CROP IMPROVEMENT

- The process of bringing wild species under human management is called as **Domestication**.
- Crop improvement or Plant Breeding is an applied branch of botany that deals with the improvement of crops and production of new crop varieties which are far superior to existing types in all characters.
- It began with the **selection** of some plants by man for cultivation. Later these are **introduced** to other places by man during his migration.
- **Babylonians** and **Assyrians** artificially cross pollinated date – palms.
- **Camararius** discovered sex in plants.
- **Cotton Mather** identified natural hybridization in Maize.
- **Thomas Fairchild** produced the first artificial hybrid.
- The German **Joseph Kolreuter** made extensive crossings in tobacco and produced several hybrid varieties.
- **Knight** applied hybridization to develop several new fruit varieties.
- **Norman Borlaug** laid foundations for green revolution.
- Plant breeding developed as a science only after rediscovery of Mendal's laws.
- Techniques of *cytogenetics* are useful in achieving wonderful results in plant breeding.
- Now-a-days the techniques of **molecular genetics** are applied to save time in crop improvement.

Aims and Objectives

- It aims to improve agronomically and economically useful characters in crop plants.
- The main objective is incorporating as many desirable characters as possible into a single variety to make it as superior variety.

1. To *increase the yield* of various types of plant products such as grains, pulses, fibre, oil, fodder etc.
2. To *improve the quality of* produce such as size, colour, shape, taste, nutritional value, storing ability of grains, vegetables, fruits etc. and many other features such as high sugar content, high protein content in pulses, long and fine fibre in fibre crops, fruit size in fruit crops.
3. To develop *varieties resistant* to diseases, insects, drought, frost, floods, alkaline and saline conditions.
4. To produce *early mature* crops for crop rotation purpose.
5. To *change the growth habit and agronomic characteristics* of plants and to produce dwarf varieties, plants with profuse branching or more tillering, winter hardiness in certain situations and tolerance to moisture and salt stress.
6. Suitability of crops for easy harvesting, adaptability to wide regions are some of the other objectives.

Methods of Plant Breeding

- These are dependent on the type of reproduction and pollination mechanisms in plants. There are 5 methods of plant breeding known as 1. Plant Introduction, 2. Selection, 3. Hybridization, 4. Mutation breeding and 5. Polyploidy breeding.

1. PLANT INTRODUCTION :

- It is introducing plants into new regions from its growing locality.
- It is carried out between two districts, two states, two countries and two continents.
- Tourists, scientists, researchers etc. introduced several plants into their respective countries.

Advantages

1. It is easiest and simplest method. It requires only some skill but not scientific knowledge.
2. The new varieties can be directly used in agriculture and horticulture.
3. They serve as germplasm banks for crop improvement.

Limitations

1. The introduced plant must be acclimatized to the new environment. Otherwise it perishes. The adjustment of introduced plant to the new climatic conditions is known as **acclimatization**.
2. Some times along with the introduced plant material, pathogens and weeds also seek entry into the new locality and may grow luxuriantly in the new climatic conditions. Hence care must be taken to prevent the entry of such organisms by following quarantine laws. The pathogen *Phytophthora infestans* that causes **late blight disease** in **Potato** was introduced into India from Europe.

Achievements:

A. **Wheat:** Ridley variety from Australia, Sonora 63 and 64 from Mexico are introduced into India.
B. **Maize:** Dixies 11 and 22 and Texas 21 are introduced from America.
C. **Tomato:** Sioux variety from America
D. **Sweet potato:** FA 17 variety from China
E. **Rice:** Taichung Native 1 from Taiwan and IR – 8 from Philippines

2. Selection

- It is choosing the plants with desirable characters for cultivation.

- It is the oldest breeding method
- In natural selection (Charles Darwin) the nature itself selects the plants that fit to survive in the new environments and the weaker ones are wiped out.
- In Artificial selection, the selecting agent is man.
- Selection is basis for crop improvement. Most of the existing crops are obtained by selection. Greater the genetic variability in the crop, the better are the results obtained due to selection. There are three methods of selection known as Mass selection, Pureline selection and Clonal selection.

i) MASS SELECTION

- It is oldest method of selection and is useful in cross pollinated crops.
- The farmer, every year, selects the best appearing plants in his field and collects the seed from those plants to raise the next generation crop.
- This practice improves the quality and yield of the crop.
- Best results are based on the heterozygosity within the crop varieties.
- It takes about 8 years to produce a variety by this method.

Advantages

- It is the easiest method of crop improvement. There is no need of scientific knowledge except some amount of skill. Therefore it is more of an art than a science.
- It is the only method to improve wild and local cross pollinated varieties.

Limitations

- Selection is based only on phenotypic characters. Hence it is very difficult to predict the influence of environment, heredity on them.
- Since there is segregation of characters, results are apparent for only for short time.

Achievements:

- Most of the existing crops are products of mass selection

A. **Groundnut**: TMV. 1, TMV. 2
B. **Cotton**: Dharwar American, Dodahatti Local, Cambodias
C. **Bajra**: Pusa Moti

ii) PURELINE SELECTION

- The progeny of single, self-pollinated homozygous individual is known as **Pureline**. Choosing the desired purelines from a group of purelines is called as **Pureline selection**.
- The term pureline was introduced and pureline selection method for crop improvement was suggested by **Johannsen**. He conducted Pureline selection method in '**princess variety of beans** (*Phaseolus vulgaris*).'
- It is applied to only self-pollinated crops. In this, **200 – 300** plants are selected first and grown separately. Superior plants in every row are identified and seed is collected and sown in the next season. This process is continued for **10** years to produce a new variety.

Advantages

1. This is the only method to improve local self-pollinated crops.
2. It increases homozygosity and consequently all the progeny developed by this method are phenotypically and genotypically uniform.

Limitations

I. There is no chance for incorporating the characters not existing in the population. After reaching the higher level of homozygosity, there is no scope for further development.
II. Plants show poor acclimatization due to homozygosity
III. It is more complex and laborious process than mass selection. It requires skill and scientific knowledge. It is more as science than art.

Achievements

Groundnut : H.G. 8, K.T. 18
Rice : CO. 4, 6, 10, 14
Wheat : N.P. 4, 6, 12; K. 13, 54

iii) CLONAL SELECTION

- A group of plants obtained from a single plant by vegetative propagation is called as clone.
- Choosing the desired clones from a group of clones for cultivation is called as clonal selection.
- Individuals of a clone are phenotypically and genotypically same but in heterozygous condition.
- The units of clonal selection are sets in sugarcane, cuttings in roses, tubers in potato, bulbs in onion and suckers in banana.

Method

- Healthy parts of healthy plants selected on the basis of desired phenotypical characters after field tests.

- Selection within clone is not effective unless there are desirable mutations. Selection is made between the clones.
- It is applicable for both local and introduced varieties.
- The selected clones are tested for **3** years in different regional research stations and the best performing clones are released as new varieties.
- The time taken for the production of a variety by this method depends on the type of vegetative reproduction of the crop.

Advantages

1) Progeny of clone remains stable for any number of generations.
2) Hybrid vigour of the progeny can be exploited for any number of generations.

Limitations

1. It is limited to only vegetatively propagated crops.
2. There is no scope of producing new genotypes.

Achievements

Potato : Kufri red, Kufri safed

Mango : Mundapa Pedda Neelam

3. Hybridisation

- It is the most important method of crop improvement
- It is cross between genetically unrelated parents for crop improvement.
- The objective is to incorporate as many desirable characters as possible into a variety to produce **superior variety**.
- There is ample scope to obtain a rice variety with fine grain and disease resistance when a cross is made between a variety with **disease resistance and coarse grain** and variety with **fine grain and disease susceptibility**.
- **Genetic variability** obtained due to crossing is exploited for crop improvement.

Types of Hybridisation

A. Varietal Hybridisation: It has two types.

Intravarietal hybridisation: It is cross between two genetically different plants of the same variety.

Ex: Cross between two inbred lines of **Maize** to produce an intravarietal hybrid.

Intervarietal hybridisation: It is cross between two different varieties of the same species.

Ex: Paddy

Cross between **TN 1** and **T 141** produces Jaya. Padma is produced by crossing **T 141** with **TN 1**.

Tomato:

Cross between **Sioux** with **Meeruthi** yields **Pusa rubi.**

Interspecific hybridisation

It is cross between two different species of the same genus. It is also known as **Intrageneric hybridisation**. This method is usually employed to transfer disease drought resistance characters into the variety.

Ex:

1. Wheat: *Triticum aestivum* × *Triticum durum* → **P. I. 94587** variety (Resistant to hessian fly)
2. Cotton: *Gossypium hirsutum* × *Gossypium arboreum* → **Deviraj**
   Gossypium hirsutum × *Gossypium herbaceum* → **Devitej**
3. Tomato: *Lycopersicon esculentum* ×
   L. pimpinellifolium → **Red Plum**

C. Intergeneric hybridization

- It is cross between two different genera of the same family. It is difficult and rarely the hybrids are obtained.

Ex: *Raphanus sativus* × *Brassica oleracea var. capitata* → **Raphanobrassica**

Triticum aestivum × *Secale cereale* → **Triticale**

Method

1. Selection of parents

- This is the **first step** in hybridisation
- Homozygous plants with desirable characters must be selected as parents.
- If heterozygous, they must be subjected to self pollination till the traits become homozygous.

2. Emasculation

- It is removal of anthers in the bisexual flowers of female parents before the opening of flowers to prevent self pollination.
- In larger floral buds, it is easily carried out with the help of **sterilized needle** and **forceps**. During this, care must be taken not to injure the other floral parts.

- If the flowers are crowded and small, emasculation can be done by keeping the inflorescence in hot water at **45 to 50°C** for **1-10 minutes**. At this temperature, the gynoecium is undamaged but the pollen grains are made functionless.
- **Emasculation** can be avoided by using **male sterile lines** as female parents.

3. Bagging

- It is covering the emasculated flowers with **polythene** or **paper bags** to avoid unwanted cross pollination.

4. Artificial Cross Pollination

- Pollen grains of male parent are collected with the help of **brush** or **blotting paper** and carefully placed on the stigmatic surface of female parent. It is known as artificial cross pollination or **hybridisation**.
- The flowers must be **bagged** immediately.
- **Labels** carrying the information of the parents, date of pollination must be tagged to female parent.

5. Trials, Multiplication and distribution of Hybrids

- The hybrid plants produced by different methods must be tested at different research stations.
- Seeds are multiplied and finally released to farmers for cultivation.

Advantages

1. New genetic combinations can be created
2. Most of the hybrids exhibit hybrid vigour
3. A large number of desirable characters can be incorporated into a single variety.

Limitations

1. Thorough Scientific knowledge and field techniques are required.
2. It is laborious and expensive process.

Hybrid vigour or Heterosis

- It is superiority of the hybrid over its parents in terms of size and vigour.
- **Kolreuter** discovered it in tobacco but didn't give the reasons for it.
- **Shull** introduced the term **heterosis** upon conducting experiments on maize.
- He found decrease in the vigour of hybrid due to continuous selfing. It is known as **inbreeding depression**. When he crossed the weaker inbred lines he observed hybrid vigour.
- Plant breeders exploit it in developing high yielding hybrid varieties.
- The reason for hybrid vigour is presence of more number of dominant genes or heterozygosity.

Method:

- The hybrid plants obtained upon crossing the parents must be individually subjected to selfing for **5 – 7** generations to obtain homozygous inbred lines. These lines show **inbreeding depression**.
- Single crosses are carried out between two different inbredlines to obtain hybrids.
- The hybrids are tested and double crosses (cross between two different F_1 hybrids or single crosses) are made between the desirable hybrids.
- Hybrids of double crosses show more hybrid vigour.

4. Mutation breeding

- Mutation is sudden inheritable change in an organism
- **Hugo de Vries** discovered mutations in *Oenothera lamarkiana* (Evening Primrose).
- Inducing desirable mutations and exploiting them for crop improvement is known as Mutation breeding.
- **Muller** and **Stadler** laid foundations for mutational breeding.

Types of Mutations

- Based on origin, mutations are classified into two types. They are **spontaneous mutations** and **induced mutations**.

i. Spontaneous mutations:

- These are caused by themselves in nature. Its frequency is very low.
- **Electric currents, temperature variations, atomic particles** and **rays cause** spontaneous mutations.
- *Oenothera gigas* (large sized Evening primrose) and *Oenothera nanella* (small sized Evening Primrose) are familiar examples for natural mutations.

ii. Induced mutations

- **Muller** was the first person to induce mutations by using x-rays in *Drosophila*.
- **Stadler** induced first time induced mutations in barley by using x-rays.
- Genetic variations can be brought in relatively short period.
- Substances that induce mutations are called as mutagens.
- These are physical and chemical mutagens.
- Ionising radiations (x-rays, α-rays, β-rays, γ-rays) and non-ionising radiations like ultraviolet radiations are powerful physical mutagens.

- Seeds, seedlings, buds and flowers are subjected to irradiations to induce mutations.
- **Colchicine, Nitrous oxide, Mustard gas, formaldehyde, Ethyl methane sulphonate, Methyl methane sulphonate, Malic hydrazide** etc. are chemical mutagens. They mainly cause gene mutations.

Achievements

1. Disease resistance for leaf spot, blast disease, leaf blight in high yielding dwarf variety of paddy IR – 8.
2. **Jagannadh** variety of Paddy
3. Hardiness in **swedish** variety of barley
4. **Primex** variety of White mustard
5. **Aruna** variety of castor
6. Sharbati Sonora variety of Wheat.

Limitations

1. Most of the induced mutations are **undesirable** and even some are lethal.
2. A **large number of plants** have to be tested in order to get desirable mutations.
3. Mutant variety is subjected to **prolonged testing** in order to ensure the true breeding nature of mutagenic trait.

5. Polyploidy breeding

- Presence of more than two sets of chromosomes in a cell or organism is known as polyploidy.
- Utilising polyploidy for the improvement of crops is called as Polyploidy breeding.
- Many grasses are polyploid.

Types of Polyploids

i. Triploids

- These have three sets of chromosomes and usually sterile.
- These are formed due to cross between **tetraploids** and **diploids**.

Examples:

1. Seedless **watermelons** (*Citrullus vulgaris*) produced due to cross between tetraploid females and diploid males. These are commercially cultivated in Japan
2. Triploid sugarbeets (*Beta vulgaris*) produce larger roots with more sugar content.
3. **T.V. 29** of Tea produced by Tea Research Association of India is cultivated in North India. It produces **larger shoots, leaves** and **tolerant** to drought.
4. Cultivated banana (Musa paradisiacal) produces larger and seedless fruits.

ii. Tetraploids

- These polyploids have **4 sets** of chromosomes.
- These are **autotetraploids** and **allotetraploids**.

a. Autotetraploids

- These are produced by doubling the chromosome number of diploids.
- Many **ornamental plants, Groundnut, Coffee** and **Potato** crops are autotetraploids.
- When compared with diploids, these have larger leaves, flowers, fruits and seeds.
- Autotetraploids are produced in vegetatively propagated crops.

Examples

A. **Pusa Giant Berseem** (*Trifolium alexandrium*) is the **first polyploid variety** released for general cultivation in India. It yields **20 – 30%** more fodder than diploid varieties.

B. **Sugandha** variety of **Vetiver grass** yields **10%** more oil over diploid varieties.

C. iii. Hexaploids

D. Example: The commercial Bred Wheat

Triticum monococcum (2n = 14) × *Aegilops speltoides* (2n = 14)
AA ↓ BB
AB (2n = 14)
Intergeneric hybrid (Sterile)
↓
Amphidiploid (4n = 28) × *Aegilops squarrosa*
AABB (2n = 14) DD
↓
Triploid hybrid (3n = 21)
ABD (Sterile)
↓ Doubling
Hexaploid wheat → *Triticum aestivum* (6n = 42)

AABBDD

- Presence of all the chromosomes in a set or sets of polyploids is called as **Euploidy.**
- Change in the normal number of chromosomes of a set or sets of polyploids is called as **Aneuploidy**.

Methods of producing artificial polyploids

1. Cold treatment to dividing **zygote.**
2. Treating the floral and vegetative buds with chemicals like **Acenaphthene, Colchicine** and **Coumarins.**
3. Subjecting the floral and vegetative buds to **x–ray treatment**.

b. Allotetraploids

- These are produced by doubling the chromosome number of F_1 hybrid produced due to intergeneric and interspecific crosses.
- These are also known as **Amphidiploids** because they contain two diploid sets of chromosomes of two different species. Hence pairing and segregation is possible.

Examples

a. **White cotton**
   (Gossypium hirsutum × G. barbadense)
b. **Tobacco** (Nicotiana tabacum × N. rustica)
c. **Raphanobrassica**. It is obtained by crossing Raphanus sativus (Radish with 2n – 18) with Brassica oleracea var. capitata (Cabbage with 2n 18) and the F_1 hybrid with genotype R B(2n –18) is subjected to Colchicine treatment to obtain allotetraploid (4n – 36 and genotype is RRBB). It is the first man made synthetic genus by Karpachenko. Though commercially it has no significance, genetically it is notable success.
d. **Triticale** is another synthetic genus obtained due to cross between Triticum aestivum and Secale cereale.

- **Colchicine** is an alkaloid obtained from the corms of *Colchicum autumnale*. It prevents the formation of **spindle** during mitosis.

Limitations

1. Increase in the ploidy of existing polyploids decreases the size of various organs of the plant.

Vegetative growth is more and seed fertility is less. Hence it is extensively used in fodder and forage crops and crops where roots and tubers are useful parts