COURSE CODE:	*PBS 504*
COURSE TITLE:	*Plant Breeding*
NUMBER OF UNITS:	*2 Units*
COURSE DURATION:	*Two Hours per week*

COURSE DETAILS:

Course Coordinator: Dr. C. O. Alake. B.Sc., M.Sc., Ph.D
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COURSE CONTENT:

Definition of Plant Breeding. Role of Plant breeding in increasing global food supply. Quantitative characters in plant breeding. Role of environment in plant breeding. Self-incompatibility system. Methods of breeding self-pollinated crops. Pedigree breeding, Pure line breeding. Mass selection. Bulk-population breeding. Backcross breeding.Methods of breeding cross-pollinated crops: Mass selection, Re-current selection. Reciprocal recurrent selection. Synthetic varieties, Hybrid varieties. Methods of breeding Asexually propagated crops. Breeding for diseases resistance, germplasm conservation and evaluation. Tissue culture in plant breeding. Practicals
Identification of crop varieties on the field. Emasculation. Selfing and crossing techniques in pollination. Mechanism for preventing contamination after pollination. Collection of types of flowers and how each type affects breeding. Cloning and its effects in genetic variability. Field layout in varietal trials. Excursion to research institutes engaged in plant breeding.

COURSE REQUIREMENTS:

This is a college course. However, all students that register for the course are expected to participate fully in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

1) S. S. Bhojwani, M. K. Razdan 1996. *Plant tissue culture: theory and practice, Revised edition* Elsevier, vii+767 pp. ISBN 0444816232 A few pages are available in Google books
2) Jack Brown and Peter, D.S Caligari. An introduction to Plant Breeding, Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX42DQ, UK

LECTURE NOTES

DEFINITION OF PLANT BREEDING

Plant breeding is the conscious human efforts needed to improve and develop new plants, which are called crop varieties in order to satisfy the demand for human food and animal feeds.

It is a type of selection made possible when there is genetic variability. It is specifically aimed at improving certain yield related character (traits) in a crop plant. It is very important for a potential plant breeder to know and understand the reproductive system of the plant; he/she wants to work with.

It is also very important to know the people to work with. Plant breeders will work with geneticists, physiologists, pathologists, biometricians, botanists, biochemists, seed technologist and nutritionist.

ROLE OF PLANT BREEDING IN INCREASING GLOBAL FOOD SUPPLY

1. Production of crops that have definite improvement over the existing or local varieties.
2. Production of crops that give increase yield per unit area at minimum cost of production.
3. Production of crops that are adapted to the need of the growers and consumers.
4. Production of crops that gives high quality yield or product.
5. Production of crops that are resistant to insect pest and diseases.
6. Faster crop breeding methods compared with traditional methods.
7. Production of crops that are adapted to specific environments or peculiar weather such as drought, water logging, salinity etc.

QUANTITATIVE AND QUALITATIVE CHARACTERS IN PLANT BREEDING

Quantitative characters are also known as metric characters. They are controlled by many genes. Such characters are agronomic in nature and have complex inheritance. They are easily influences by the environment. They are continuous in their phenotypic expression and they segregate in the second filial generation F_2. Such characters cannot be grouped into distinct classes but they can be improved by recurrent selection leading to small but steady genetic gain in each selection cycle. They are responsive to high temperature and water and are physiological in nature. Examples are grain yield, total dry matter, plant height, protein and oil content in plants and general disease resistance.

Qualitative characters are traits that show simple Mendelian inheritance. They are controlled by one or two pairs of genes. They are easily measured and their phenotype in the second filial generation F_2 has close resemblance with their parents. E.g. flower or leaf colour, leaf shape, fruit shape, etc.

It should be noted that selection is faster when dealing with qualitative traits compared with quantitative traits because unfavourable traits can be easily eliminated.

$$\mathbf{P = G + E}$$

$$\mathbf{V^2p = V^2g + V^2e}$$

Where P =Phenotype, G = genotype and E = environment, V^2 = variance

HERITABILITY

Heritability is a measure of the genetic contribution to phenotypic variability

Types:

Broad-Sense Heritability: this expresses that proportion of variance due to the genetic component:

$$\mathbf{H^2 = V_G/V_P}$$

Where V_G is the genetic variance and V_P is the phenotypic variance

Narrow-Sense Heritability:

$$\mathbf{h^2 = V_A/V_P}$$

Because $V_P = V_E + V_G$ and $V_G = V_A + V_D$, we obtain:

$$\mathbf{h^2 = V_A / V_E + V_A + V_D}$$

Where V_A =additive variance, V_D =dominance variance,

Example

The mean and variance of corolla length in two highly inbred strains of Nicotiana and their progenies are shown in table below. One Parent (P1) has short corolla length and the other (P2) has a long length.

Strain	**Mean (mm)**	**Variance**
P1	40.47	3.12
P2	93.75	3.87
F_1 (P1xP1)	63.90	4.47
F_2 (F1xF1)	68.72	47.70

Calculate the heritability for corolla length

Solution

$\mathbf{H^2 = V_G/V_P}$, $\mathbf{V^2p = V^2g + V^2e}$

Because the strains breed true, they are assumed to be homogenous and the variance 3.12 and 3.87 is considered to be as a result of the environmental influences.

The average = (3.12 + 3.87)/2 = 3.50

F_1 is also genetically homogenous; hence it gives us an additional estimate of the environmental factors. By averaging over the two parents, we have:

(3.50 + 4.47)/2 =4.12

$\mathbf{V^2p = V^2g + V^2e}$

$47.70 = V^2g + 4.12$

$\mathbf{V^2g}$ =43.58

$\mathbf{H^2 = V_G/V_P}$,

=43.58/47.70

=0.91

=91%

This implies that about 91% of the variation in corolla length is due to genetic influences.

ROLE OF THE ENVIRONMENT IN PLANT BREEDING

Environment affects selection and progress from selection. The genetic gain or response to selection is the difference between the mean phenotypic value of selected offspring from parental population and that of the parental population before selection. Response to selection is used to compare selection methods and to predict environments.

Response to selection = rg[hx/hy]

Where rg =genetic correlation between trait (x) and yield (y),

hx = heritability for character x

hy = heritability for yield

The bigger the response to selection the better it is. It has no unit.

Heterosis

Heterosis, or hybrid vigor or outbreeding enhancement, is the increased function of any biological quality in a hybrid offspring. It is the occurrence of a genetically superior offspring from mixing the genes of its parents.

Heterosis is the opposite of inbreeding depression, which occurs with increasing homozygosity. The term often causes controversy, particularly in terms of the selective breeding of domestic animals, because sometimes it's inaccurately claimed, that all crossbred plants are genetically superior to their parents. It's only true in certain circumstances. When a hybrid is seen to be superior to its parents, this is known as hybrid vigor. When the opposite happens, and a hybrid inherits traits from its parents that makes it unfit for survival, the result is referred to as outbreeding depression.

Hybrid vigour is measured in two ways:

(1) Mid-parent heterosis (Hmp)

=(F – mp)/mp

(2) Hetero-betiosis (better parent heterosis) Hbp

= (F – bp)/bp

Where F = Mean of F1

mp = mean of the two parents

bp = better parent

Example:

Giving the mean yield of two inbred strains A=80kg , B= 50 and F1 is 90kg, calculate

i. Hmp

ii. Hbp

Solution:

1. mp =(80+50)/2

= 65

Hmp = (F – mp)/mp

= (90 – 65)/65

=0.3846

This implies that the hybrid vigour is 38.46%

2. Hbp = (F – bp)/bp

= (90 – 80)/80

=0.125

Herobetiosis is 12.5%

The better parent heterosis is more significant as far as breeding is concerned because individual progenies are more superior to the better parent.

Manifestations of Heterosis

1. increased heterozygosity
2. increased size and productivity in plants
3. Greater resistance to diseases, insects and environmental factors

4. Early maturity when compared to either of the parents.

INCOMPATIBILITY SYSTEMS

There are various forms of incompatibility. Araso (1998) defined incompatibilityas the inability of a plant to produce functional gametes or inability of a plant producing functional gametes to set seed when self-pollinated.

Causes of Incompatibility

1. Failure of the pollen tube either to penetrate the stigma and;
2. To grow normally the full length of the style so that fertilization may occur.

In the later above, the pollen tube grows sowly that it may never get to reach the ovule and if it does, it would be so late that the ovule would have either been pollinated by compatible pollen or would have withered. Incompatibility restrics self fertilization and inbreeding but it fosters cross fertilization.

Genesis of incompatibility

1. Protandry: Stamen maturing before the stigma
2. Protogyny: Stigma matures before the stamen
3. Hercogamy: This involves the physical arrangement of male and female organs on the same plant preventing self pollination in the absence of an insect.

Apart from the morphological mechanism, which ensures open pollination, there are also some genetic and physiological mechanisms which ensure incompatibility. Based on this, incompatibility can be divided into two groups:

A. Heteromorphic Incompatibility
B. Homomorphic Incompatibility

A. Heteromorphic Incompatibility

This system is based on the difference in the length between the stamen and the style. The flower with long style and short filament is called PIN where as the flower with long filament and short style is called THRUM.

In PIN the pollen grains contains the gene labeled (ss) while that of THRUM has heterozygous gene (Ss).

Consequently, pollination is possible only between the anther and stigma of the same height i.e. between stamen of PIN and stigma of THRUM or between the stima of Pin and stamen of THRUM.

PIN		THRUM	
ss		Ss	parents
s	x	Ss	gametes
	↓		
	Ss ss		F1- generation

In addition to the floral differences or floral morphology, PIN and THRUM plants also differ in other characteristics such as pollen size and the size of stigmatic cells. Consequently a combination of PIN x PIN is incompatible and THRUM x THRUM is also incompatible. It means that homozygous SS will not exist.

B. Homomorphic Incompatibility

Under this condition, differences in floral morphology are excluded. We therefore have gametophytic and sporophytic incompatibilities.

i. Gametophytic Incompatibility: This system is also known as the opposition factor system and it depends on a series of alleles on a single locus i.e. the ability of a pollen to fertilize the stigma depends on the type of gene in each locus. Under this system, pollen tube growth is usually very slow within a style that contains similar alleles e.g. S_1S_1 or S_2S_2.

Consequently, plants are virtually always heterozygous at this locus S_1S_2 or S_2S_3 or S_1S_3 for compatibility to be possible.

A situation with two alleles with gametophytic control with no dominance is impossible because all plants could be incompatible and sterile. The phenomenon of incompatibility gives rise to three types of pollination.

1. Fully compatible (S_1S_2 x S_1S_2)

In this case both alleles are common in the male and the female. All gametes are non-functional and so, no offspring is produced.

2. Half of pollen is compatible (S_1S_2 x S_1S_3)

Half of the pollen is compatible in which one allele is different in both the male and female gametes. S_3 is the functional male and S_1 is non-functional male.

S_1S_2 x S_1S_3

↓

S_1S_1 **S_1S_3** S_1S_2 **S_2S_3** ----- **F_1**

4. All pollen are compatible (S_1S_2 x S_3S_4)

In this case both alleles differ giving the progenies:

S_1S_3 S_1S_4 S_2S_3 S_2S_4

ii. Sporophytic Incompatibility:

This is similar to the gametophytic system in that genetic control is by a single gene with multiple alleles. However, unlike gametophytic type, the functionality of pollen is determined by the genetic constitution of the plant producing it. It also differs from the gametophytic system in that the alleles may show dominance. Thus, individual action or competition in either pollen or style is according to the allele combination involved. The main feature of sporophytic system that differentiates it from the gametophytic system are:

a. There are frequent reciprocal differences

b. Incompatibility can occur within the female parent

c. A family can consist of three incompatible groups or more

d. Homozygosity is a normal part of the system

e. An incompatible group may contain two genotypes.

STERILITY

Sterility covers all cases of infertility or bareness in plants resulting from irregularities with the sexual reproductive system. Infertility may be caused by abnormal or imperfect development of the reproductive organs. The stamen or pistil may be malformed, pollen may be defective or the ovules aborted. Infertility may also result from failure of viable pollen to function after germination. The pollen tube may not penetrate the stigmatic surface or the pollen tube growth in the style may be reduced so that the spermatic cells do not reach the ovule.

In some cases even though fertilization occurs, the embryo may not develop normally so no viable seeds are formed. After seed formation, infertility in hybrid may result from chromosomal an irregularity that inhibits chromosomal pairing or normal division at meiosis of from other genetic causes. Regardless of the specific causes, infertility is a hindrance that should be understood and overcomed by the breeder if he is to obtain genetic recombination through inter-specific or intra-specific crosses.

TISSUE CULTURE AND PLANT BREEDING

Plant tissue culture is a practice used to propagate plants under sterile conditions, often to produce clones of a plant. Different techniques in plant tissue culture may offer certain advantages over traditional methods of propagation, including:

- The production of exact copies of plants that produce particularly good flowers, fruits, or have other desirable traits.
- To quickly produce mature plants.

- The production of multiples of plants in the absence of seeds or necessary pollinators to produce seeds.
- The regeneration of whole plants from plant cells that have been genetically modified.
- The production of plants in sterile containers that allows them to be moved with greatly reduced chances of transmitting diseases, pests, and pathogens.
- The production of plants from seeds that otherwise have very low chances of germinating and growing, i.e.: orchids and nepenthes.
- To clean particular plant of viral and other infections and to quickly multiply these plants as 'cleaned stock' for horticulture and agriculture.

Plant tissue culture relies on the fact that many plant cells have the ability to regenerate a whole plant (totipotency). Single cells, plant cells without cell walls (protoplasts), pieces of leaves, or (less commonly) roots can often be used to generate a new plant on culture media given the required nutrients and plant hormones.

Techniques

Modern plant tissue culture is performed under aseptic conditions under filtered air. Living plant materials from the environment are naturally contaminated on their surfaces (and sometimes interiors) with microorganisms, so surface sterilization of starting materials (explants) in chemical solutions (usually alcohol or bleach) is required. Mercuric chloride is seldom used as a plant sterilant today, as it is dangerous to use, and is difficult to dispose of. Explants are then usually placed on the surface of a solid culture medium, but are sometimes placed directly into a liquid medium, particularly when cell suspension cultures are desired. Solid and liquid media are generally composed of inorganic salts plus a few organic nutrients, vitamins and plant hormones. Solid media are prepared from liquid media with the addition of a gelling agent, usually purified agar.

In-vitro tissue culture potato explants

The composition of the medium, particularly the plant hormones and the nitrogen source (nitrate versus ammonium salts or amino acids) have profound effects on the morphology of the tissues that grow from the initial explant. For example, an excess of auxin will often result in a proliferation of roots, while an excess of cytokinin may yield shoots. A balance of both auxin and cytokinin will often produce an unorganised growth of cells, or callus, but the morphology of the outgrowth will depend on the plant species as well as the medium composition. As cultures grow, pieces are typically sliced off and transferred to new media (subcultured) to allow for growth or to alter the morphology of the culture. The skill and experience of the tissue culturist are important in judging which pieces to culture and which to discard.

As shoots emerge from a culture, they may be sliced off and rooted with auxin to produce plantlets which, when mature, can be transferred to potting soil for further growth in the greenhouse as normal plants.[1]

Choice of explant

The tissue obtained from the plant to culture is called an explant. Based on work with certain model systems, particularly tobacco, it has often been claimed that a totipotent explant can be grown from any part of the plant. However, this concept has been vitiated in practice. In many species explants of various organs vary in their rates of growth and regeneration, while some do not grow at all. The choice of explant material also determines if the plantlets developed via tissue culture are haploid or diploid. Also the risk of microbial contamination is increased with inappropriate explants. Thus it is very important that an appropriate choice of explant be made prior to tissue culture.

The specific differences in the regeneration potential of different organs and explants have various explanations. The significant factors include differences in the stage of the cells in the

cell cycle, the availability of or ability to transport endogenous growth regulators, and the metabolic capabilities of the cells. The most commonly used tissue explants are the meristematic ends of the plants like the stem tip, auxiliary bud tip and root tip. These tissues have high rates of cell division and either concentrate or produce required growth regulating substances including auxins and cytokinins.

Some explants, like the root tip, are hard to isolate and are contaminated with soil microflora that become problematic during the tissue culture process. Certain soil microflora can form tight associations with the root systems, or even grow within the root. Soil particles bound to roots are difficult to remove without injury to the roots that then allows microbial attack. These associated microflora will generally overgrow the tissue culture medium before there is significant growth of plant tissue.

Aerial (above soil) explants are also rich in undesirable microflora. However, they are more easily removed from the explant by gentle rinsing, and the remainder usually can be killed by surface sterilization. Most of the surface microflora do not form tight associations with the plant tissue. Such associations can usually be found by visual inspection as a mosaic, de-colorization or localized necrosis on the surface of the explant.

An alternative for obtaining uncontaminated explants is to take explants from seedlings which are aseptically grown from surface-sterilized seeds. The hard surface of the seed is less permeable to penetration of harsh surface sterilizing agents, such as hypochlorite, so the acceptable conditions of sterilization used for seeds can be much more stringent than for vegetative tissues.

Tissue cultured plants are clones, if the original mother plant used to produce the first explants is susceptible to a pathogen or environmental condition, the entire crop would be susceptible to the same problem, conversely any positive traits would remain within the line also.

Applications

Plant tissue culture is used widely in plant science; it also has a number of commercial applications. Applications include:

- Micropropagation is widely used in forestry and in floriculture. Micropropagation can also be used to conserve rare or endangered plant species.
- A plant breeder may use tissue culture to screen cells rather than plants for advantageous characters, e.g. herbicide resistance/tolerance.
- Large-scale growth of plant cells in liquid culture in bioreactors for production of valuable compounds, like plant-derived secondary metabolites and recombinant proteins used as biopharmaceuticals [2].
- To cross distantly related species by protoplast fusion and regeneration of the novel hybrid.
- To cross-pollinate distantly related species and then tissue culture the resulting embryo which would otherwise normally die (Embryo Rescue).
- For production of doubled monoploid (dihaploid) plants from haploid cultures to achieve homozygous lines more rapidly in breeding programmes, usually by treatment with colchicine which causes doubling of the chromosome number.
- As a tissue for transformation, followed by either short-term testing of genetic constructs or regeneration of transgenic plants.
- Certain techniques such as meristem tip culture can be used to produce clean plant material from virused stock, such as potatoes and many species of soft fruit.
- micropropagation using meristem and shoot culture to produce large numbers of identical individuals.

Laboratories

Although some growers and nurseries have their own labs for propagating plants by the technique of tissue culture, a number of independent laboratories provide custom propagation

services. The Plant Tissue Culture Information Exchange lists many commercial tissue culture labs. Since plant tissue culture is a very labour intensive process, this would be an important factor in determining which plants would be commercially viable to propagate in a laboratory.

BREEDING METHODS

The goal of Plant Breeder is to create superior crop cultivars. A cultivated variety or cultivar, denotes a group of related plant within a specie maintained either by sexually or asexually propagation whose distinguishable characters are of agricultural significance.

Cultivar is an international term for the category known in different languages by different names. e.g. 'Variety' in English, 'Veriete' in French, 'Sort' in Scandiavian languages and in Russian 'Ros' or 'Varieteit' in Dutch and 'Razza' or 'Varieta' in Italian.

KINDS OF CULTIVARS

A cultivar (variety) may be any of this following:

CLONE: A genetically uniform assemblage of individuals, derives originally from a single individual by vegetative propagation e.g. cuttings, divisions, grafts or apomixes.

LINE: An assemblage of sexually reproducing individuals of uniform appearance, propagated by seeds or by spores, its stability maintained by selection to a standard.

OPEN-POLLINATED VARIETY: An assemblage of individual showing genetically differences but having one or more characteristics by which it can be differentiated from other cultivars (varieties).

F_1 HYBRIDS: A uniform assemblage of individuals which is a first generation hybrid (F_1) reconstituted on each occasion by crossing two or more breeding stocks, maintained either by inbreeding or as clone, or recurrently made as F_1 hybrids.

Methods of improvement have been developed for cultivars of all kinds.

(A) The improvement of vegetative propagated crops (mainly fruits crops, woody ornamentals, potato, sugarcane, yam, cassava) involves production of a single desirable genotype. In developing population from which to select a desirable genotypes inbreeding should be avoided.

(B) Breeding methods for the improvement of sexually propagated crops depends on the genetic structure of the cultivars which is governed by the natural method of pollination. The amount of cross-pollinating ranges from essentially none in such plants as soybeans to 100% in dioecious and self-incompatible plants. For breeding purposes, two main groups are recognized.

i) Naturally self-pollinated plants in which cross-pollination is less than 4%.

ii) Naturally cross-pollinated plants in which cross-pollination exceeds 40% e.g. maize.

Self-pollinated plants are ordinarily homozygous for practically all genes. The exceptions are the results of chance cross-pollination and mutations. In such plants heterozygosity is usually quickly eliminated as a consequence of natural inbreeding. The basic problems in improving self-pollinated plants lie in producing and selecting the best homozygous genotype. Once this is accomplished, the problem of genetic maintenance is much smaller than it is with cross-pollinated species.

The genes in naturally cross-pollinated, seed-propagated plants are recombined constantly from generation to generation. The problems encountered in improving cross-pollinated plants include maintaining uniformity while avoiding the decline in vigour associated with homozygosity. Once a desirable population is achieved, there is still the perpetual problem of maintenance. One method of maintaining both uniformity and heterozygosity is to produce hybrids through the crossing of selected diverse inbred lines.

INTRODUCTION

The first step in any crop improvement programme is to assemble the natural variants available (i.e. cultivars and related wild specie). From a study of their performance it may be

possible to make an immediate improvement merely by choosing some cultivars not being grown. There should be Plant Genetics and Germplasm Institute to carry out the exploitation and introduction of genetic variability. Collections of germplasm or germplasm bank are currently available for many crops in many crop research institutes all over the world.

Genetic variability is the raw material of the Plant Breeder. The richest source of genetic variability for a particular cultivated species has been shown to be its geographical area of origin.

SELECTION

Selection refers to differential reproduction of individual in a population. Selection is achieved by preserving favourable variants and eliminating undesirable ones. Selection is often a natural process, because in the absence of human interference those plants adapted to survive and reproduce leave the most descendants.

Almost all the crops in cultivation today were domesticated before the advent of written history. Improvement of these crops has been continuous as a result of human selection either consciously or unconsciously over the years. Many of such cultivated species are now very different from their wild ancestors.

The efficient use of selection process is one of the principal tools of a plant breeder. However, selection does not create genetic variability but merely act on the genetic variation already available. Thus, the Breeder must first of all create a variable population form which to select. He must be able to recognize and propagate those individual with superior characteristics. The proper choice of parental materials is one of the crucial decision in any breeding programme.

IMPORTANCE OF MODE OF REPRODUCTION

The mode of reproduction of a crop determines its genetic composition, which, in turn, is the deciding factor to develop suitable breeding and selection methods. Knowledge of mode of reproduction is also essential for its artificial manipulation to breed improved type.

Only those breeding and selection methods are suitable for crops which does not interfere with its natural state or ensure the maintenance of such a state. It is due to such reasons that imposition of self-fertilization on cross-pollinating crops leads to drastic reduction in their performance.

For teaching purpose, plant breeding is presented as four categories:

Line breeding (autogamous crops)

Population breeding (allogamous crops)

Hybrid breeding (mostly allogamous crops, some autogamous crops),

Clone breeding (vegetative propagated crops).

METHODS OF BREEDING SELF-POLLINATED/AUTOGAMOUS CROPS

Two fundamentally different types of populations of self-pollinated crops exists.

1) Mixture of different homozygous lines-found in a collection of cultivars. In this type of population, selection consists of determining the best genotype by testing. The best genotype can be duplicated from the selfed-seeds.
2) A mixture of different heterogeneous genotypes, as found in the generation of cross between homozygous cultivars. This population consists of many different genotypes with varying degree of heterozygosity. To obtain an improved type from this type of population, the best genotype must be selected and then transformed into homozygous, true-breeding line without loosing the essential characteristics of the selected individual.

PEDIGREE BREEDING

Pedigree selection is widely used for self-pollinating crops. Individual plants are generally selected from a segregating population (typically the F_2 generation) and selection proceeds between and within progenies in each subsequent generation until genetic purity are reached.

Since selfing bring absent 50% or more homozygosity in each generation, the variation between lines is halved with each generation. Thus, at the fifth generation, the line derived from single plant selection will be homozygous fro more than 95% of their genes. If testing shows any of these lines to be superior to the existing cultivars, it can be named as a new cultivar.

PROCEDURE OF PEDIGREE METHOD

First year: Hybridization of selected parents

2^{nd} year (F_1): 10 – 30 seed spaced planted, harvested in bulk.

3^{rd} year (F_2): (i) 2000 – 10,000 plant space plated

(ii) 100 – 500 superior plant selected

4^{th} and 5^{th} year: (i) Individual plant progeny space-planted

(ii) Superior plant selected

6^{th} year: (i) Individual plant progeny planted in multi-row plot

(ii) Superior plant selected from superior progenies

7^{th} year: (i) As in (i) and (ii) for F_5

(ii) Preliminary yield trial (PYT) may be conducted.

8^{th} year: (i) PYT

(ii) Quality test

9^{th} – 13^{th} year: (i) Coordinated yield trial

(ii) Disease and Quality test

14^{th} year: (i) Seed increase for distribution

ADVANTAGES OF PEDIGREE

1) It gives the maximum opportunity for the breeder to use his skill and judgement for selection of plants, particularly in the early segregating generation.

2) It is well suited for the improvement of character which can be easily identified and inherited.
3) Transgressive segregates for yield and other quantitative characters may be recovered in addition to the improvement in specific character.
4) It takes less time than bulk method to develop a new variety.
5) Plants and progenies with visible defects and weakness are eliminated of early stape in the breeding programme.
6) The breeder may often be able to obtain information about the inheritance of qualitative characters from the pedigree method.

DISADVANTAGES OF PEDIGREE

1) Maintenance of accurate pedigree records takes up valuable time.
2) Selection in a large number of progenies in every generation is laborious and time consuming.
3) No opportunity for natural selection to influence the population.
4) Selection for yield in F_2 and F_3 is ineffective.

MASS SELECTION

Mass selection can also be used in the improvement of self pollinated crops by planting segregating populations in large plots and harvesting in bulk. Selection may be practiced in each generation by eliminating undesirable plants. After 5 to 10 generations, the population will consist of heterogeneous mixture of somewhat selected homozygous genotypes. The best genotype is then determined by testing. Mass selection permits a large pool of germplasm to be manipulated and carried along.

The combination of mass selection and pedigree selection is well suited for self-pollinated crops. Pedigree selection may be utilized in the early segregating generation to exploit the major genetic differences to eliminate undesirable types. Then mass selection technique may be used. Most modern breeding techniques involve a combination of these systems.

STEPS IN MASS SELECTION

First year: A large number of phenotypically similar plants are selected for their vigour, plant type, disease resistance etc. The number many vary from few hundred to few thousands. Seeds from selected plants are composited to raise next generation.

Second year: The composite seeds are planted in a Preliminary Yield Trial along with standard variety as check. The variety from which the selection was made should also be included as a check to determine if there has been an improvement due to selection. Phenotypic characteristics are critically observed.

Third to Six year: The variety is evaluated in a coordinated yield trials of several locations.

Seventh year: The variety may be released for cultivation if found suitable and if recommended.

APPLICATION OF MASS SELECTION

In self-pollinated crops, mass selection has two basic applications

(1) Improvement of local varieties

(2) Purification of existing varieties

ADVANTAGES OF MASS SELECTION

1) Since a large number of plants are selected, the adaptation of the original variety is not changed.
2) Reduction in time and cost because extensive and prolong yield trials are expensive.
3) It retains considerable genetic variability.
4) It is a less demanding method. The breeder can devote more time to other breeding programmes.

DISADVANTAGES OF MASS SELECTION

1) The varieties show variations.
2) The improvement through mass selection is generally less than that through pure-line.
3) It is not commonly use in self-pollinating crops.
4) In the absence of progeny test, it is impossible to determine if the selected plant is homozygous.
5) The varieties are more difficult to identify than pure line in seed certification programme.
6) It utilizes the variability already present in the population.

PURE-LINE BREEDING

This is the development of the new varieties from the old 'Land' varieties that have passed down from generation to generation of the farmers. Although they may be reasonably similarly in gross morphology, lines within a farmer variety may be different in agricultural value. Most plants selected from such varieties can be expected to be homozygous and hence the starting point of a new true breeding variety.

PROCEDURE

Select a number of single plant, compare their progenies in field trials; and save the single most valuable progenies as a new variety. Many valuable varieties are traced back to a single chance variant noticed and selected by farmers.

BACKCROSS BREEDING

A cross between hybrid and one of its parents is known as backcross. In the backcross breeding, the hybrid and the progenies in the subsequent generations are repeatedly backcross to to that of the parent to which it is backcrossed. At the end of the 6 – 8 backcrosses, the progeny one of the parents. As a result, the genotype of a backcross progeny becomes increasingly similar would be almost identical with the parent use for backcrossing.

OBJECTIVE

This is to improve one or two specific defect of a high yielding variety, which is well adapted to the area and has other desirable characteristics. The characters lacking in this variety are transferred to it from a donor parent.

REQUIREMENT FOR SUCCESSFUL BACKCROSSING

1) Suitable recurrent parent must be available which lacks in one or two characters.
2) Suitable donor parent.
3) Character to be transferred must have high heritability.
4) A sufficient number of crosses should be made so that the genotype of the recurrent parent is recovered in full. Ordinarily 6 – 7 backcrosses are sufficient for the purpose.

BULK POPULATION BREEDING

In this method, F_2 and subsequent generations are backcrossed in mass or as bulk to raise the next generation. At the end of the bulking period, individual plants are selected and evaluated in a similar manner as in pedigree method of breeding. It is suitable for handling the segregating generation of cereals, smaller millet, grain legumes and oil seeds.

USES

1) Isolation of homozygous lines
2) Waiting for the opportunity of selection
3) To provide opportunity for natural selection to change the composition of the population.

NOTE: In bulk method, the population is carried to F_6 or F_7 as bulk, by the time the population approaches 96% homozygosity.

PROCEDURE

First year: Selected parents are hybridized.

Second year: F_1 space planted, seeds harvested in bulk.

3rd to 7th year: F_2 – F_6 planted of commercial seed rate, seeds harvested in bulk, use of artificial selection, disease epiphytontics etc.

8th year i.e. F_7 is space planted, individual plant selected and seeds harvested separately.

9th year: (i) Individual plant progenies grown

(ii) Inferior progenies eliminated

10th year: (i) Preliminary Yield Trials using standard variants as checks.

(ii) Quality test done

11th – 15th year: (i) Multiplication yield trials

(ii) Seed increase for distribution

ADVANTAGES OF BULK BREEDING

1) Simple, convenient and inexpensive
2) Isolation of desirable types thus becomes much easier.
3) Natural selection increases the chances of superior the in the population.
4) Little work or attention is needed in F_2 and subsequent generation.
5) No pedigree record is to be kept which saves time and cost.
6) Artificial selection may be practiced to increase frequency of desirable genes.
7) It is suitable for studies on the survival of genes and genotypes in population.

DISADVANTAGES OF BULK BREEDING

1) Longer time to develop new variety.
2) It provides little opportunity for breeder to exercise his skill.
3) Large number of progenies at the end of the bulking period.
4) Information on the inheritance of characters can not be obtained.
5) In short term, bulk i.e. isolation of homozygous lines, natural selection has little effect on the genetic composition of population.

METHODS OF BREEDING CROSS-POLLINATED CROPS MASS SELECTION

One of the oldest and widely used breeder's procedure with cross-pollinating crops. It is based on phenotypic selection of fruits that can be identified, they are the fruits that can be easily picked, it also effective in sorting at and accumulating gene at particular quantitative characters which can be seen or measured easily and therefore can be used as bases for selection. It can be used in open-pollinated maize to develop variety change in earliness to maturity, height of plant, size of ear, type identification by continuous mass selection.

PROCEDURE

Several hundreds or thousands of desirable individual plants are selected based on their phenotype, harvest and the seeds bulked without any progeny test to produce the next generation in a single plots Selection can be carried out by tagging or roughing when number of selected plants is few.

During the next growing season, crop is inspected at regular interval throughout the life cycle of the plants/crops to remove off types (plants that have arise because they have escaped to be unobserved in the previous season or those that develop due to spontaneous mutation). The bases for combined with specific characteristics, which appeal to the breeder.

The purposes of mass selection are

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

The efficiency with which is accomplish under a system of random selection depends on

1) **The effect of genes for desirable characters:** The success of mass selection of a particular trait is higher if such trait is being controlled by genes with additive effects than genes with dominance effect.
2) **Heritability of the trait:** Mass selection is based on the choice of phenotype. Its success depends to the large extent on the heritability of the desirable trait. If the level is high, the progenies in the subsequent generation would be similar to the selected

phenotype. If on the other hand, it is low, which is the case with many quantitative traits, the progenies might differ from the selected phenotype.

3) **Genotype x environment interaction:** Selection will not be successful if G x E is high, this is the case with genes with low heritability.

4) **Sample or Population size:** Sample size especially with open pollinated lines should be as large as possible to avoid inbreeding depression which frequently cause yield reduction.

The breeding progress that may be made by mass selection is limited because of three main causes.

1) Inability to identify superior genotypes from the phenotypic appearance of single plants.
2) Uncontrolled pollination, so that selected plants are pollinated by both superior and inferior pollen parents
3) Strict selection leading to reduce population size which in turn might lead to inbreeding depression.

RECURRENT SELECTION

The recurrent selection schemes were devised in relation to heterosis breeding. The idea was to ensure the isolation of superior inbreds from the population subjected to recurrent selection from their ultimate utilization in the production of hybrids and synthetic varieties. Recurrence selection is effective in increasing the frequency of desirable genes in the population.

The recurrent selection schemes are in four different types based on the ways in which plants with desirable characters are identified.

1) Simple recurrent selection for phenotype
2) Recurrent selection for general combining ability
3) Recurrent selection for specific combining ability
4) Reciprocal recurrent selection

Generally, recurrent selection is particularly useful where:

1) The frequency of genes for particular quantitative character is to be increased or concentrated.
2) When you want genetic recombination to increase by providing for recombination among lines derived from different foundation lines.
3) Maintenance of genetic variability in the breeding population is needed.

PROCEDURE FOR RECURRENT SELECTION

First year (i) Several phenotypically superior plants selected

(ii) Selected plants self-pollinated

(iii) Seeds harvests separately

(iv) Seeds evaluated, superior seeds retain

Second year (i) Individual plant progeny planted

(ii) Possible intercrosses made

(iii) Equal amount of seeds from all intercrosses composited

Third year (i) Composited intercross seeds planted

(ii) As in (i) to (iv) in the first year

Four year (i) Individual plant progency planted

(ii) As in (ii) to (iii) in the second year.

The cycle continues until the desired aim is achieved or when there is no more progress in terms of desired characters.

Recurrent selections meant to include reselection generation after generation of selection provide for genetic recombination, thus selection among isolated inbred lines or clones is not recurrent until such selected plants are interbred and a new cycle of selection is initiated.

ADVANTAGES

1) The highest performance of this breeding method is set not by the genotype of a single foundation plant but by the most favourable combination of genes contained in the group of foundation.
2) The satisfactory individuals showed within selfed or mildly inbred lines estimated in the populations of recurrent selection.
3) Since the rate of inbreeding can be kept at a low level, it is possible to maintain high genetic variability and hence provide for effective selection over a longer period.

RECURRENT SELECTION FOR PHENOTYPE

In this type of RS, plants are selected on the basis of phenotypic scores taken on individual plants or their selfed progenies. Since test crosses are not made, the effective use for recurrent selection for phenotype is restricted to characteristics with sufficiently high heritability so that an accurate phenotypic reevaluation of the characteristics can be made visually or by simple effectiveness in breeding for improved combining ability for yield. E.g. it can be used to concentrate genes for resistance to leaf blight of maize.

RECURRENT SELECTION OF GENERAL COMBINING ABILITY

In this type of RS, a number of plants which appeal to the breeder are selected from the source population. These selected plants are selfed and also crossed to heterozygous tester stock to identify the selected individual with good general combining ability.

Heterozygous means that the tester has a broad genetic base.

A tester is a common pollen parent, which may be a standard variety or test hybrid of a single cross.

Test cross is the cross between the superior progeny and the testers.

RECURRENT SELECTION FOR SPECIFIC COMBINING ABILITY

This type of RS has the same operational procedure as recurrent selection for general combining ability except for different tester. Here the progeny test is with homozygous tester line i.e tester line with narrow genetic base. It is either an inbred line or a selfed plant. With this kind of selection procedure, it is possible to increase the proportion of each cycle of selection as well as to increase the frequency of desirable genes in the inbred lines.

RECIPROCAL RECURRENT SELECTION (RRS)

This method employs two heterozygous source populations A is B. each of which is the tester for the other. These two populations must be genetically unrelated.

PROCEDURE

Select a number of plants from population A and outcross with a sample of plants from source B.

Select a number of plants from population B self them and make crosses with A and evaluate progeny performance from population A and B singly. The plant selected are then interbred each source group separately, group bulk the seeds separately and the resulting cross seeds will serve as a source population for another cycle.

Population developed by RRS will be utilized by producing commercial seeds from crosses between A and B source groups.

HYBRID VARIETIES BREEDING

This refers to the production of heterozygous population from crosses of homozygous lines.

Hybrid breeding is mostly applicable to cross pollinated crops where exploitation of heterosis is relied upon. It however has limited usefulness in self-pollinated crops. It came into prominence with maize.

There are two technical steps in the production of hybrid seeds for cross-pollinated crops.

1) Production of homozygous lines
2) Crossing of these lines to obtain hybrid sees.

PRODUCTION OF HOMOZYGOUS LINES

Usually through continue inbreeding. In self-pollinated crops, homozygous lines occur naturally but in cross-pollinated crops they must be produced by the Plant Breeder.

A) In perfect flower species: The inflorescence merely needs to be bagged to exclude foreign pollen.

B) In Monoecious crops: The pistillate flower must be protected and pollens must be collected and applied to the stigma surface of the pistil.

C) A number of crops resist self fertilization because of incompatibility mechanisms. Foreign pollen will be required to effect fertilization. Haploid can also be produced which can be doubled latter.

Although maximum heterosis is obtained by crossing two diverse inbred lines, a number of other combinations produce hybrid vigour. The various kinds of crosses that are referred to as hybrid in the trade are distinguished as follows.

Single cross hybrid: Inbred x Inbred (A x B) A single cross hybrid is usually made by alternate planting of 2 rows of seed parents to one row of pollinator-inbred line in an isolated plot. The seed parent should be detasselled. The planting distance of the crop should be the

normal or standard spacing for the chosen crop. The tassel on the male parent is left on the plant to fertilize the seed parent (female parent). The planting agent is wind.

Three-way-cross: F1 hybrid x inbred i.e.

i) Inbred x Inbred – F_1 (seed parent)

ii) F_1 x Inbred (Pollinator)

The single cross is used as the female parent. To be successful, the inbred line being used, as the male parent must also excel in pollen production.

Double cross: F_1 hybrid x F_1 hybrid. It involves four inbred and two single crosses i.e. it is the hybrid between two single crosses involving four inbred lines. In this type of hybrid, the seed used for commercial planting is produced on a single cross seed parent (female parent) that yields 2 or 3 as much as any inbred lines. Pollen is produced in abundant by the other single cross. The superior pollen producing ability of the single cross pollinator permit planting rate of 6 rows of seed parents to 2 rows of pollen parent.

ADVANTAGES OF HYBRID

1) Distinctly more productive than even the base open-pollinated varieties.
2) They are much more disease resistant.
3) They have significantly better stock strength.

DISADVANTAGES OF HYBRID

1) The yield ability of the hybrids lack consistent superiority from year to year. Hence farmers get new set of seed seasonally. Synthetic varieties can be used to curb this.
2) They are costlier to produce than open-pollinated plant because a lot of work and manpower is needed.

SYNTHETIC VARIETIES (SV)

SV uses an appreciable out of hybrid vigour in addition to open pollination. SV is a variety maintains from open-pollinated seed following it's combinations among a number of selected genotypes. These genotypes can be clones, inbred lines a mass selected population

(i.e. open pollination) superior for their good character. Also, this genotype must have been tested for combining ability and found to combine well with other parents to produce superior character.

The larger the number of genotypes that are tested for combining ability, the wider the genetic base of the synthetic varieties obtained. Some scientist after working with maize Hayes and Garber (1919) have this conclusion:

The production of improved variety through the recombination of several selfed lines/ strains has more advantage over either the single or double crossed plan (i.e. hybrid maize) in that the farmer can save his own seeds from the yearly crop and that yearly crosses need not be made.

STEPS INVOLVED IN PRODUCTION OF SYNTHETIC VARIETY

i) Isolation of one generation of one selfed lines.

ii) Test these lines in top crosses for yield and other characters (i.e. combining ability by looking for their $F_{1.}$

iii) Allow random mating among the better lines to produce synthetic variety.

iv) Repetition of the above processes of intervals after a generation of 2 open pollinations.

USES OF SYNTHETIC VARIETIES

1) Synthetic variety has value as reservoir of desirable germplasm (i.e. gene bank) because of its wide variability.
2) Also of value where the cost of hybrid seeds is too high compared to the value of accepted crop.
3) The greater variability of SV then that of double crosses permits more flexibility in meeting the changeable growing conditions of marginal areas.
4) Also useful were the commercial acreage available is too small to support a hybrid seed industry.

SELECTION IN ASEXUALLY PROPAGATED CROPS

Selection is straight forward in asexually propagated crops since any genotype may be perpetuated intact. Obtaining segregating populations from which superior genotypes may be found is the problem in breeding asexually propagated materials.

BREEDING OF ASEXUALLY PROPAGATED CROPS

Mode of reproduction:

All living things reproduce themselves before they die; the purpose of flowers in plants is to reproduce the plant. Seeds, which grow into new plants, develop from flowers. Some plants reproduce by (more or less strict) self-fertilization, other plants only (mainly) allow cross fertilization. Asexual propagation (vegetative propagation) can also occur in plants (e.g. cuttings from cassava plants). This gives a new plant which is genetically identical to its parent plant. All these differences change the way plant breeders work.

Importance of mode of reproduction:

The mode of reproduction of a crop determines its genetic composition, which in turn, is the deciding factor to develop suitable breeding and selection methods. Knowledge of mode of reproduction is also essential for its artificial manipulation to breed improved types. Those breeding and selection methods which are suitable for a crop, does not interfere with its natural state. They ensure the maintenance of such a state. It is for this reason that imposition of self-fertilization on cross-pollinating crops leads to drastic reduction in their performance (inbreeding depression)

Plant breeding is the propagation and genetic manipulation of plants, for the purpose of selecting improved offsprings. Here, it is therefore as applied to asexually propagated crops. Asexual reproduction covers all those modes of multiplication of plants where normal gamete formation and fertilization does not take place making these distinctly different from normal seed production crops. In the absence of sexual reproduction, the genetic composition of plant material being multiplied remains essentially the same as its source plant. Many plant species are propagated vegetatively e.g. potato, grapevine, fruit trees, cassava, some forest trees etc. Vegetatively propagated offsprings are used to develop stable varieties without any

deterioration due to segregation of gene combinations. A vegetative part taken from a plant, such as a tuber, a root, a rhizome, a leaf or a stem, may be used for asexual vegetative propagation.

Clonal propagation is to obtain the largest possible superior genotype resulting in identical and uniform progenies which can't be obtained by sexual propagation. This is so because plants arising from a clone are identical and have the same genetic constitution as the mother plant. Variability amongst plants within a single clone can be classified as environmental because they can not be inherited by progenies. The only form of heritable variability is somatic mutation which is inherited through the vegetative mode of propagation.

Grafting

Apart from direct vegetative propagation through tubers, rhizomes, corms etc, horticultural crops (fruit trees, grapevine, and decorative plants) can also be propagated by grafting. Grafting is joining the stems of two different plants of the same genus so that they grow together as one plant. The recipient plant which grows into the roots is called a STOCK while the vegetative part used for the grafting and which grows into the stem and branches is called a SCION. Grafting is not for production of new cultivars but for speedy propagation of superior genotypes that will be identical to the scion. Grafting may bring about larger variability than propagation without grafting. These changes may be classified into:-

(a) Non – heritable
- Modification – type changes
- Chimera – type changes

(b) Heritable
- Mutation – type changes

Non – Heritable
- Modification type changes

Most grafting methods practiced bring modification type changes. Such changes are :- more or less vigorous growth, larger or smaller fruits, earlier maturation on one stock than on another etc. These changes are not transferred to progenies by sexual means.

- Chimera type changes

These are brought about by mixing of tissues after grafting. These changes are called chimeric changes and are different from modification type changes. Different types of chimeras (sectoral, periclinal, shoot with only scion tissue, shoot with only stock tissue) develop as a result of different modes of fusing and mixing of plant tissues of the stock and scion. These changes are sometimes so striking and unusual that it is difficult to accept them

as non-heritable changes. Chimeras are maintained only by vegetative propagation and being used in a number of horticultural species.

Heritable changes

Various substances come to scion from stock during tissue fusing. The larger the difference between stock and scion, the more different are the substances exchanged between them. A possibility exists for some organic substances exchanged between scion and stock to be mutagenic and to cause in some cases mutations of a certain gene. The frequency of such changes is very low (thousandths of one percent).

Advantages of grafting

1. It allows the propagation of somatic or vegetative mutations which cannot be achieved by sexual means
2. It allows the stabilization and utilization of heterozygous genotypes (which is not possible in selfers and only in large population of crossers in equilibrium)

Source of materials for plant improvement

There are two (2) main sources of materials for plant improvement in vegetatively propagated crops:

(a) Clones or population of mixed clones usable for the production of stocks and scions (cultivars)

(b) Populations of seedlings usable for the production of stocks and scions.

Selection of clonal stocks and scions

Clones are genetically homogenous because all plants originate from one ancestral mother plant. But, in some cases not all members of a given clone have the same genotype e.g. in case of spontaneous mutation of certain buds or when one branch is diploid and another triploid etc). Clonal selection of positive/ beneficial mutants A heterogeneous population of mixed clones (from different ancestral mother plants) contains different genotypes and as such a good population for selection of clonal stocks or scions.

can produce new varieties

STOCKS: Selection of clonal stocks is important because different stocks are suitable for different cultivars as well as for various climatic and soil conditions. Success in production depends not only on the traits of the scion but also on that of the stock (Cummins and Aldwinckle, 1983). Rootsocks obtained by clonal selection are therefore preferred to those

from seedlings because they produce high uniformity of fruit bearing trees to allow for simultaneous application of chemicals, mechanized harvest and to meet market demands.

Criteria for selection of stock:

1. Propagation ability – propagation requirement of the commercial nursery
2. Graft compatibility – The stock must be compatible to most commercial scions (cultivars)
3. Yield – It must induce early flower buds and good fruit set together with regular and heavy production
4. Longevity – Good survival under the prevailing conditions
5. Resistance to diseases found in the soil e.g. *fusarium* wilt, nematodes etc.

SCIONS: Methods of mass and individual selection may be applied in the selection of clones for scions. The procedure of mass selection starts with positive selection of the plant materials to be used for cloning. When cloning is done and the scions are grafted unto certain stocks, negative selection (individuals) is conducted to remove weak and diseased nursery plants. Individual clonal selection is done for best trees or vines based on important agronomic traits because considerable variability exists in certain cultivars that make individual trees differ in productivity, quality, disease resistance etc. These selected trees or vines are then vegetatively reproduced (cloned). Examples are found in the development of walnut cultivar shampion on the basis of individual trees of a Yugoslav local population (Korac *et al*., 1988)

Selection of seedling stocks and scions:

Sexual reproduction of fruit trees produces populations of seedling which exhibits large genetic variability due to cross pollination and mutation. There are three (3) main sources from which to select seedlings:

1. Natural populations (populations in the wild)
2. Artificial populations (seeds develop as a result of uncontrolled mating in orchards, therefore fruit seeds produce a heterogeneous population which serves for selection of seedlings for new stock and scions).
3. Known hybrid populations (mating of known cultivars in an orchard)

STOCKS: Seedlings from natural populations are mostly used for the production of stocks (sexually produced stocks). Seedlings are grown in a nursery and selected for one or more years depending on the plant species. Being heterogeneous populations, seedlings are separated into groups. Within group negative selection is practiced to eliminate seedlings

which are poorly developed, susceptible to diseases or possess other undesirable traits. The best seedlings are transplanted and multiplied vegetatively (e.g. in large no of fruits such as peach, almond, cheery, olive, walnuts etc)

Disadvantage:

It is difficult to produce uniform and homogenous stocks (due to segregation) and consequently, the orchard differs in growth and productivity. This in turn creates problems in plant protection, picking and fruit quality (Pejkic, 1980). Vegetative or clonal stocks are quite uniform and are being used instead.

SCIONS: Artificial populations are used for the production of scions from which to select new cultivars. Artificial populations are rich sources of new cultivars because seedlings found accidentally in them may give rise to some novel cultivars. Seedlings from artificial populations are grown in a nursery, with individual selection based mostly on visual observations carried out. Examples are found in some apple cultivars, pear cultivars etc.

Known/Planned hybrid population

Natural and artificial populations result from natural hybridization. They do not fit into the concept of planned development of cultivars. Cultivars possessing certain desirable traits are developed on the basis of planned hybridization preceded by careful selection of parental pairs.

Particular attention must be paid to rootstock breeding because it is quite different from scion cultivar breeding. The physical environment (temperature, gas exchange, moisture, soil etc) are quite different in the rhizosphere than above ground of scion; the biotic environment (pathogens, insects, symbiotic relationships etc) and also, the physiology of root is quite different from that of the leafy portion (scion) of the tree.

Merits:

1. It comes out with new and desirable gene recombination
2. It allows for the vegetative use of F_1 generation which frequently contains the best recombination of genes of the two parents (highest level of heterozygosity)
3. Vegetative reproduction allows desirable genotypes from the F_2 and subsequent generations to be used without having to wait for them to become homozygous. Examples abound in a number of grapevines, peaches etc (self pollinating species) and also in cross-pollinated species where known parents were hybridized.

Apomixis:

Vegetative propagation can also be achieved by the use of seeds of apomictic origin. Apomixis is a type of reproduction in which the sexual organs or related structures take part, but in which seeds are formed without union of the male and female gametes, but in an essentially asexual way i. e. without fertilization (fatherless plants). Seeds formed in this manner are vegetative in origin and resemble only the female parent. As a reproductive method it eliminates genetic changes. All that is necessary in order to have identical seedlings the next season is to take seeds from prolific stock. The seedlings of the next generation are identical to each other and to the female parent plant, on account of their high uniformity, are very useful for the production of root stocks for citrus plants. Examples are also found in some species of forage grasses (*Panicum maximum, Eragrostis curvula* etc.) There are several types of apomixis of which apogamy, apospory, diplospory, and parthenogenesis are the most frequent:

(a) Apogamy

The embryo develops from the fusion of two haploid cells other than the eggs i.e. nuclei of the embryo sac. The cells are either synergids or antipodals. The resulting plant is diploid and it develops normally.

(b) Apospory

The embryo sac is formed directly from a somatic cell (2n), without reduction. The embryo in turn develops directly from a diploid cell in the embryo sac without fertilization.

© Diplospory

This occurs when the embryo develops from the megaspore mother cell without chromosome reduction.

(d) Parthenogenesis

The embryo develops directly from an unfertilized egg. If the chromosome number of the gamete (egg) has been reduced at meiosis and chromosome doubling of the unfertilized gamete does not occur, the embryo and the plant developing from it will be haploid. If the egg cell has an unreduced chromosome number (during meiosis) as a result of some abnormal occurrence (spindle fibres refusing to form) during meiosis, the embryo and plant will be diploid.

Some plant species are obligate apomictics while some are facultative apomictics.

- Obligate apomictics only reproduce by apomictic means, hybridization and gene recombination are precluded from their life cycle.
- Facultative apomictics have both apomictic and sexual reproduction.

N/B

It is important that a breeder be informed of the tendency of a species to produce seed by apomixis to avoid confusion and error in breeding experiments.

Advantages

(a) Crosses attempted in apomictic species would generally produce progenies identical to the mother plant.

(b) It can be used for the propagation of superior genotypes, especially if they are heterozygous. This is because a superior plant type which produces seed by apomixis will usually breed true for the characteristics of the mother plant.

Disadvantage

In case of obligate apomictics, in which hybridization and gene recombination are precluded, apomixis reduces genetic variability and therefore lowers breeding success. Facultative apomictics are thus preferred because they are open to gene recombinations and the development of new genotypes.

BREEDING FOR DISEASE RESISTANCE

This is breeding for varieties / cultivars of crops that will not allow the activities of pathogens in their systems. This type of research is important for the following reasons:-

1. Diseases and pests develop on the leaf surfaces in most cases, thus reducing photosynthetic activity and hence the yield of such crops which eventually translates to economic loss to the grower
2. It is also important in order to reduce the chemical means of control to a minimum, so as to lower production costs, increase the nutritional value of agricultural products and to improve the environment.

Fungi, bacteria and viruses are the most frequent pathogens of plants. Trying to achieve higher yields and production per unit area, modern agriculture has introduced monoculture which involves growing pure varieties and the application of high doses of mineral fertilizers, especially nitrogen. This has created very favourable conditions for the development of pathogenic organisms. When a pathogen occurs in the most favorable spot in a field, it spread rapidly over the entire field and, if the same cultivar is grown in the neighbouring fields, it causes an epidemic. The consequences are reductions in yield and quality which in turn bring about large economic losses. This therefore calls for efficient measures of protection against diseases and pests.

There are four main methods of controlling pathogenic organisms:

1. Development of cultivars resistance to certain pathogens
2. Manipulation of agricultural practices (crop rotation, intercropping, avoidance of monoculture etc)
3. Biological control of parasites

The Parasite – Host Relationship

Plant growers are interested in having a healthy crop in which large economic damages cannot be inflicted by parasites. Whether a crop is healthy or diseased depends on the relationship established between the parasite and the host plant.

- Complete resistance: is an ability of the host to prevent any multiplication of the parasite. The resistant plant is considered to be hypersensitive, using the products of metabolism (toxins) to prevent the parasite from invaliding the plant and thriving on it
- Incomplete or partial resistance: has 50% resistance and 50% susceptibility.
- Tolerance: is also a kind of genetic resistance. Some cultivars are susceptible to a pathogen which develops on them, however, these cultivars tolerate the attack without suffering a significant yield reduction. The degree of tolerance of a cultivar may be calculated from the ratio between yields in an infected and an uninfected plot, the tolerance being higher as the ratio approaches unity.

Types of Resistance:

Resistance to plant diseases can be described either in functional or in genetic terms. The functional terms recognize that resistance may be both highly specific and effective against some parasite races but not others. This is race-specific resistance. OR Non-race specific and equally effective against a range of biotypes (races). These two types can also be called vertical or horizontal resistance respectively. Tolerance is sometimes described as a form of horizontal resistance. The genetic terms that describe resistance describes its mode of inheritance. Oligogenic resistance is usually determined by single genes. We have cases of single dominant genes and also single recessive genes e.g. gene HT (dominant gene) in maize confers resistance to *Helminthosporum turcicum*; rhm gene is a recessive gene also conferring resistance to *Helminthosporum maydis* race - O and race –T. Polygenic resistance is controlled by many genes of individually small effect. It is usually general; affording resistance to a wide spectrum of pathogen races.

Breeding Methods:

Breeding for resistance is usually carried out co-operatively by a plant breeder and pathologist. The possible control of disease through host resistance is an important biological

principle that is well established. Breeding programmes designed to produce resistant varieties must obviously start with resistance conferring genes. Resistance most useful in plant breeding is that found in varieties of the same species. Sometimes however, adequate resistance does not appear to exist in cultivated species and then the breeder usually has two alternative sources. Firstly, he can search for resistance in related species or genera; secondly, is to attempt to induce resistance through mutagenic agents.

The best sources of resistance, nowadays, can be found in international nurseries. Most resistance genes have been transferred from wild relatives to cultivated crops, which saves breeders the trouble of having to go the long way of inter-specific hybridization. Local varieties and populations which are becoming extinct used to be more tolerant to parasites because of their genetic diversity and heterogeneity than the new high yielding cultivars, which are genetically uniform and homogeneous. The local varieties are therefore prospective sources of resistance genes, whether oligogenes or polygenes.

After resistance genes are known, they may be transferred to an adapted variety by standard hybridization procedures. Breeding for disease resistance differs in no fundamental way from breeding for other characteristics. Therefore, any of the various methods of breeding appropriate for the crop in question can be used in developing disease resistant varieties. When genes for resistance occur in existing commercial varieties, selection within these varieties will almost always promote the easiest and most satisfactory method of developing resistant strains. When adequate resistance is not found in commercial varieties, but only in types that cannot be used commercially, because of their unsuitable agronomic properties, either the backcross or pedigree method of breeding is usually used. With either method, one of the parents is select on the basis of demonstrated high level of resistance to maximum number of races and minimum number of genes controlling resistance and the other is chosen for its good agronomic or horticultural characteristics. If the resistant parent is wholly unadapted type, the backcross method is the logical option as a breeding procedure to transfer the gene for resistance unto the other parent. If, one the other hand the breeder is satisfied that the resistant parent can also contribute to improved adaptation, quality or yield, he may choose the pedigree or bulk methods of handling segregating generations. The pedigree method has been very widely used in breeding for disease resistance, and the majority of disease resistant varieties have been produced by this procedure.

In breeding for resistance, exposure to the disease, either in natural or artificially induced epiphytotics, is necessary to distinguish between the resistant and the susceptible plants. Epiphytotics is often irregular and light in natural conditions, therefore, induced epiphytotics

will be more appropriate. Progeny tests of resistant plants are made to verify the inherent nature of the resistance and to ensure that uninfected plants have not merely escaped infection. The resultant strains will be selected both from the stand point of disease resistance and agronomic characters that will adapt them for agricultural use. In the final selection of varieties for the farmer to grow it is often necessary to compromise between superior disease resistance and superior adaptation when both characteristics are not found in the desired intensity in the same variety.

GERMPLASM CONSERVATION

A wide range of plant species has evolved as a result of the interactions of diverse climatic, ecological and edaphic factors and the culmination of thousand of years of natural evolution, mutation and to some extent human manipulation. These species constitute a pool of diversity from which plant scientists tap the raw materials they need for their crop improvement programmes. Plant genetic diversity is a key ingredient for sustainable agricultural development. Germplasm is a term used to describe a collection of these genetic resources for an organism. The plant germplasm consists of the reproductive structures of plants through which genes are transmitted from one generation to another and may include pollen, anthers, or ovules.

For a long time the genetic diversity of crops was naturally preserved. However, in recent decades, there has been a rapid deterioration of natural resources resulting in loss of genetic diversity. The rapid increase in population has resulted in an ever increasing pressure on the environment and the destruction of natural habitats. Also, the shift to monoculture and more uniform varieties over the last few decades as the world strive to feed its ever increasing population and frequent famine and drought, has led to erosion of genetic diversity an biological resources in general. Overgrazing of most grasslands, an increase in both the number and frequency of bush fires and the spread of soil erosion have all played a major part in the reduction of genetic resources. There is therefore an urgent need to preserve and conserve this diversity, both ex-situ and in-situ, for future use in adapting crops to new and changing environmental conditions and to sustain increase in agricultural production and development.

For many species, in-situ and on-farm conservation in protected areas may be the most appropriate method of conserving the gene pool. For a conservation effort to be sustainable, the long term security of the germplasm must be assured as well as its availability and adequate information to make it useful. Conservation without utilization could become a burden, especially for developing countries. This is what ex-situ conservation is all about

because the long term conservation cannot be achieved in-situ. International plant Genetic Resources Institute (IPGRI) focuses especially on how best to conserve the genetic diversity of wild crop relatives and forest species ex-situ.

Germplasm Collection:

Before and during the 1970s, especially in Africa, very few collecting expeditions with the primary goal of conservation of germplasm took place. Most expeditions were rescue mission targeted at endangered species and the collecting of specific crop species of major priority; mostly cereals and grain legumes. The trend in recent years is towards specialized collecting and acquisition of the wild relatives of crop species. This will continue as plant breeding techniques become more advanced and the value of these wild relatives is increasingly recognized. Also, attention is increasingly being focused on a regional or country basis rather than on emergency situations to salvage endangered species.

The work of conserving crop plant genetic resources is more than just conserving variation per se, but also has to do with the effective use of the resources conserved. A collection methodology that can make important contributions to both objectives is the Core collections. It has over the past decades become an increasingly important aspect of conserving and utilizing crop garmplasm effectively.

What is a Core Collection?

A core collection consists of a limited set of accessions of a crop species and its wild relative chosen to represent, with a minimum of repetitiveness, the genetic diversity and spectrum of a crop species and its wild relatives. The core should include as much as possible of its genetic diversity and provide potential users with a large amount of the available genetic variation of the crop gene pool in a workable number of accessions. It would therefore be useful to plant breeders seeking new characters which require screening techniques not possible with a large collection. Because each of the accessions in a core collection is, to some extent, representative of a number of accessions (from a particular area of the world or with some shared characters), the core can also be used as a point of entry to the active or base collections of a crop. Detailed research can be carried out on a core to obtain an effective picture of the characteristics of the gene pool as a whole.

The core collection has been able to solve two major problems militating against effective use of germplasm collection. Firstly, because of the emergency salvage mission embarked upon in the early 1970s, the volume of the collections that were assembled worldwide has far outgrown the management resources and regimes of the established gene banks. Secondly the

use that has been made of these collections to bring about economically significant improvements in yield and profit has been patchy and often not up to the expectations of governments. Generally, this has been because gene bank managers have been unable to cope with the major task of evaluating their material to enable crop breeders to select from it the samples most likely to meet their needs.

Germplasm Conservation:

Conservation as defined by the United Nation (UN) means "the rational use of the earth's resources to achieve highest quality of living for mankind". It is the vital link between the acquisition and utilization of plant genetic resources and includes all the ways in which plant germplasm is stored and preserved. Germplasm can be conserved as seed, as vegetative materials, as tissue cultures or as living plants in- situ or ex-situ. One or more of these methods may be used for any crop. The needs of conservation and the resources devoted to it vary widely with the crop. The representative nature of the core makes it suitable for developing new methods of conservation such as ultra-dry seeds, in vitro or cryogenic storage. Curators are faced with the task of regenerating and multiplying old and neglected collections in the gene bank. They are also to monitor the viability of materials in the bank by routine seed testing.

Characterization /Evaluation:

Characterisation of the collected resources, prior to storage, is essential for further utilization. Thus, the potential of all accession needs to be assessed. Equally important is the information (passport data) that is collected during the collecting of the germplasm. The use of IPGR descriptor lists and collecting forms during collecting missions and the distribution of these forms to all collecting institutions and collectors has helped to standardize and initiate systematic characterization and documentation. The forms are designed to ensure that relevant information is collected during the collecting exercise. Characterization may be undertaken during the regeneration of old collections and sometimes during the multiplication of small-sized samples before their storage.

Use of germplasm in breeding programmes*:*

In cases where the germplasm is well characterized and documented, further evaluation leads to its use in breeding programmes:

1. Increased food production using stable, high-yielding varieties can be achieved by incorporating the useful adapted genotypes
2. High-yielding varieties of crops which are tolerate/resistance to insect attacks, diseases and various stresses such as drought or poor soil fertility can be developed by screening the germplasm collections

3. Nutritional values of various crops can also be improved
4. A rare/novel variant might be discovered through the screening of the germplasm