Obsolete varieties have several desirable characters they constitute an important part of gene pool. Example : Wheat varieties K65, K68, pb 591 were most popular traditional tall varieties before introduction of high yielding dwarf Mexican wheat varieties. Now these varieties are no more cultivated. They are good genetic resources and have been widely used in wheat breeding programmes for improvement of grain quality. Now such old varieties are found in the genepool only.

3. Modern cultivars

The currently cultivated high yielding varieties are referred to as modern cultivars. They are also known as improved cultivars or advanced cultivars.

- These varieties have high yield potential and uniformity as compared to obsolete varieties land races.
- They constitute a major part of working collections and are extensively used as parents in the breeding programmes.

- As these are good sources of genes for yield and quality, can be introduced in a new area and directly released.
- However, these have narrow genetic base and low adoptability as compared to land races

4. Advanced breeding lines

These are pre-released plants which have been developed by plant breeders in modern scientific breeding programmes. These are known as advanced lines, cultures and stocks. This group includes, nearly homozygous lines, lines derived from biotechnology programmes i.e. transgenic plants and mutant lines etc. These lines which are not yet ready for release to farmers. They often contain valuable gene combinations.

5. Wild forms of cultivated species

Wild forms of cultivated species are available in many crop plants. Such plants have generally high degree of resistance to biotic and abiotic stresses and are utilized in breeding programmes. They can easily cross with cultivated species. Wild forms of many crop species are extinct.

6. Wild Relatives

Those naturally occurring plant species which have common ancestry with crops and can cross with crop species are referred to as wild relatives or wild species. Wild relatives include all other species, which are related to the crop species by descent during their evolution. Both these groups are sources of valuable genes for biotic and abiotic stress and for quality traits and yield.

7. Mutants

Mutation breeding is used when the desired character is not found in the genetic stocks of cultivated species and their wild relatives. Mutations do occur in nature as well as can be induced through the use of physical and chemical mutagens. The extra variability which is created through induced mutations constitutes important components of genepool. Mutant for various characters sometimes may not be released as a variety, but they are added in the genepool. The germplasm includes those carrying gene mutations, chromosomal aberrations and markers genes etc. are considered special genetic stocks. They are useful in breeding programmes.

The gene pool system of classification

The pool of a crop includes all cultivars, wild species and wild relatives containing all the genes available for breeding use.

Based on degree of relationship, the gene pool of crops can be divided into three groups (Harland and Dewet, 1971), viz.,

1. **Primary gene pool**
2. **Secondary Gene pool**
3. **Tertiary gene pool**

These are briefly discussed below :

1. **Primary gene pool (GP1)** : This is also known as gene pool one (GP1). The gene pool in which intermating is easy and leads to production of fertile hybrids is known as primary gene pool. It includes plants of the same species or of closely related species which produce completely fertile offspring on intermating. In such gene pool, genes can be exchanged between lines simply by making normal crosses. This is the material of prime breeding importance.
2. **Secondary gene pool (GP2)** : This type of gene pool is also known as gene pool two (GP2). The genetic material that leads to partial fertility on crossing with GP1 is referred to as secondary gene pool. It includes plants that belong to related species. Such material can be crossed with primary gene pool, but usually the hybrids are sterile and some of the progeny to some extent are fertile. Transfer of gene from such material to primary gene pool is possible but difficult.

Tertiary gene pool (GP3) : The genetic material which leads to production of sterile hybrids on crossing with primary gene pool is termed as tertiary gene pool or gene pool three (GP3). It includes material which can be crossed with GP1, but the hybrids are sterile. Transfer of genes from such material to primary gene pool is possible with the help of special techniques.

Types of seed collections

Based on the use and duration of conservation, seed collections are of three types

1. Base collections
 2. Active collections
 3. Working collections
1. **Base collections:** It is also known as principal collection. These consist of all the accessions present in the germplasm of a crop. They are stored at about -18°C or -20°C with $5 \pm 1\%$ moisture content; they are disturbed only for regeneration. When the germination of an accession falls below, usually, 95% of its germination at the start of storage, the accession is regenerated. For reasons of safety, duplicates of base collections should be conserved in other germplasm banks as well. High quality orthodox seeds can maintain good viability upto 100 years.

2. **Active collections** : The accessions in an active collection are stored at temperatures below 15⁰C (often near 0⁰C), and the seed moisture is kept at 5%. The storage is for medium duration, i.e., 10-15 years. These collections are actively utilized in breeding programme. These collections are used for evaluation, multiplication and distribution of the accessions. They are usually maintained by multiplying the seeds of their own accessions. But from time to time, base collection material should be used for regeneration of these collections. Germination test is carried out after every 5-10 years to assess the reduction in seed viability.
3. **Working collections** : The accessions being actively used in crop improvement programmes constitute working collection. Their seeds are stored for 3-5 years at less than 15⁰C and they usually contain about 10% moisture. These collections are maintained by the breeders using them.

Core collection

The concept of core collection was proposed by Frankel it refers to a subset of base collection which represents the large collection. Or a limited set of accessions derived from an existing germplasm collections.

Germplasm activities

There are six important activities related to plant genetic resources.

- | | |
|-------------------------------|------------------------------------|
| 1. Exploration and collection | 4. Documentation |
| 2. Conservation | 5. Multiplication and Distribution |
| 3. Evaluation | 6. Utilization |

Exploration

Exploration refers to collection trips and collection refer to tapping of genetic diversity from various sources and assembling the same at one place.

The exploration and collection is a highly scientific process. This process takes into account six important items, viz, (1) sources of collection, (2) priority of collection, (3) agencies of collection, (4) methods of collection, (5) methods of sampling and (6) sample size.

Merits and Demerits

There are several merits and demerits of exploration and collection of germplasm, some of which are as discussed below:

Merits

1. Collection helps in tapping crop genetic diversity and assembling the same at one place.
2. It reduces the loss of genetic diversity due to genetic erosion.
3. Sometimes, we get material of special interest during exploration trips.
4. Collection also helps in saving certain genotypes from extinction.

Demerits

1. Collection of germplasm especially from other countries, sometimes leads to entry of new diseases, new insects and new weeds.
2. Collection is a tedious job.
3. Collector, sometimes has encounter with wild animals like elephants, tigers etc.
4. Transportation of huge collections also poses difficulties in the exploration and collection.

2. Germplasm conservation

Conservation refers to protection of genetic diversity of crop plants from genetic erosion. There are two important methods of germplasm conservation or preservation.

or

Germplasm conservation refers to maintain the collected germplasm in such a state that there is minimum risk for its loss and that either it can be planted directly in the field or it can be prepared for planting with relative ease when ever necessary.

There are two important methods of germplasm conservation or preservation viz.,

1. In situ conservation
2. Ex situ conservation

1. *In situ* conservation

Conservation of germplasm under natural habitat is referred to as in situ conservation. This is achieved by protecting this area from human interference : such an area is often called as natural park, biosphere reserve or gene sanctuary. A gene sanctuary is best located within the centre of origin of crop species concerned, preferably covering the microcenter with in the centre of origin. NBPGR, New Delhi is making attempts to establish gene sanctuaries in Meghalaya for Citrus and in the North-Eastern region for *Musa*, *Citrus*, *Oryza*, *Saccharum* and *Megifera*.

This method of preservation has following main disadvantages

- 1) Each protected area will cover only very small portion of total diversity of a crop species, hence several areas will have to be conserved for a single species.
- 2) The management of such areas also poses several problems.
- 3) This is a costly method of germplasm conservation

Merits : Gene sanctuaries offer the following two advantages.

1. A gene sanctuary not only conserves the existing genetic diversity present in the population, it also allows evolution to continue. As a result, new alleles and new gene combinations would appear with time.
2. The risks as associated with ex situ conservation are not operative.

2. *Ex situ* conservation

Conservation of germplasm away from its natural habitat is called *ex situ* germplasm conservation. This method has following three advantages.

- 1) It is possible to preserve entire genetic diversity of a crop species at one place.
- 2) Handling of germplasm is also easy
- 3) This is a cheap method of germplasm conservation

Preservation in the form of seed is the most common and easy method, relatively safe, requires minimum space and easy to maintain. Glass, tin or plastic containers are used for preservation and storage of seeds. The seed can be conserved under long term, medium term and short term storage conditions.

Roberts in 1973 classified seeds on the basis of their storability, into two major groups. *viz.*,

1. Orthodox seeds
2. Recalcitrant seeds

1. **Orthodox Seeds** : Seeds of this type can be dried to low moisture content of 5% and stored at a low temperature without losing their viability are known as orthodox seeds. Most crop seeds belong to this category. Such seeds can be easily stored for long periods; their longevity increases in response to lower humidity and storage temperature. Eg. Wheat, Rice, Corn, Chickpea, Cotton, Sunflower
2. **Recalcitrant seeds** : The viability of this group of seeds drops drastically if their moisture content is reduced below 12-30%. Seeds of many forest and fruit trees, and of several tropical crops like Citrus, cocoa, coffee, rubber, oil palm, mango, jackfruit, etc. belong to this group. Such seeds present considerable difficulties in storage. They require *in situ* conservation.

3. Evaluation

Evaluation refers to screening of germplasm in respect of morphological, genetical, economic, biochemical, physiological, pathological and entomological attributes.

Evaluation requires a team of specialists from the disciplines of plant breeding, physiology, biochemistry, pathology and entomology. First of all a list of descriptors (characters) for which evaluation has to be done is prepared. This task is completed by a team of experts from IPGRI, Rome, Italy. The descriptors are ready for various crops. The evaluation of germplasm is done in three different places, *viz.*, (1) in the field, (2) in green house, and (3) in the laboratory.

4. Documentation

It refers to compilation, analysis, classification storage and dissemination of information. In plant genetic resources, documentation means dissemination of information about various activities such as collection, evaluation, conservation, storage and retrieval of data. Now the term

documentation is more appropriately known as information system. Documentation is one of the important activities of genetic resources. Large number of accessions are available in maize, rice, wheat, sorghum, potato and other major crops. About 7.3 million germplasm accessions are available in 200 crops species. Handling of such huge germplasm information is only possible through electronic computers.

5. Distribution

The specific germplasm lines are supplied to the users on demand for utilization in the crop improvement programmes.

1. Distribution of germplasm is the responsibility of the gene bank centres
2. The germplasm is usually supplied to the workers who are engaged in research work of a particular crop species.
3. Supplied free of cost to avoid cumbersome work of book keeping.
4. The quantity of seed samples depends on the availability of seed material and demands
5. Proper records are maintained about the distribution of material.
6. It helps in acclimatization and purification of the material.

6. Utilization

It refers to use of germplasm in crop improvement programmes. The germplasm can be utilized in various ways. The uses of cultivated and wild species of germplasm are briefly discussed below:

a) Cultivated Germplasm

It can be used in three main ways: (1) as a variety, (2) as a parent in the hybridization, and (3) as a variant in the gene pool.

b) Wild Germplasm

it is used to transfer resistance to biotic and abiotic stresses, wider adaptability and sometimes quality such as fibre strength in cotton.

Organizations associated with germplasm

IPGRI – International Plant Genetic Resources Institute

NBPGR – National Bureau of Plant Genetic Resources

Lecture No: 24

CENTRES OF DIVERSITY AND GENE BANKS

Gene Sanctuaries

The genetic diversity is sometimes conserved under natural habitat. The areas of great genetic diversity are protected from human interference. These protected areas in natural habitat

are referred to as gene sanctuaries. Gene sanctuary is also known as natural park or biosphere reserve. Gene sanctuary is generally established in the centre of diversity or microcenter. India has setup its first gene sanctuary in the Garo Hills of Assam for wild relatives of citrus. Efforts are also being made to setup gene sanctuaries for Banana, Sugarcane, Rice and Mango. In Ethiopia gene sanctuary for conservation of wild relatives of coffee was setup in 1984.

Gene sanctuaries have two main advantages.

1. It protects the loss of genetic diversity caused by human intervention.
2. It allows natural selection and evolution to operate.
3. The risks associated with *ex situ* conservation are not operative

There are two main drawbacks of gene sanctuary.

1. Entire variability of a crop species can not be conserved.
2. Its maintenance and establishment is a difficult task.
3. It is a very good method of *in situ* conservation.

Genetic Erosion

Genetic erosion refers to loss of genetic diversity between and within populations of the same species over a period of time.

or

Gradual reduction in genetic diversity in the populations of a species, due to elimination of various genotypes, is called genetic erosion.

Thus genetic erosion leads to reduction of the genetic base of a species due to human intervention and environmental changes.

There are five main reasons of genetic erosion

- 1. Replacement of land races with improved cultivars :** The main features of modern cultivars are high yield, uniformity, narrow genetic base and narrow adaptability. On the other hand land races and primitive cultivars have more genetic diversity, broad genetic base, wider adaptability and low yield potential. Thus replacement of land races with modern cultivars has resulted in reduction in genetic diversity because land races are disappearing.
- 2. Modernization of agriculture :** Clean and modern agriculture, Improved crop management practices has resulted in the elimination of wild and weedy forms of many crops. These weedy forms enhance the genetic diversity through introgression of genes from crop to weedy forms and weedy forms to crop plants.
- 3. Extension of farming into wild habitats :** It has resulted in destruction of wild relatives of various crops resulting in reduction of their genetic diversity.

4. **Grazing into wild habitats :** Grazing of animals in the wild habitat also reduces genetic diversity by destroying the wild and weedy forms of crop plants.
5. Developmental activities like Hydroelectric projects, growth of towns, cities, roads, air ports and industrial areas also lead to genetic erosion of crop plants, because vast areas are cleaned for such activities.

Extinction

Extinction refers to permanent loss of a crop species due to various reasons.

Introgression

Transfer of few genes from one species into the full diploid chromosome complement of another species.

Gene banks

Gene bank refers to a place or organization where germplasm can be conserved in living state. Gene banks are also known as germplasm banks. The germplasm is stored in the form of seeds, pollen or *in vitro* cultures, or in the case of a field gene banks, as plants growing in the field. Gene banks are mainly of two types, viz.,

1. Seed gene banks
2. Plant or field gene banks
3. Meristem gene banks
4. Cell and organ gene banks and
5. DNA gene banks

These are briefly discussed below :

1. Seed gene banks :

A place where germplasm is conserved in the form of seeds is called seed gene banks. Seeds are very convenient for storage because they occupy smaller space than whole plants. However, seeds of all crops can not be stored at low temperature in the seed banks. The germplasm of only orthodox species (whose seed can be dried to low moisture content without losing variability) can be conserved in the seed banks. In the seed banks, there are three types of conservation, viz., (1) short term, (2) medium term, and (3) long term. Base collections are conserved for long term (50 years or more) at -18 or -20°C . Active collections are stores for medium term (10-15 years) at zero degree Celsius and working collection are stored for short term (3-5 years) at $5-10^{\circ}\text{C}$. The main advantages of gene banks are as follows.

- 1) Large number of germplasm samples or entire variability can be conserved in a very small space.

- 2) In seed banks, handling of germplasm is easy
- 3) Germplasm is conserved under pathogen and insect free environment

There are some disadvantages of germplasm conservation in the seed banks.

- 1) Seed of recalcitrant species can not be stored in seed banks
- 2) Failure of power supply may lead to loss of viability and there by loss of germplasm
- 3) It requires periodical evaluation of seed viability. After some time multiplication is essential to get new or fresh seeds for storage.

2. Field Gene banks

Field gene banks also called plant gene banks are areas of land in which germplasm collections of growing plants are assembled. This is also *ex situ* conservation of germplasm. Those plant species that have recalcitrant seeds or do not produce seeds readily are conserved in Field gene banks. In field gene banks, germplasm is maintained in the form of plants as a permanent living collection. Field gene banks are often established to maintain working collections of living plants for experimental purposes. Field gene banks have been established in many countries for different crops.

Field gene banks in some countries

Name of country	Crop species for which field gene bank is established
Malaysia	Oil palm has been conserved on 500 hectares
Indonesia	Earmarked 1000 hectare area for coconut and other perennial crops
Philippines	South East Asia germplasm of banana has been conserved
India	Global collection of coconut has been conserved in Andman & Nicobar

Field gene banks have some advantages and disadvantages.

Advantages

1. It provides opportunities for continuous evaluation for various economic characters.
2. It can be directly utilized in the breeding programme

Disadvantages

1. Field gene banks can not cover the entire genetic diversity of a species. It can cover only a fraction of the full range of diversity of a species.
2. The germplasm in field gene banks is exposed to pathogens and insects and sometimes is damaged by natural disasters such as bushfires, cyclones, floods, etc.

- Maintenance of germplasm in the field gene banks is costly affair

Meristem gene banks

Germplasm of asexually propagated species can be conserved in the form of meristems. This method is widely used for conservation and propagation of horticultural species. *In vitro* method can be used in two ways. First for storage of tissues under slow growth conditions. Second, for long term conservation of germplasm by cryopreservation. In cryopreservation, the tissues are stored at a very low temperature i.e. at -196°C in liquid nitrogen. At this temperature, all biological processes virtually come to a stop.

Shoot Tip Gene Banks

In such gene banks, germplasm is conserved as slow growth cultures of shoot-tips and nodal segments. Their regeneration consists of sub-culturing the cultures, which may be done every 6 months to 3 years. The chief merits for the conservation of germplasm of vegetatively propagated crops and tree species.

- Genotypes of the accessions can be conserved indefinitely free from diseases and pests.
- They can be used for such crops, which either do not produce seeds or produce recalcitrant seeds.
- Subculture becomes necessary only after relatively long periods (every 6-36 months).
- Regeneration i.e., subculturing, requires a comparatively very short time.

In addition, cuttings, bulbs and tubers can be maintained under controlled humidity and temperature conditions; however, this approach is practical for the short and medium term storage, and it should be used in conjunction with a field gene bank.

Cell and Organ Gene Banks

A germplasm collection based on cryopreserved (at -196°C in liquid nitrogen) embryogenic cell cultures, shoot-tips and or somatic/zygotic embryos may be called cell and organ bank. The techniques for cryopreservation of plant cells and tissues are being rapidly refined, and some such banks have been established, e.g., for potato in Germany.

DNA Gene Banks

In these banks, DNA segments from the genomes of germplasm accessions are maintained as cosmid clones, phage lysates or pure DNA (the last one being for relatively short periods). These DNA segments can be evaluated and the desired ones may be used to produce transgenic plants. This approach is applicable to the conservation of genetic materials of already extinct species since DNA extracted from well preserved herbarium specimens can often be cloned. However, it is very expensive and highly sophisticated. A world-wide network of DNA banks for threatened / endangered species has been established

IDEOTYPE BREEDING

Crop **ideotype** refers to model plants or ideal plant type for a specific environment. In broad sense an **ideotype is a biological model which is expected to perform or behave in a predictable manner within a defined environment**. More specifically, crop ideotype is a plant model which is expected to yield **greater quantity of grains, fibre, oil or other useful product** when developed as a cultivar. The term ideotype was first proposed by **Donald in 1968 working on wheat**.

Ideotype Breeding

Ideotype breeding can be defined **as a method of crop improvement which is use to enhance genetic yield potential through genetic manipulation of individual plant character**. Main features of ideotype breeding are

1. Emphasis on individual trait

In ideotype breeding, emphasis is given on individual morphological and physiological trait which enhances the yield. The value of each character is specified before initiating the breeding work.

2. Includes yield enhancing traits

Various plant characters to be included in the ideotype are identified through correlations analysis. Only those characters which exhibit positive association with yield are included in the model.

3. Exploits physiological variation

Genetic differences exist for various physiological characters such as photosynthetic efficiency, photo respiration, nutrient uptake, etc. Ideotype breeding makes use of genetically controlled physiological variation in increasing crop yields, besides various agronomic traits.

4. Slow progress

Ideotype breeding is a slow method of cultivar development, because incorporation of various desirable characters from different sources into a single genotype takes long time. Moreover, sometimes undesirable linkage affects the progress adversely.

5. Selection

In ideotype breeding selection is focused on individual plant character which enhance the yield

6. Designing of model

In ideotype breeding, the phenotype of new variety to be developed is specified in terms of morphological and physiological traits in advance.

7. Interdisciplinary approach

Ideotype breeding is in true sense an interdisciplinary approach, it involves scientist from the disciplines of genetics, breeding, physiology, pathology, entomology etc.

8. A continuous process

Ideotype breeding is a continuous process, because new ideotypes have to be developed to meet changing and increasing demands.

Differences between traditional and ideotype breeding

<i>S. No.</i>	<i>Traditional Breeding</i>	<i>Ideotype Breeding</i>
1.	The main objective is defined before initiating the breeding work.	The conceptual theoretical model is prepared before initiation of breeding work
2.	Selection is focused on yield and some other characters.	Selection is focused on individual plant characters.
3.	It usually includes various morphological and economic characters.	It includes various morphological, physiological and biochemical plant characters
4.	Value of each character is not fixed in advance	Value of each trait is defined in advance.
5.	This is a simple and rapid method of cultivar development	This is a difficult and slow method of cultivar development.
6.	The phenotypic of a new variety is not specified in advance	Phenotype of new variety to be developed is specified in advance.

Features of crop ideotypes

The crop ideotype consists of several morphological and physiological traits which contribute for enhanced yield or higher yield than currently prevalent crop cultivars. The morphological and physiological features of crop ideotype differ from crop to crop and sometimes within the crop also depending upon whether the ideotype is required for irrigated cultivation or rainfed cultivation. Ideal plant types or model plants have been discussed in several crops like wheat, rice, maize, barley, cotton and beans. The important features of ideotype from some crops are

Wheat

The term ideotype was coined by Donald in 1968 working on wheat. He proposed ideotype of wheat with following main features:

1. **A short strong stem.** It imparts lodging resistance and reduces the losses due to lodging.
2. **Erect leaves.** Such leaves provide better arrangement for proper light distribution resulting in high photosynthesis or CO₂ fixation.
3. **Few small leaves.** Leaves are the important sites of photosynthesis, respiration and transpiration. Few and small leaves reduce water loss due to transpiration.
4. **Larger ear.** It will produce more grains per ear.
5. **An erect ear.** It will get light from all sides resulting in proper grain development.
6. **Presence of awns.** Awns contribute towards photosynthesis.
7. A single culm.

RICE

The concept of plant type was introduced in rice breeding by Jennings in 1964, through the term ideotype was coined by Donald in 1968. He suggested that in rice an ideal or model plant type consists of

1. Semi dwarf stature
2. High tillering capacity and
3. Short, erect, thick and highly angled leaves
4. More panicles /m²,
5. High (55% or more) harvest index.

Now emphasis is also given on physiological traits in the development of rice ideotype.

MAIZE

IN 1975, Mock and Pearce proposed ideal plant type of maize.

1. Stiff-vertically-oriented leaves above the ear.
2. Maximum photosynthetic efficiency.
3. Efficient translocation of photosynthate into grain.
4. Short interval between pollen shed and silk emergence.
5. Small tassel size.
6. Photoperiod insensitivity
7. Cold tolerance
8. Long Grain -filling period

BARLEY

Rasmusson (1987) reviewed the work on ideotype breeding and also suggested ideal plant type of six rowed barley.

1. Short stature
2. Long awns
3. High harvest index
4. High biomass.

Kernel weight and kernel number were found rewarding in increasing yield.

COTTON

Ideotype for irrigated cultivation

1. Short stature (90-120 cm)
2. Compact and sympodial plant habit making pyramidal shape
3. Determinate in fruiting habit with unimodal distribution of bolling
4. Short duration (150-165 days)
5. Responsive to high fertilizer dose
6. High degree of inter plant competitive ability
7. High degree of resistance to insect pests and diseases, and
8. High physiological efficiency.

Rainfed conditions (Singh and Narayanan 1993)

1. Earliness (150-165 days)
2. Fewer small and thick leaves
3. Compact and short stature, indeterminate habit
4. Sparse hairiness,
5. Medium to big boll size
6. Synchronous bolling
7. High response to nutrients
8. Resistance to insects and diseases.

FACTORS AFFECTING IDEOTYPES

There are several factors which affect development of ideal plant type. These are briefly discussed below:

1. Crop Species

Ideotype differs from crop to crop. The ideotype of monocots significantly differs from those of dicots. In monocots, tillering is more important whereas in dicots branching is one of the important features of ideotype.

2. Cultivation

The ideotype also differs with regard to crop cultivation. The features of irrigated crops differ from that of rainfed crop. The rainfed crop needs drought resistance, fewer and smaller leaves to reduce water loss through transpiration. In dicots, indeterminate types are required for rainfed conditions, because indeterminate type can produce another flush of flowers if the first flush is affected by drought conditions.

3. Socio-economic Condition of Farmers

Socio-economic condition of farmers also determines crop ideotype. For example, dwarf *Sorghum* is ideal for mechanical harvesting in USA, but it is not suitable for the farmers of Africa where the stalks are used for fuel or hut constructions.

4. Economic Use

The ideotype also differs according to the economic use of the crop, for example, dwarf types are useful in *Sorghum* and pearl millet when the crop is grown for grain purpose. But when these crops are grown for fodder purpose, tall stature is desirable. Moreover, less leafy types are desirable for grain purpose and more leafy genotypes for fodder purpose. The larger leaves are also desirable in case of fodder crop.

STEPS IN IDEOTYPE BREEDING

Ideotype breeding consists of four important steps,

1. Development of Conceptual Model

The values of various morphological and physiological traits are specified to develop a conceptual theoretical model. For example, values for plant height, maturity duration, leaf size, leaf number, angle of leaf, photosynthetic rate etc., are specified. Then efforts are made to achieve this model.

2. Selection of Base Material

Selection of base material is an important step after development of conceptual model of ideotype. Genotypes to be used in devising a model plant type should have broad genetic base and wider adaptability. Genotypes for plant stature, maturity duration, leaf size and angle and resistance are selected from the global gene pool of the concerned crop species. Genotypes resistant or tolerant to drought, soil salinity, alkalinity, diseases and insects are selected from the gene pool with the cooperation of physiologist, soil scientist, pathologist and entomologist.

3. Incorporation of Desirable Traits

The next important step in combining of various morphological and physiological traits from different selected **genotypes into single genotype**. Various breeding procedures, *viz.* single cross, three way cross, multiple cross, backcross, composite crossing, intermating, mutation

breeding, heterosis breeding etc., are used for the development of ideal plant types in majority of field crops.

4. Selection of Ideal Plant Type

Plants combining desirable morphological and physiological traits are selected in segregating populations and intermated to achieve the desired plant type. Morphological features are judged through visual observations and physiological parameters are recorded with the help of sophisticated instruments. Screening for resistance to drought, soil salinity, alkalinity, disease and insects is done under controlled conditions.

PRACTICAL ACHIEVEMENTS

Ideotype breeding has significantly contributed to enhanced yields in cereals (wheat and rice) and millets (*Sorghum* and pearl millet) through the use of dwarfing genes, resulting in green revolution. Semidwarf varieties of wheat and rice are highly responsive to water use and nitrogen application and have wide adaptation. The Norin 10 in wheat and Dee-geo-Woo-gen in rice are the sources of dwarfing genes. The genic cytoplasmic male sterile systems in *Sorghum* and pearl millet laid the foundation of green revolution in Asia (Swaminathan, 1972). Thus ideotype breeding has been more successful for yield improvement in cereals and millets than in other crops.

Lecture No: 27, 28 & 29

BREEDING FOR BIOTIC STRESS RESISTANCE DISEASE RESISTANCE

Stress: Constraining influence, force, pressure or adverse conditions for crop growth caused by biological or environmental factors.

Biotic (living) : Adverse effects due to pests and diseases abiotic stresses

Abiotic (non living) : Adverse effects on host due to environmental factors
eg: Drought, water logging, heat, cold, salinity, alkalinity and air pollution etc.

Host : Plant effected by a disease or which can accommodate pathogen.

Pathogen : An organism that produces the disease

Disease : an abnormal conditions in the plant caused by an organism (pathogen)

Pathogenicity : The ability of a pathogen to infect a host strain

Virulence : Capacity of a pathogen to incite a disease

Avirulence : The inability of a pathogen to cause or incite a disease

Physiological race : Strains of a single pathogen species with identical or similar morphology but differ in pathogenic capabilities.

Pathotype : Strains of a pathogen classified on the basis of their virulence to known resistance genes present in the host.

Epidemic : Severe and sudden outbreak of disease beginning from a low level of infection.

Variability in fungal pathogens:

- a) **Hybridization:** Recombination of genes of the two parental nuclei takes place in the zygote, and the haploid nuclei or gametes resulting after meiosis are different both from gametes that produced the zygote and from each other.

Thus every diploid pathogen individual is genetically different from any other pathogen even within the same species and variability of the new individual pathogens is continued indefinitely.

e.g., Phytophthora infestans.

- b) **Heterokaryosis:** Condition in which fungal hyphae that are genetically different come together in the same cell to form heterokaryons.
- c) **Parasexualism** : Parasexuality – re-assortment of genetic material both in haploid and diploid condition, ready for natural and artificial selection.

Mixtures of races grown together on a susceptible host combine genetically to produce new races *e.g. phytophthora infestans*

- d) **Mutation:** The rate at which new variants of a pathogen are produced will depend on the mutation rate of the genes at a particular locus. The mutation rate varies from gene to gene and from pathogen to pathogen.

e.g. Melampsora lini – new race produced with UV rays (Flor 1956)

- e) **Cytoplasmic adaptation:** There are several examples of cytoplasmic inheritance of important characteristics such as growth rate and virulence (Jinks 1966).

Virulence of *P.graminis f. sp. Avenae*, carrying gene E, is maternally inherited and may be controlled by single plasma gene (Johnson *et al* 1967)

MECHANISMS OF DISEASE RESISTANCE:

There are different ways of disease resistance *viz.*, disease escape, disease endurance or tolerance disease resistance and immunity

1. **Disease escape** : The ability of susceptible host plants to avoid attack of disease due to environmental conditions factors, early varieties, change in the date of plating, change in the site of planting; balanced application of NPK etc.

Eg. Early varieties of groundnut and potato may escape ‘Tikka’ and ‘Late blight’ diseases respectively since they mature before the disease epidemic occurs.

Changing planting season in sugarcane from June to October has successfully escaped leaf-rust.

Virus free seed potato is produced by sowing the crop in October in Jullundher and other places instead of November, the normal planting time.

2. **Disease endurance or tolerance** : The ability of the plants to tolerate the invasion of the pathogen without showing much damage. This endurance is brought about by the influence of external characters. Generally, tolerance is difficult to measure since it is confounded with partial resistance and disease escape. To estimate tolerance the loss in yield and some other trait of several host varieties having the same amount of disease eg., leaf area covered by disease etc., is compared.

Eg. In Barley the variety Proctor shows 13% yield loss as compared to 20% loss in the varieties Zephy and Sultan.

- Wheat varieties when fertilized with potash and phosphorus are more tolerant to the rust and mildew infection.
- The Rice crop fertilized with silicate is resistant to blast infection in Japan.

3. **Disease Resistance** : The ability of plants to withstand, oppose or overcome the attack of pathogens. Resistance is a relative term and it generally refers to any retardation in the development of the attacking pathogen. In case of resistance, disease symptoms do not develop and the rate of reproduction is never zero i.e., $r > 0$ but it is sufficiently lower than 1 (the rate of reproduction on the susceptible variety) to be useful. The inhibition of growth of the pathogen is believed to be nutritional in nature and in some cases chemical growth inhibitors may be involved.

Resistance is largely controlled by inherited characters i) may be controlled by single dominant gene in Ottawa 770 B, Newland flax variety, wheat all rusts NP 809

4. **Immunity**: When the host does not show the symptoms of disease it is known as immune reaction. Immunity may result from prevention of the pathogen to reach the appropriate parts of the host e.g. exclusion of spores of ovary infecting fungi by closed flowering habit of wheat and barley. It is more generally produced by hypersensitive reaction of the host usually immediately after the infection was occurred. In immune reaction the rate of reproduction is zero i.e. $r = 0$

5. **Hypersensitivity**: Immediately after the infection several host cells surrounding the point of infection are so sensitive that they will die. This leads to the death of the pathogen because the rust mycelium cannot grow through the dead cells. This super sensitivity (hypersensitivity) behaves as a resistant response for all practical purposes. Phytoalexins are specific polyphenolic or terpenoid chemicals and are produced by the host in response to the infection by a pathogen. More than 30 different phytoalexins have

been identified. Phytoalexins are either fungicidal or fungistatic. Eg. Rust fungi and virus attack.

Factors for disease resistance (Causes of Disease resistance)

The disease resistance may be caused due to

1. Morphological, structural and functional characteristics which prevents the entrance of the pathogen *i.e.* prevents the first stage of infection.
2. Biochemical or anatomical properties of tissue which prevent the establishment of parasitic relationship.

a. Morphological characters

Certain morphological features of the host may prevent infection.

Eg. Resistance to Jassid attack in cotton has been shown to be correlated with the hairiness of varieties : hairy type resists the attack more, than glabrous types.

Failure to germinate rust spores on the leaves of the barley due to waxy coating.

Young sugarbeet leaves practically immune to attack of the *circospora* because the stomata size is very small.

b. Physiological characters

Protoplasmic factors or chemical interactions :

By virtues of its chemical composition the protoplasm may exert an inhibitory influence on the pathogen bringing about the desired resistance in the plant.

Eg. :Resistance of grape to powdery mildew is highly correlated with the acidity of cell sap.

Presence of toxic substance in the red pigment in the coloured onions. The outer scales resist the smudge fungus attack when the scales are removed they become susceptible.

c. Anatomical: More secondary thickening of the cell walls of resistant potato varieties which resists the mechanical puncture of the invading *Pythium* pathogen.

d. Nutritional factors : Reduction in growth and in spore production is generally supposed to be due to unfavourable physiological conditions within the host. Most likely a resistant host does not fulfill the nutritional requirements of the pathogen and thereby limits its growth and reproduction.

e. Environmental factors : In addition to the above the environmental factors have marked effect on the pathogen attack. Temperature, moisture, humidity and soil P^H and fertility status of the soil effects the pathogen reaction greatly.

Genetic basis of disease resistance

The first study on genetics of disease resistance was done by Biffen in 1905. He reported the inheritance of resistance to leaf rust of wheat variety Rivet in crosses with some susceptible varieties. In F_2 there were 3 susceptible : 1 resistant plants indicating that resistance was controlled by a single recessive gene. Most of the earlier studies were conducted without taking into consideration the physiological specialization (pathotype differentiation) of the pathogen which can materially influence the conclusions drawn. It is now recognized that disease resistance may be inherited in three different ways :

Oligogenic

Polygenic and

Cytoplasmic inheritance

Oligogenic inheritance:

The disease resistance is governed by one or few major genes and resistance is generally dominant to the susceptible reaction. The action of major resistance genes may be altered by modifying genes in many cases. Eg. bunt resistance in Wheat. Oligogenes generally produce immune reaction. The chief characteristic of the oligogenic disease resistance is pathotype-specificity, i.e. resistant gene is effective against some pathogens, while it is ineffective against the others. In most cases, there are a number of major genes that determines resistance to a particular disease Eg. more than 20 different resistance genes are known for leaf rust of wheat, while those for stem rust resistance exceed 30. The genetics of oligogenic resistance has advanced by two events *viz.*,

1. Discovery of a resistance gene to the prevalent pathotype and
2. Evolution of a pathotype virulent to the new resistance gene.

Oligogenic resistance is synonymous to vertical resistance.

Gene for gene hypothesis:

The concept of gene for hypothesis was first developed by Flor in 1956 based on his studies of host pathogen interaction in flax rust caused by *Malampsora lini*. The gene for gene hypothesis states that for each gene controlling resistance in the host, there is a corresponding gene controlling pathogenicity in the pathogen. The resistance of host is governed by dominant genes and virulence of pathogen by recessive genes. The genotype of host and pathogen determine the disease reaction. When genes in host and pathogen match for all the loci, then only the host will show susceptible reaction. If some gene loci remain unmatched, the host will show resistant

reaction. Now gene-for-gene relationship has been reported in several other crops like potato, *Sorghum*, wheat etc. The gene for gene hypothesis is known as “Flor Hypothesis”.

A simple scheme to explain gene for gene relationship hypothesis (Fehr, 1987)

<i>Varieties</i>	<i>Host genotype</i>	<i>Pathogen genotypes</i>	<i>Disease Reaction</i>
1. One gene pair	AA	aa	Susceptible
	Aa		
	BB	bb	Susceptible
2. Two gene pair	Bb		
	AA CC	aa	Resistant
	Aa CC	cc	Resistant
3. Three gene pair	Aa Cc	aacc	Susceptible
	AA BB CC	aa bb	Resistant
	AA BB CC	aa cc	Resistant
	Aa Bb Cc	aabbcc	susceptible

Note: Dominant genes in the host are responsible for resistance and recessive genes in the pathogen for virulence.

Vertifolia Effect : Vander plank introduced the term vertifolia effect and refers to epidemic development in a variety carrying vertical resistance genes (oligogenes) leading to heavy economic losses. Total failure of vertical resistance leading to a disease epidemic is known as vertioalia effect. This failure occurs because of two reasons :

1. The level of horizontal resistance in varieties carrying oligogenes is usually low and
2. The pathogen is able to evolve new virulent pathotypes.

Polygenic inheritance

In this type the disease resistance is governed by many genes with small effects and a continuous variation for disease reaction is produced. The genes show additive and non additive effects and the environmental effect is also observed. The polygenic resistance does not show pathotype-specificity as against the oligogenic resistance. It is almost same as horizontal resistance. In some cases the polygenic inheritance may have a oligogenic component, the oligogenes acting in an additive manner eg. bacterial blight resistance in cotton

Cytoplasmic inheritance :

Resistance in some cases is determined by cytoplasmic genes or plasma gene(s).

Eg. The T-male sterilizy cytoplasm (cms-T) in maize is extreamly susceptible to *Helminthosporium* leafblight, while the non-T cytoblasms are resistant to this disease.

Vertical and Horizontal Resistance (Vander plank)

<i>Feature</i>	<i>Vertical resistance</i>	<i>Horizontal resistance</i>
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1. Pathotype – specificity	Specific	Non specific
2. Nature of gene action	Oligogenic	Polygenic; rarely oligogenic
3. Response to pathogen	Usually, hypersensitive	Resistant response
4. Phenotypic expression	Qualitative	Quantitative
5. Stage of expression	Seedling to maturity	Expression increases as plant matures
6. Selection and evaluation	Relatively easy	Difficult
7. Host pathogen interaction	Present	Absent
8. Commonly used, synonyms	Major: gene, race -specific seedling, monogenic, pathotype specific resistance	Polygenic, race nonspecific, pathotype-nonspecific, mature plant, adult plant, field uniform resistance
9. Efficiency	Highly efficient against specific races	Variable, but operates against all races

Sources of Disease Resistance

Resistance to diseases may be obtained from four different sources :

1. A known variety
 2. Germplasm collection
 3. Related species
 4. Through mutations
1. **A known variety:** Disease reactions of most of the cultivated varieties are documented and a breeder may find the resistance he needs in a cultivated variety. Resistant plants were also lated from commercial varieties as in the case of cabbage yellows in cabbage curlytop resistance etc. These provide the basis for new resistance varieties.
 2. **Germplasm collection :** When resistance to a new disease or a new pathotype of a disease is not known in a cultivated variety germplasm collection should be screened. Several instances disease resistance were found from the germplasm collections.
Eg. resistance to neckblotch in barley resistance to wilt in watermelon
 3. **Related species :** Often the resistance to a disease may be found in related species and transferred through interspecific hybridization.
Eg. Resistance to stem, leaf & stripe rusts of wheat
 4. **Mutation :** Resistance to diseases may be obtained through mutation arising spontaneously or induced through mutagenic treatments.
Eg.
 1. Resistance to Victoria blight in oats was induced by irradiation with x-rays or thermal neutrons / also produced spontaneously
 2. Resistance to stripe rust in wheat
 3. Resistance to brown rust in oats
 4. Resistance to mildew in barley

5. Resistance to rust in linseed
6. Resistance to tikka leaf spot and stem root in groundnut

Vertical and Horizontal Resistance (Van der plank)

Vertical Resistance is generally determined by major genes and is characterized by pathotype specificity. Clearly immune or susceptible response in the case of vertical resistance depends on the presence of virulent pathotype. When virulent pathotype becomes frequent, epidemics are common in the cases of vertical resistance. Thus an avirulent pathotype will produce an immune response i.e. $r=0$ or close to 0 but the virulent pathotype will lead to susceptible reaction i.e. $r=1$. It is also known as race specific, pathotype specific or simply specific resistance.

Horizontal Resistance

Race non-specific, pathotype-nonspecific and partial, general or field resistance. Horizontal resistance is generally controlled by polygenes i.e. many genes with small effects and it is pathotype nonspecific. In this case, the reproduction rate is not zero but it is less than one. Poly genes, govern horizontal resistance.

Methods of Breeding for Disease Resistance

The methods of breeding for disease resistance are essentially same as those used for other agronomic traits. They are :

1. Introduction
2. Selection
3. Hybridization
4. Budding & Grafting
5. Mutation Breeding
6. Biotechnological methods.

1. **Introduction** : Resistant varieties may be introduced for cultivation in a new area.

Eg.

- Early varieties of groundnut introduced from USA have been resistant to leaf spot (Tikka)

- Kalyanasona and Sonalika wheat varieties originated from segregating material introduced from CIMMYT, Mexico, were rust resistant.
 - African bajra introductions have been used in developing downy mildew resistant cms lines.
2. **Selection** : Selection of resistant plants from commercial varieties is easiest method.
- Eg.
- Kufri Red potato is selection from Darjeeling Red round
 - Pusa Sawani behind (yellow mosaic) selection from a collection obtained from Bihar
 - MCU I was selection from CO4 for black arm resistance in cotton
3. **Hybridization** : Transferring disease resistance from one variety or species to the other.
- a. Pedigree method is quite suitable for horizontal resistance. Artificial disease epiphytotics are produced to help in selection for disease resistance.
- Eg. In wheat Kalyana Sona, Sonalaka, Malvika 12
Malvika 37, Malavika 206, Malavika 234
Laxmi in Cotton (Gadag 1 x CO2) for leaf blight resistance
- b. Backcross method is used to transfer resistance genes from an undesirable agronomic variety to a susceptible, widely adoptable and is agronomically highly desirable variety.
- If the resistant parent is a wholly unadapted variety, backcross method is a logical choice.
- If resistant variety also possess some good qualities then chose pedigree method of handling segregating material.
4. **Budding & Grafting** : The disease resistance in vegetatively propagated material is transferred by adopting either by budding or grafting. By grafting or budding the resistant material, the resistance can be transferred.
5. **Mutation Breeding** : When adequate resistance is not available in the germplasm ; Mutation breeding is resorted to induce resistance. This is also used to break the linkages between desirable resistant genes and other desirable genes.

Precautions

1. The donor parent must possess the required amount of resistance
2. It must be simply inherited without any linkage
3. The recovery in the recipient parent should be more
4. Proper condition for full expression of the resistant genes has to be provided

Advantages with breeding for disease resistance

1. Helps in reducing the losses caused by pathogens
2. Reduces the high cost of disease control by chemical treatment
3. Helps to avoid the use of poisonous fungicides
4. Only method available to some specific diseases like viruses, wilt etc.

Limitations

1. Linkage of resistant genes with genes of inferior quality
2. Occurrence of physiological races of varying capacities
3. Self sterility in host plants

Utilization and achievements

1. Rice ADT 10 x Co4 (resistant to blast)
2. Potato *Solanum tuberosum* x *Solanum demissum*
(susceptible to late blight) (wild resistant to late blight)
F₁ backcrossed with *Sol. tuberosum*
Resistant variety

Varieties resistant to different diseases

Rice : Blast	Co25, Co26,
Wheat : all three rusts	: NP 809
Yellow rust	: NP 785, NM86
Black rust	: NP 789
Brown rust	: NP 783, NP 784
Sugarcane : Red rot	Co 419, Co 421, Co 527
Cotton : Wilt	Vijay, Kalyan, Suyog
Tikka leafspot	Ah 45
Chilli : Mosaic resistant	Pusa red, Pusa orange

Contd/- 27.28&29

INSECT RESISTANCE

Global average loss due to insect pests is 14%. Estimated losses in individual crops vary from 5% in wheat to 26.7% in rice and still more in crops like cotton & sugarcane.

Insect Resistance :

1. The ability of a plant to withstand, oppose or overcome the attack of an insect is known as insect resistance.
2. It is the property of a variety or a host crop due to which it is attacked by an insect pest to a significantly lower degree than are other varieties of the same host.

Biotypes : Strains of a species of an insect pest, differing in their ability to attack different varieties of the same host species (syn: Physiological races)

Host Habitation :

- | | |
|---------------|------------------------|
| 1. Polyphagy | 3. Seasonal Oligophagy |
| 2. Oligophagy | 4. Monophagy |
1. Polyphagy : Insects feed on a wide range of hosts avoiding few plant species. Eg. Scales & moths.
 2. Oligophagy : Live on one taxonomic unit only. Eg. Hessianfly on wheat
 3. Seasonal oligophagy : Insects may live on many species in one part of the year and on few in another part of the year. Eg : Aphids.
 4. Monophagy : Avoid all hosts except one particular species or variety Eg. Boll weevil on cotton.

Mechanism of Insect Resistance :

Insect resistance is grouped into four categories :

- | | |
|-------------------|---------------|
| 1. Non preference | 2. Antibiosis |
| 3. Tolerance | 4. Avoidance |
1. **Non preference** : Host Varieties exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest. This type of resistance is also termed as non-acceptance and anti-xenosis. Non preference involves various morphological and biochemical features of host plants such as – color, hairness, leaf angle, taste etc.
 2. **Antibiosis** : Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and/or reproduction of the insect pest. In severe cases, it may even lead to the death of the insect pest. Antibiosis may involve morphological, physiological or biochemical features of the host plant; some cases of insect resistance involve a combination of features. Eg. Resistance to BPT is due to antibiosis & non preference
 3. **Tolerance** : An insect tolerant variety is attacked by the insect pest to the same degree as a susceptible variety. But at the same level of infestation, a tolerant variety produces a higher yield than a susceptible variety. Ability of the host plant to withstand the insect population to a certain extent which might have damaged a more susceptible host. Tolerance is mainly a host character and it may be because of greater recovery from pest damage. Eg. Rice varieties tolerant to stem borer/gall midge produce additional tillers to compensate yield losses (as in stem borer in sorghum) or due to the ability of host to suffer less damage by the pest eg. aphid tolerance in Sugarbeet & Brassica sps. And

green bugs tolerance in cereals. Inheritance of tolerance is complex in many cases and is supposed to be governed by polygenes.

4. **Avoidance** : Pest avoidance is the same as disease escape , and as such it is not a case of true resistance. Mostly insect avoidance result from the host plants being at a much less susceptible developmental stage when the pest population is at its peak.

Eg. 1. Early maturing cotton varieties escape pinkboll worm infestation, which occurs late in the season.

Nature of Insect Resistance / Factors for insect-resistance

Insect resistance may involve :

1. Morphological
 2. Physiological (or)
 3. Biochemical features of the host plant
1. **Morphological features** : Morphological factors like, hairiness, colour, thickness and toughness of tissues etc. are known to confer insect resistance.
- a) Hairiness of leaves is associated with resistance to many insect pests leaf beetle in cereals, in cotton to Jassids, in turnip to turnip aphid.

- b) Colour of plant : Color may contribute to non preference in some cases.

For example : Red cabbage, Red leaved brussel's sprouts are less favored than green varieties by butterflies and certain Lepidoptera for oviposition. Boll worms prefer green cotton plants to red ones.

- c) Thickness and Toughness of plant – Tissues prevent mechanical obstruction to feeding and oviposition and thereby lead to non-preference as well as antibiosis.

Eg.

1. Thick leaf lamina in cotton contributes to Jassid resistance
2. Solid stem in wheat confers resistance to wheat stem sawfly
3. Thick and tough rind of cotton bolls makes it difficult for the boll worm larve to bore holes and enter the bolls.

Other characters : also contribute to insect resistance.

- Eg. 1. *Gossypium arboretum* varieties with narrow lobed and leathery leaves are more resistant to Jassids than are those with broad lobed and succulent leaves.

2. Cotton varieties with longer pedicels are more resistant to boll worms.

2. **Physiological Factors** : Osmotic concentration of cell sap, various exudates etc; may be associated with insect resistance.

Eg.

- 1) Leaf hairs of some *solanum* *sps.* secrete gummy exudates. Aphids and colorado beetles get trapped in these exudates.
- 2) Exudates from secondary trichomes of *Medicago disciformis* leaves have antibiotic effects on alfalfa weevil.
- 3) Cotton- High osmotic concentration of cell sap is associated with Jassid resistance.

3. **Biochemical Factors** : Several biochemical factors are associated with insect resistance in many crops. It is believed that biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis.

Eg.

- 1) High concentrations of gossypol is associated with resistance in several insect pests in cotton.
- 2) In rice – high silica content in shoots gives resistance to shoot borer

Genetics of Insect Resistance

Insect resistance is governed by -

1. Oligogenes
2. Polygenes
3. Cytoplasmic genes

1. **Oligogenic Resistance** : Insect resistance is governed by one or few major genes or oligogenes, each gene having a large and identifiable individual effect on resistance. Oligogenic resistance may be conditioned by the dominant or the recessive allele of the concerned gene. The differences between resistant and susceptible plants are generally large and clear-cut. In several cases, resistance is governed by a single gene (monogenic resistance)

Eg. In wheat to green bugs

In cotton to Jassids

In apple to woolly aphis

In rice to plant & leaf hopper

2. **Polygenic Resistance** : It is governed by several genes, each gene producing a small and usually cumulative effect. Such cases of resistance.

- 1) Involve more than one feature of the host plant
- 2) Are much more durable than the cases of oligogenic resistance.
- 3) Difference between resistance & susceptible plants are not clear cut
- 4) Transfer of resistance is much more difficult

Examples for polygenic resistance

- 1) In wheat to cereal leaf beetle

- 2) In alfalfa to spotted aphid
- 3) In rice to stem borer
- 4) In maize to ear worm and leaf aphid

Evolution of resistance breaking biotypes is almost rare.

3. **Cytoplasmic Resistance** : governed by plasmagenes

Eg. 1. Resistance to European corn borer in maize

2. Resistance to root aphid in lettuce

Sources of Insect Resistance

1. A cultivated variety
 2. Germplasm collections.
 3. A related wild species
 4. An unrelated organisms
1. Cultivated variety : Resistance to many insect pests may be found among the cultivated varieties of the concerned crop.
Varieties SRT 1, Khand waz ; DNJ 286 and B 1007 of *G. hirsutum* are good sources of resistance to Jassids.
 2. Germplasm collection :
Eg.
 - 1) In apples for rosy apple aphid, green apple, apple maker and apple saw-fly.
 - 2) In cotton, several strains resistant to Jassids.
 3. Related wild species :
Eg.
 - 1) Resistance to both the species of potato nematodes has been transferred from *Solanum vernei* to potato
 - 2) Jassid resistances is known in wild relatives of cotton *G. tomentosum*; *G. anomalum* and *G. armourianum*
 4. An unrelated organism : It is done through recombinant DNA technology
 - a) The 'Cry' gene of *Bacillus thuringiensis* is the most successful example.
Other genes of importance are the
 - b) Protease inhibitor encoding genes found in many plants eg. the cowpea pea, trypsin inhibitor (cp TI) gene.

Breeding Methods for Insect Resistance

1. Introduction
 2. Selection
 3. Hybridization
 4. Genetic Engineering
1. Introduction :
Eg. *Phylloxera vertifoliae* resistance grape root-stocks from U.S.A. into france.
 2. Selection :
Eg.
 - 1) Resistance to potato leaf hopper
 - 2) Resistance to spotted alfalfa aphid

Rice – Vajram, chaitanya, Pratibha – BPH

Lec No: 30 & 31

BREEDING FOR ABIOTIC STRESS RESISTANCE DROUGHT RESISTANCE

Drought: Scarcity of moisture (soil moisture) which restricts the expression of full genetic yield potential of a plant.

Drought resistance: The ability of crop plants to grow, develop and reproduce normally under moisture stress.

Mechanisms of drought resistance

There are 4 mechanisms of drought resistance.

1. **Drought Escapes** : It is due to ability of a genotype to mature early, before occurrence of drought. Drought escape is most common in plants grown in desert region.

Eg. Early maturing varieties of sorghum, maize, bajra, wheat, rice etc; give more yield than late maturing under drought.

2. **Drought Avoidance** (Dehydration avoidance) : It is due to the ability of plants to maintain favourable water balance even under stress. The plants which avoid drought retain high moisture content in their tissues and lose less water. This is possible either because of :

- i) Increased water uptake (due to increase in root development) plants are called water spenders.(or)
- ii) Reduced water loss (due to reduction in growth of aerial parts are called water savers (i.e. to avoid transpiration)

Dehydration avoidance is interpreted as the ability of genotypes to maintain high leaf water potential when grown under soil moisture stress:

Several traits contribute to dehydration avoidance Such as :

Leaf rolling, folding and reflectance narrow leaves, increased pubescence on aerial organs, presence of awns, osmotic adjustment of stomata, cuticular wax, increased water uptake ;

Reduced Transpiration : Increase in concentration of Abscisic Acid (ABA), closure of stomata, ABA plays a role in reduction of leaf expansion, Promotion of root growth etc.

3. **Drought Tolerance** (Dehydration tolerance) : Ability of plants to produce higher yield even under 'low water potential'. In cereals drought tolerance generally occurs during reproductive phase. Tolerant cultivars exhibit better germination, seedling growth and photosynthesis. Drought tolerance may be because of

- i. high proline accumulation
 - ii. maintenance of membrane integrity
4. **Drought Resistance** : It is the sum total of avoidance and Tolerance. It refers to the genetic ability of plants to give good yield under moisture stress conditions.

Various morphological, physiological and biochemical features / parameters associated with drought resistance

a. Morphological

1. Earliness
2. Reduced tillering
3. Leaf characters : Leaf rolling , Leaf folding, Leaf shedding, Leaf reflectance
4. Reduced leaf area : Narrow leaf, Change in leaf angle
5. Hairiness (presence of hairs on leaf and other parts, lowers leaf temperature and reduce transpiration)
6. Colour of leaves
7. Wax content
8. Awns (eg. wheat and barley)
9. Root system (rooting depth and intensity)

b. Physiological

1. Photosynthesis (efficient system like C4) under stress, photosynthetic efficiency is reduced due to chloroplast damage.
2. Reduced Transpiration and reduced respiration losses
3. Stomatal behavior (closure of stomata, also change in size and number of stomata)
4. Osmotic adjustment
5. Leaf enlargement (increase in thickness)
6. Leaf cuticle wax (increases)

c. Biochemical

1. Accumulation of proline and betaine
2. Increase in Abscisic acid (barley) and Ethylene (maize & wheat)
3. Protein synthesis (increases under stress)
4. Nitrate – reductase activity

Sources of drought resistance

1. Cultivated varieties
2. Land (old or desi primitive varieties)

3. Wild relatives (reported in several crops)

For example :

S.No.	Crop	Wild sps	Resistant to
i	Wheat	<i>Aegilops. variabilis</i>	drought
		<i>Aegilops speltoides</i>	"
		<i>Aegilops umbellulata</i>	"
		<i>Aegilops squarrosa</i>	"
ii	Sugarcane	<i>Sacharum. spontaneam</i>	Drought & salinity

4. Transgenes :

Eg. 'Rab' (Responsive to abscisic acid) in rice

Screening / Evaluation

1. Field Env. Highly desirable
2. Green house Env. More precisely controlled than field

Breeding Methods and Approaches

It is important that drought resistance be incorporate in material with high genetic potential for yield.

1. Yield and yield components are best evaluated under non stress / optimal environments, while
2. Drought resistance must be evaluated under water stress.

Breeding methods : Methods are same as for yield and other economic characters. Breeding for drought resistance refers to breeding for yield under moisture stress, i.e. developing varieties which can give high yields under stress. The common methods are

1. Introduction
2. Selection
3. Hybridization
4. Mutation
5. Biotechnology

Limitations :

1. Generally resistant varieties have low yield
2. Do not have much wider adaptability (as abiotic resistant is location specific)
3. Drought resistant genes may have linkage with undesirable genes.
4. Transfer of resistant genes from wild types may post problem.
5. Drought resistance is a consequence of a combination of characters and single character can be used for selection.

6. Measurement of many drought resistant traits is difficult and problematic, since virtually all the useful drought resistant traits are under polygenic control. (So pedigree method most common). But if resistant genes is from agronomically inferior race then 1-2 backcrossing with cultivated type in made. If resistance gene is from wild species-go for backcrossing breeding.

Generally selection is performed on individual plant progenies instead of individual plants (i.e. similar to line breeding)

7. Creation of controlled moisture stress Environments
8. Selection require considerable resources

WATER LOGGING

As per Levitt (1980 b) flooding (i.e. water logging) is the presence of water in soil excess of field capacity. It leads to deficiency of O₂ and build up of CO₂, Ethylene and other toxic gases and this leads to reduction in aerobic respiration.

Effects of water logging:

1. Once soil becomes water logged, air space in soil is displaced with water, the O₂ in the soil in dissolved in water. i.e. O₂ decreases; CO₂ ethylene and other toxic gases increases.
2. O₂ replacement in the soil is very inefficient. Diffusion of atmospheric O₂ into the water logged soils is very inefficient (because of the slow diffusion of atmospheric O₂ to water logged soil).
3. Root systems are suddenly plunged into an anaerobic condition. This switching from aerobic to anaerobic respiration disrupts root metabolism.
4. Carbohydrates level get depleted it is due to
 - a. Dissipation of metabolism
 - b. High water temperature
 - c. Low light

Characteristics of plants in response to water logging stress :

1. Reduced growth / elongation.
2. Chlorosis, senescence and abscission of lower leaves
3. Wilting & leaf curling
4. Hypertrophy (increase in size of organ due to increase in cell size)
5. Epinasty (downward growth of petioles)

Mechanisms of tolerance:

1. Adventitious root formation on lower part of stem (close to surface so that O₂ tension is quickly restored after transient water logging) eg. Tomato
2. Lenticel (i.e. raised pores in the stem of plants) formation
3. Aerenchyma formation (soft plant tissue contains air spaces found in aquatic plants) in the cortex that provide canal parallel to the axis of the root through which gases can diffuse longitudinally (eg rice)
4. Elongation capacity (In rice – best elongation response give 100% recovery from submergence and poorest elongation gives upto 49% recovery)

Scoring for elongation can be done between booting and flowering stage after flooding the crop to varying depths.

In sugarcane, *S. spontaneum* has more tolerance to flooding. Some canes gave upto 70% of their production potential when in continuous flood for 5 months (in an east at canal point Florida, USA)

Ideotype for flooded areas : The postulated ideotype for flooded areas should have the following characteristics.

1. Capacity to carry out functional activity at low O₂ concentration (i.e. High cytochrome activity)
2. Ability for photosynthesis under low light intensity
3. Capacity to synthesis food rapidly
4. Regeneration capacity of shoots when damaged by flood
5. Ability to withstand drought at later growth stage
6. Deep root system
7. Narrow, medium long and dark green leaves with high sugar and protein content.

Breeding methods : Same as in other stresses.

BREEDING FOR SALT TOLERANCE

Salt Tolerance: refers to the ability of plants to prevent, reduce or overcome injurious effects of soluble salts present in their root zone.

It is a global problem as saline and alkali soils are found in almost all the countries of the world, more in Semi Arid Tropic (SAT) of world.

Problem of salinity can be overcome by two ways:

1. Soil reclamation : costly, time consuming and short lived
2. Resistant varieties : less costly, more effective, long lasting require longer period to develop.

Behavior / characteristics of plants to salt :

1. Land races more tolerant than High yielding varieties. Tolerant plants varieties are found in salt affected areas
2. Salt tolerance capacity differs from species to species. Also genetic differences exist among cultivars for their salt tolerance capacity.
3. Different crop plants show differential response to salinity

Salinity

Crops

- | | |
|------------------------------|----------------------------------------------------------------------------------------------------------------|
| a. Highly tolerant crops | Sugarbeet, sunflower, barley (grain), cotton, datepalm, asparagus |
| b. Moderately Tolerant crops | Barley (Forage), rye, soghum, wheat, safflower, soybean |
| c. moderately sensitive | Rice, corn, foxtail millet, cow pea, peanut, sugarcane, tomato, potato, sweet potato, radish, alfalfa, cabbage |
| d. Extremely sensitive | Citrus, straw berry, melon, peas, other legumes, apple, rajmabean, carrot, okra, onion (orange) |
4. Higher ploidy level crops are more tolerant than lower ploidy level crops.
Eg. Hexaploid wheat more tolerant than tetraploid
Tetraploid Brassica more tolerant than diploid Brassica
 5. In rice tall, coarse grained, late maturing varieties- more tolerant
 6. In sugarcane different strains have differential tolerance Barley more tolerant than wheat.

Symptoms of plants to salt stress :

1. Retardation / cessation of growth
2. Necrosis
3. Leaf abscission
4. Loss of turgor
5. Ultimate death of plant

Mechanisms of salt tolerance :

2 types of mechanisms

1. **Salt Tolerance** : Plants respond to salinity stress by accumulating salt, generally in their cells or glands and roots etc.
2. **Salt avoidance** : plants avoid salt stress by maintaining their cell salt concentration unchanged either by water absorption eg. Rice, chenopodiaceae family or by salt exclusion eg. Tomato, soybean, citrus, wheat grass

Glycophytes (Non-halophytes) plants owe their resistance primarily to avoidance. Eg. Barley

Halophytes (plants that grew in salty or alkaline soils) show tolerance by ion accumulation mechanism

Breeding methods

Breeding methods are same but breeding strategies are

1. Breeding for yield potential should have greater emphasis than breeding for salt resistance per se (As screening is done on the basis of yield reduction in stress environment as compared to non-stress Environment.).
2. Selection should be done in stresses target environments (As abiotic stress resistance is an important part of Environ. Fitness & is bound to be location specific i.e. it is related to narrow adaptation).

Screening Techniques

Common methods are

1. Sand culture by using nutrient solution in sand & irrigation with saline water
2. Solution culture by using solution culture tanks (Hydroponic culture)
3. Microplot techniques by using small microplots

Microplot Techniques: By using small microplots of size 6 x 3 x 1 m (CSSRI, Karnal, Haryana) at central soil salinity Research Institute.

Then Multilocation Trial (MLT) conducted over seasons to get more reliable results.

Genotypes which survive better under salinity are considered tolerant & tested further.

Selection criteria

1. Germination (%) in saline medium
2. Dry matter accumulation (seedling / plant dry wt.) / Early vigour
3. Leaf senescence or death – Estimated by total dead leaf area or No. of dead leaves
4. Leaf necrosis
5. Leaf ion content

6. Osmoregulation (Determined as maintenance of turgor under stress) Measured as proline or CHO accumulation or accumulation of glycine, betaine etc.
7. Yield – Economic yield

Problems

1. Creation of reliable controlled salinity Env.
2. Scoring for salinity resistance
3. Genetic control – it is complex & polygenic
4. Mechanisms of resistance poorly understood. Salinity may have interaction with other stresses.

COLD TOLERANCE

When temperatures remain above-freezing *i.e.* $>0^{\circ}\text{C}$ to $<10^{\circ}\text{C}$ - 15°C it is called chilling

When temperature remain below freezing *i.e.* $<0^{\circ}\text{C}$ it is called Freezing.

A. Chilling Resistance:

Chilling sensitive plants are typically tropical plants. Temperate plants are generally tolerant to chilling injury.

Effects of chilling stress on plants :

1. Reduced germination
2. Poor seedling establishment
3. Stunted growth
4. Wilting
5. Chlorosis
6. Necrosis
7. Pollen sterility
8. Poor fruit set / seed formation
9. Reduced root growth
10. Locked open stomato
11. ABA accumulation

At subcellular level

12. Reduces membrane stability
13. Poor chlorophyll synthesis (affected)
14. Reduced photosynthesis & respiration
15. Toxicity due to H_2O_2 formation

Chilling Tolerance

Ability of some genotypes to survive / perform better under chilling stress than other genotypes is called chilling tolerance. It is because of chilling hardening, *i.e.* an earlier exposure to a near chilling temperature for a specific period as a result of which chilling tolerance of the concerned plants increases.

Mechanisms of chilling tolerance:

1. Membrane lipid un-saturation
2. Reduced sensitivity of photosynthesis
3. Increased chlorophyll accumulation
4. Improved germination
5. Improved fruit / seed set

6. Pollen fertility

Sources of chilling Tolerance :

1. Late adopted breeding populations eg. maize
2. Germplasm (eg. That collected from high altitude , low temperature geographic regions)
3. Induced mutants for cold tolerance
4. Cold tolerant somaclonal variants
5. Related wild species eg. Tomato

Selection criteria

Based on -

1. Germination test
2. Growth under stress (measured as plant dry matter accumulation)
3. Chlorophyll Loss under chilling stress eg. rice, cucumber, tomato (measured as seedling colour)
4. Membrane stability : (Assayed in terms of solute leakage from tissues)
5. Photosynthesis : Chilling injury to photosynthesis is assayed as variable chlorophyll fluorescence at 685 nm
6. Seedling mortality
7. Seed / Fruit set
8. Pollen fertility (apply during injury at PMC)

B. Freezing Resistance

Freezing injury / Frost injury / cryo injury

Freezing Stress : Dormant state is conducive to freezing resistance, while resistance in actively growing tissue is rare : Thus Freezing resistance largely involves surviving freezing stress in such a manner as to enable subsequent regrowth when the temperature rises.

As water in plants cools below 0°C, it may either

1. Freeze *i.e.* form ice or
2. Super cool without forming ice.

Effects of freezing stress

1. Ice formation : Two types
 - Intercellular ice formation
 - Intracellular ice formation

Intercellular Ice formation: Initiation of ice formation on plant surface is sufficient to induce freezing of the internal (intercellular & xylem vessels etc.) water in most plant species.

Intracellular ice formation: It is more lethal may be due to physical disruption of subcellular structure by ice crystal. Intracellular ice formation is the major and terminal freezing stress.

Extracellular ice formation in a cases the concentrations of extracellular solutes, there by water is withdrawn from the cells during extracellular ice formation. This creates water-stress in the frozen tissue / plant.

2. Membrane disruptions :

- Freezing causes disruptions is and / or alter the semipermeable properties of plasma membrane
- Loss of solutes from the cells occur
- Cells remain plasmolyzed even after thawing which is often called as frost plasmolysis
- Cells may become highly turgid due to uptake of excess water.

3. Supercooling :

Cooling of water below 0°C without ice crystal formation is called supercooling

- In plants water may cool down to -1 to -15°C in herbaceous sps and to -40 to -45°C in hardy trees.
- This becomes possible apparently because internal ice-nucleators are absent in such cases.
- This is regarded as an important mechanism of freezing avoidance

4. Stress due to external factors : Consequent to freezing

- 1) Ice sheet formation below and above the ground causes reserve depletion anoxia etc. in plants.
- 2) Tissues killed during freeze-thaw are highly prone to pathogen attacks
- 3) Auto toxicity may occur

Mechanism of Freezing Resistance :

The ability of a genotype to survive freezing stress and to recover and re grow after thawing is known as freezing resistance. Freezing resistance is a complex trait involving physiological, chemical & physical processes at the tissue and cell level.

Mechanism of Freezing resistance.

1. **Freezing avoidance** : The ability of plant tissues / or genes (but the whole plants) to avoid ice formation at sub zero temperature is called freezing avoidance

Supercooling is a mechanism of freezing avoidance it is controlled by

1. Lack of ice-nucleators
2. Small cell size
3. Little or no intercellular space
4. Low moisture content
5. Barriers against external nucleators
6. Presence of antinucleators

2. **Freezing Tolerance** : Ability of plants to survive the stresses generated by extra cellular ice formation and to recover and regrow after thawing is known as freezing tolerance.

The various components of freezing tolerance are as follows:

- 1) Osmotic adjustment
- 2) Amount of bound water
- 3) Plasma membrane stability
- 4) Cell wall components properties
- 5) Cold-responsive proteins Eg. ABA

Sources of freezing tolerance

1. Cultivated varieties
2. Germplasm lines
3. Induced Mutations
4. Related wild species Eg. Wheat *Agropyron* sps; rye
Barley – *H. jubatum*, *H.brachyantherum* x *H.bogdanii*, *H.jubatum* x *H.compressum*
Oats – *Avena sterilis*
5. Transgenes : Eg. chemical Synthe sized antifreeze protein gene, ala 3, in tobacco

Selection criteria:

Based on

1. Field survival
2. Freezing test in laboratory
3. Cryo freezing
4. Osmoregulation

Problems in breeding for freezing tolerance

1. Freezing Tolerance is a complex trait & involves several components. So, it is not ready measurable under field conditions
2. Breeding work under field conditions is highly influenced by other environ factors and biotic stresses
3. Due to large G X E for the trait field survival shows poor heritability
4. Freezing tolerance also shows a large GXE interaction which limits progress under selection

5. Laboratory tests are yet to be developed to screen large breeding population

Lecture. No. 32

Genotype – Environment – Interaction and Adaptation

It is established that $P = G + E$,

Phenotype (p) is the function of the genotype (G) and environment (E). this is relevant to an individual subjected to a particular environmental condition. When the same individual is subjected to more than one kind of environment, its phenotypic expression for any trait may often change. Then, the differences in phenotypic expression for any trait cannot be accounted for by G and E alone, since $P > G + E$.

This lack of correspondence between heritable and non-heritable effects, or the remainder of 'P' that cannot be accounted for by 'G and 'E', is attributed to the interaction of G with E (i.e. G X E).

Then

$$P = G + E + (G \times E)$$

This holds true for all the individuals or populations which tend to behave differentially in diverse environmental conditions due to genotype x environment interaction.

Genotypes, Environments and their Interaction

1. Genotypes (G) : Comprises all the crop varieties (cultivars), improved or unimproved, homogeneous or heterogeneous, under domestication, and genetic stocks in the breeder's nursery.
2. Environments (E) : Plants surrounded and influenced by physical, chemical and biological conditions of their habitat. All these conditions constitute an environment. These conditions might vary over time (years or seasons) and space (locations or altitudes).

According to Comstock and Moll, 1963 there are two types environments Micro Environment & Macro Environment.

Micro-environment : The environment of a single plant or organism as opposed to that of another growing at the same time in almost the same place is known as micro environment. Each member of a population is subjected to a specific environment of its own. The individual itself contributes to its environment by way of maintaining a certain level of temperature and humidity around it. This micro environ differ from one individual to another in a pop. And includes solar radiation, disease and pest incidence and soil factors and weather fluctuations.

Macro-environment : The environment associated with variables having large and easily recognizable effect is termed as macro-environment and may include differences over years, locations (latitude / altitude) fertilizer levels, planting dates, irrigation schedules etc.

A macro environment can be viewed as a collection of micro environments whose individual effects on organism are quite small.

Allard and Bradshaw (1964) : classified the environmental variation into two types:

1. Predictable and
2. Unpredictable variations.

Predictable component variations : include all the permanent attributes features of the environment, such as climate, edaphic factors (soil types), day length (photo period), agronomic practices such as planting dates, plant density, water management, fertilization etc.

Unpredictable variations / component : All the uncontrollable actors i.e. it include fluctuations, mild or violent, in weather / season / year with respect to annual precipitation (rainfall), temperature, relative humidity, etc. coupled with variant agronomic practices.

Genotypes x Environment Interaction It is the differential behaviour of the genotype under varietal environmental conditions. This concept was put forth by Allard.

The performance of a crop variety in there resultant effect of its genotype and the environment in which it grows. The variety may perform differently in different environments. The interplay of genetic and non-genetic effects causing differential relative performances of different genotypes (varieties) in different environments is called genotype environment (GE) interaction.

Table: Yield of varieties in two locations (e.x)

Variety	Location	
	Yield quintal per acre Maruteru	Yield quintal per acre Nizamabad
Surekha	18.00	23.00
Pothanna	16.00	27.00
Mean	17.00	25.00

Each genotype attains its maximum biological performance in a particular environment. Due to negative G E interaction – environmental element fall short to produce, of the required biological optimum. Depending on the optimally considerations of different genotypes it is possible to develop genotype suited to ‘or’ tailored for a range of environments

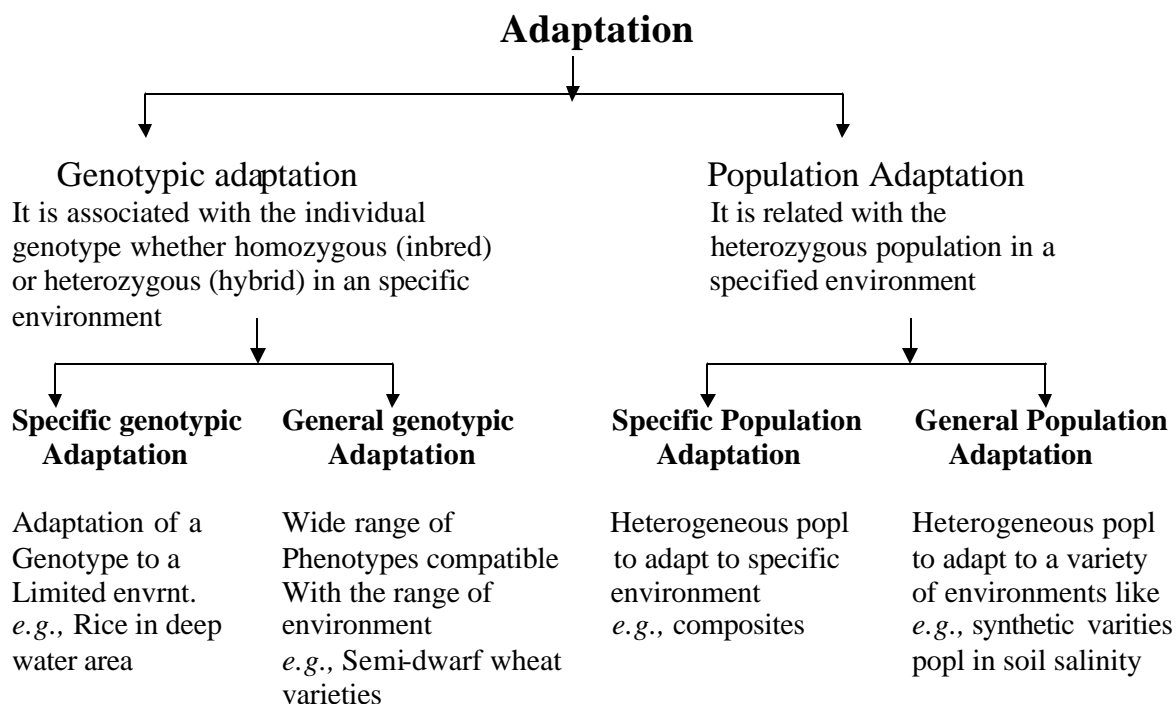
ADAPTATION : It is the capacity of genotypes to adjust themselves in a specific or particular environmental condition, so as to reach a certain level of phenotypic expression.

TYPES OF ADAPTATION

There are four types of adaptation, viz., (1) specific genotypic adaptation, (2) general genotypic adaptation, (3) specific population adaptation and (4) general population adaptation. These are briefly described below.

1. **Specific Genotypic Adaptation:** It is the close adaptation of a genotype to a limited environment. For the production of rice in a deep water area; a variety's capacity for rapid inter-node elongation is an essential feature of its specific adaptation.
 2. **General Genotypic Adaptation:** It refers to the capacity of a genotype to produce a wide range of phenotypes compatible with a range of environments. Semi-dwarf varieties of wheat and rice which can be grown over a wide range of environmental conditions are examples of this type of adaptation (i.e., adaptability).
 3. **Specific Population Adaptation:** It refers to the capacity of a heterogeneous population to adapt to specific environment. A composite or a varietal mixture giving stable production is an example of this category. Here the competition is between the components of variety or mixture rather than adaptation of components themselves.
 4. **General Population Adaptation:** It is the capacity of heterogeneous populations to adapt to a variety of environments. Synthetic varieties of forage crops are example of this type of adaptation. This property of adaptation is specific to an individual genotype or a group of genotypes and is termed as **homeostasis**.
1. Morphological adaptation : Growth habit, stalk strength, radial symmetry of rhizome etc.
 2. Physiological adaptation : Resistance to parasites, greater ability to compete for nutrients or to stand desiccation.

TYPES OF ADAPTATION



ADAPTABILITY : is the ability of a genotype to produce a relatively narrow range of phenotypes in different environments. It is the result of genetic homeostatis, refers to the buffering capacity of a genotype to environmental fluctuations.

STABILITY: It refers to its performance with respective changing environmental factors overtime within a given location. This means that a stable variety is less sensitive to the temporal environmental changes that may take place.

MODELS FOR STABILITY ANALYSIS :

1. Finlay and Wilkinson Model (1963)
2. Eberhart and Russell Model (1966)
3. Perkins and Jinks Model (1968)
4. Freeman and Perkins Model (1971)

Eberhart and Russel (1966) Model

This is the widely used model and it is relatively simple yet quite informative.

They defined a stable variety as one with regression co-efficient of unity ($b=1$) and a minimum deviation from the regression line ($S^2d = 0$, i.e. not significantly different from zero) with high mean.

