M.Sc. Second Year – Plant Breeding

Detailed, Easy-Language Notes: Unit 1 & Unit 2

Coverage: Introduction of Plant Breeding; Plant Introduction; Selection; Hybridization; Pedigree, Bulk and Backcross methods.

UNIT 1 – INTRODUCTION OF PLANT BREEDING

1.1 Definition of Plant Breeding

Plant breeding is the science and art of changing the genetic constitution of plants in a planned manner to develop improved varieties or hybrids with desirable characters. It uses genetic variation, selection, hybridization and other methods to combine useful traits.

Simple idea: Existing plants have useful and undesirable characters. Plant breeding identifies useful variation, combines or selects desirable genes, and develops a stable improved variety.

Aim of Plant Breeding

- To develop genetically improved crop varieties suitable for farmers and consumers.
- To increase yield and yield stability.
- To improve resistance to diseases, insects and other pests.
- To improve tolerance to drought, salinity, heat, cold, flooding and other stresses.
- To improve quality, nutrition, processing characteristics and market value.

Objectives of Plant Breeding

- **Higher yield:** Increase grain, fruit, fibre, oil, sugar, biomass or other economic yield.
- **Improved quality:** Improve protein, oil, vitamins, minerals, fibre, cooking quality, taste, colour, storage quality, etc.
- **Biotic stress resistance:** Develop resistance to diseases, insects, nematodes and other pests.
- **Abiotic stress tolerance:** Improve performance under drought, salinity, heat, cold, waterlogging and nutrient stress.
- **Early maturity:** Develop varieties that mature early and fit multiple-cropping systems.
- **Adaptation:** Develop varieties suitable for particular regions, seasons and farming systems.
- **Improved agronomic traits:** Lodging resistance, suitable plant height, better tillering/branching, synchronous maturity and harvest suitability.
- **Special-purpose varieties:** Varieties for industrial use, fodder, biofuel, processing or special nutritional requirements.

Scope of Plant Breeding

- Conventional breeding using selection and hybridization.
- Mutation breeding for creating new variation.
- Polyploid breeding and chromosome manipulation.
- Wide/distant hybridization for transferring genes across related species or genera.
- Breeding for resistance to biotic and abiotic stresses.
- Quality and nutritional improvement.
- Hybrid breeding and heterosis exploitation.
- Molecular breeding, marker-assisted selection and genomic approaches.

- Modern biotechnology and gene editing can complement conventional breeding.

History of Plant Breeding

A. Pre-Mendelian era

- Farmers practiced selection long before the scientific principles of heredity were understood.
- Seeds from healthy, vigorous and productive plants were repeatedly saved for the next generation. This is called **farmer selection** or **mass selection** in a broad historical sense.
- Domestication involved choosing plants with useful traits such as non-shattering seeds, larger organs, better taste and easier harvesting.
- Early plant improvement was therefore empirical: successful plants were selected based mainly on visible performance.
- Darwin (1859) emphasized variation and natural selection, which helped establish the scientific importance of variation.
- Mendel's experiments with pea plants, published in 1866, established basic laws of inheritance, although their importance was widely recognized only after 1900.

B. Post-Mendelian era

- 1900: Mendelian principles were rediscovered independently by Hugo de Vries, Carl Correns and Erich von Tschermak.
- Early 20th century: genetics became the scientific foundation of plant breeding.
- Hybridization followed by selection became a major method for combining desirable traits.
- Pure-line theory, mutation breeding, polyploidy and cytogenetics expanded the breeder's methods.
- Development of hybrid breeding made heterosis commercially important in several crops.
- Later, molecular markers, tissue culture, biotechnology, genomics and gene editing provided additional tools.

1.2 PLANT INTRODUCTION

Definition

Plant introduction is the process of bringing a plant species, variety, strain or germplasm from its existing area of cultivation or natural distribution into a new geographical area for cultivation, evaluation, conservation or use in breeding.

Example: A crop or variety developed in one country may be introduced into another country and evaluated for adaptation, yield and useful traits.

History of Plant Introduction

- Human migration and trade have moved crops between regions for thousands of years.
- During the colonial and post-colonial periods, organized crop introductions became more systematic.
- Plant introduction became an important source of new crops, varieties and genes for breeding.
- In India, organized germplasm collection, quarantine and evaluation are associated with institutions such as the National Bureau of Plant Genetic Resources (NBPGR) and crop-based research institutes.

Types of Plant Introduction

- **Primary introduction:** An introduced genotype is evaluated and, if suitable, released directly as a variety after necessary testing. It is useful when the introduced material is already well adapted.
- **Secondary introduction:** The introduced material is used as a source of variation in breeding. Desired traits are transferred through selection, hybridization or other breeding methods before a new variety is developed.
- **Direct introduction:** Material is brought into a new area and evaluated with minimal breeding alteration.

- **Indirect introduction:** Introduced germplasm is used in breeding to create improved material rather than being released directly.

Procedure of Plant Introduction

- **1. Define objective:** Decide what crop, trait or germplasm is required.
- **2. Identify source:** Locate suitable varieties, landraces, wild relatives or breeding lines.
- **3. Obtain germplasm legally:** Follow national/international regulations and documentation.
- **4. Quarantine:** Inspect and test imported material to prevent entry of pests, pathogens and invasive organisms.
- **5. Multiplication:** Multiply healthy material under controlled conditions.
- **6. Preliminary evaluation:** Observe identity, growth, maturity, adaptation and important traits.
- **7. Replicated evaluation:** Test promising entries in replicated trials and compare with standard checks.
- **8. Multi-location testing:** Evaluate stability and adaptation across environments.
- **9. Selection/release or breeding use:** Suitable material may be released or used as a parent in breeding.
- **10. Conservation:** Preserve valuable germplasm in appropriate gene banks.

Merits of Plant Introduction

- Provides access to new genetic variation.
- Can introduce completely new crops into a region.
- May provide varieties with high yield, quality or stress resistance.
- Saves time when an introduced variety is already adapted and can be used directly.
- Introduced germplasm can serve as valuable parents in breeding programmes.
- Wild relatives and landraces may provide rare genes absent from local cultivars.

Demerits / Limitations

- Introduced material may fail to adapt to the new environment.
- Imported material may carry pests or diseases; strict quarantine is therefore essential.
- Some introductions may become invasive or disturb local ecosystems.
- Photoperiod, temperature, soil and other environmental differences may prevent flowering or seed production.
- Evaluation of large germplasm collections requires time, land, labour and resources.
- Useful traits may be linked with undesirable characters and require breeding to remove them.

Acclimatization

Acclimatization is the gradual adjustment of an introduced plant or genotype to the environmental conditions of its new locality. A plant may survive initially but may require several generations of selection and management before it performs consistently in the new environment.

- Acclimatization is different from genetic improvement: acclimatization mainly refers to adjustment/adaptation to new conditions, whereas breeding deliberately changes or selects genetic combinations.
- Factors include temperature, rainfall, day length, soil, pests, diseases and management practices.
- Repeated selection of plants that perform well under local conditions can help develop adapted populations.

Plant Introduction Agencies / Major Institutions in India

- **ICAR–National Bureau of Plant Genetic Resources (NBPGR), New Delhi:** major national organization for plant genetic resources, including acquisition, quarantine, characterization, evaluation and conservation.

- **ICAR crop research institutes and All India Coordinated Research Projects:** maintain and evaluate crop germplasm and use it in crop improvement.
- **State Agricultural Universities:** participate in germplasm evaluation, breeding and regional adaptation studies.
- **National and international gene banks/research networks:** support conservation and exchange of plant genetic resources under applicable regulations.

Note: Institutional names and responsibilities can evolve; students should use the current official ICAR/DBT/government sources when citing present-day agencies.

UNIT 2 – SELECTION AND HYBRIDIZATION

2.1 SELECTION

Definition and Introduction

Selection is the process of choosing superior plants from a variable population and using them for multiplication or further breeding. Selection works because populations contain genetic variation and desirable traits can be retained and accumulated.

History of Selection

- Selection was practiced by farmers before genetics was understood.
- Mass selection was the traditional basis of many landraces and locally adapted populations.
- After Mendel's laws and the development of genetics, selection became more systematic.
- Johannsen's pure-line studies in beans demonstrated the importance of genotype and environment and led to the concept of pure lines.
- Modern selection may combine phenotype, pedigree records, molecular markers and genomic information.

General Procedure of Selection

- Identify a variable population.
- Set clear selection objectives.
- Observe plants and select superior individuals using appropriate criteria.
- Harvest selected plants or their progeny separately when individual plant identity is required.
- Evaluate progenies and discard inferior material.
- Repeat selection as required.
- Conduct replicated and multi-environment trials of promising lines.
- Compare with standard/check varieties.
- Release the superior stable genotype after required testing and approval.

Types of Plant Selection

A. Mass Selection

In mass selection, a large number of superior plants are selected from a population based mainly on phenotype. Seeds from selected plants are bulked and used to produce the next generation. Selection may be repeated for several cycles.

Procedure:

- Grow a diverse population in a suitable environment.
- Select many healthy, superior plants based on visible performance.
- Harvest selected plants and keep seed separately or bulk them according to the breeding objective.
- Mix seed from selected plants and grow the next generation.
- Repeat selection and evaluate the resulting population.

Merits:

- Simple and inexpensive.
- Useful for improving locally adapted populations.
- Can handle large populations.
- Requires less record keeping than pedigree selection.

- Can maintain relatively broad genetic diversity.

Demerits:

- Phenotype is strongly influenced by environment.
- Less effective for low-heritability traits.
- Exact genetic identity of individual selected plants may be unknown.
- Improvement may be slower when the population has limited variation.
- Uniformity may be lower than in a pure-line variety.

B. Pure Line Selection

A **pure line** is a genetically uniform line derived by repeated self-fertilization from a single homozygous plant. Pure-line selection involves selecting superior individual plants from a heterogeneous, usually self-pollinated population and evaluating their progenies.

Procedure:

- Select superior individual plants from a variable population.
- Harvest each selected plant separately.
- Grow progeny rows of each selected plant.
- Compare progenies and select the best uniform line(s).
- Repeat testing and selection.
- Conduct replicated and multi-location trials.
- Release the superior stable line as a variety, subject to official testing.

Merits:

- Produces highly uniform varieties in self-pollinated crops.
- Superior lines can be stable and predictable.
- Individual plant identity and progeny performance are evaluated.
- Useful for exploiting existing variation in landraces and mixed populations.

Demerits:

- Requires more time and testing than simple mass selection.
- Effective improvement depends on genetic variability in the starting population.
- Usually not suitable as a direct method for highly cross-pollinated populations without modification.
- Uniformity may reduce genetic buffering against changing environments.

Mass Selection vs Pure-Line Selection

Feature	Mass selection	Pure-line selection
Basic unit	Many selected plants	Individual plant and its progeny
Seed handling	Often bulked	Kept separately initially
Main basis	Phenotype of many plants	Phenotype + progeny performance
Uniformity	Moderate	High in self-pollinated crops
Genetic diversity	Relatively broader	Narrower
Record keeping	Less	More
Best use	Population improvement/local adaptation	Develop uniform lines in self-pollinated crops

2.2 HYBRIDIZATION

Introduction

Hybridization is the crossing of two genetically different plants to produce hybrid progeny and combine desirable characters. The selected parents are crossed so that their genes can recombine in the offspring. Hybridization is followed by selection and evaluation.

Main purpose: **create and recombine genetic variation** so that desirable traits from different parents can occur together in one genotype.

Types of Hybridization

A. Intervarietal / Intraspecific Hybridization

Crossing two genetically different varieties, strains or lines belonging to the same species. Example: crossing two contrasting varieties of wheat or rice to combine high yield with disease resistance.

B. Distant Hybridization

Crossing genetically distant parents, often belonging to different species (**interspecific**) or different genera (**intergeneric**). It is used to transfer useful genes from related species or wild relatives.

- **Interspecific:** between two species of the same genus.
- **Intergeneric:** between species belonging to different genera.
- Problems may include cross incompatibility, hybrid sterility, poor seed set and chromosome imbalance.
- Techniques such as embryo rescue, chromosome doubling or bridge crosses may sometimes help overcome barriers.

Steps / Procedure Involved in Hybridization

- **1. Define objective:** Decide the trait combination required.
- **2. Select parents:** Choose complementary parents with desirable characters and good combining potential.
- **3. Synchronize flowering:** Adjust sowing time or use suitable methods so that parents flower together.
- **4. Emasculation:** Remove or prevent the male organs/anthers of the female parent before pollen shedding, where necessary.
- **5. Bagging:** Cover the emasculated flower to prevent unwanted pollen contamination.
- **6. Collection of pollen:** Collect mature, viable pollen from the selected male parent.
- **7. Pollination:** Transfer pollen to the receptive stigma of the female parent.
- **8. Re-bagging and tagging:** Protect the crossed flower and record female × male, date and other details.
- **9. Harvest F1 seed:** Collect mature seed from successful crosses.
- **10. Grow and verify F1:** Check hybridity using morphological traits or molecular markers when available.
- **11. Generate segregating generations:** Self F1 to produce F2, or follow the appropriate breeding method.
- **12. Selection and testing:** Select desirable plants/lines and evaluate them through replicated and multi-location trials.

Important Terms

- **Emasculation:** removal of anthers from a bisexual flower before pollen release to prevent self-pollination.
- **Bagging:** covering a flower/inflorescence to prevent unwanted pollen.
- **Tagging:** recording cross details such as female × male, date and breeder information.
- **F1:** first filial generation obtained from the cross.
- **F2:** generation obtained by selfing/intermating F1 plants; segregation and recombination are usually prominent.

CROP IMPROVEMENT THROUGH HYBRIDIZATION

A. Pedigree Method

The **pedigree method** is mainly used in self-pollinated crops. Individual plants are selected from segregating generations, and the ancestry of selected plants is recorded generation by generation.

Basic procedure:

- Make a cross between selected parents.
- Grow F1 and confirm the hybrid.
- Self F1 to produce F2.
- Select superior individual plants in F2.
- Grow progeny rows from selected F2 plants and record pedigree.
- In F3 and later generations, select superior plants within promising families and retain desirable families.
- Continue selection as homozygosity increases.
- Advance promising lines to replicated yield trials and multi-location testing.
- Release a superior stable line after official evaluation.

Merits:

- Individual plant selection is possible in segregating generations.
- Pedigree records help track ancestry.
- Useful for combining several traits.
- Allows selection for highly heritable characters early in generations.

Demerits:

- Requires extensive records, labour and field space.
- Large numbers of families must be maintained.
- Early-generation selection for low-heritability traits can be unreliable.
- Management becomes difficult when population size is very large.

B. Bulk Method

In the **bulk method**, segregating generations after hybridization are grown as populations and advanced with little or no individual plant selection during early generations. Natural selection may operate under the growing environment. Individual selection is emphasized later when lines become more homozygous.

Basic procedure:

- Make the desired cross and produce F1.
- Self F1 to obtain F2.
- Grow F2 as a large population and harvest seed in bulk.
- Advance F3, F4 and subsequent generations as bulk populations, usually with minimal deliberate selection.
- As homozygosity increases, select individual superior plants or lines.
- Evaluate selected lines in replicated and multi-location trials.
- Identify and release the best stable line.

Merits:

- Simple and less labour-intensive than maintaining detailed pedigrees in early generations.

- Large populations can be handled efficiently.
- Allows natural selection to influence adaptation.
- Useful when selection in early generations is difficult or inefficient.

Demerits:

- Desirable rare genotypes may be lost by natural selection or sampling.
- Exact ancestry of selected plants is not known.
- Natural selection may favour competitive ability rather than breeder's target trait.
- Requires careful population management to maintain adequate genetic diversity.

C. Backcross Method

The **backcross method** is used mainly to transfer one or a few desirable genes from a donor parent into an otherwise superior variety called the recurrent parent. The offspring are repeatedly crossed back to the recurrent parent while selecting for the desired trait.

Key terms:

- **Recurrent parent:** superior variety whose overall genetic background is to be retained.
- **Donor parent:** parent providing the desired gene/trait.
- **Backcross:** crossing the hybrid or selected progeny back to one of its parents, usually the recurrent parent in this method.

Basic procedure:

- Select a superior recurrent parent and a donor possessing the desired trait.
- Cross recurrent parent × donor to produce F1.
- Backcross F1 to the recurrent parent.
- Select plants carrying the desired trait.
- Repeat backcrossing to the recurrent parent while selecting for the target trait.
- After sufficient backcross generations, self selected plants to fix the desired gene(s).
- Evaluate the improved line for agronomic performance and confirm that the target trait is retained.
- Release after appropriate testing.

Merits:

- Very effective for transferring a specific trait into an elite variety.
- Retains most desirable characteristics of the recurrent parent.
- Particularly useful for disease, insect and quality traits controlled by one or a few genes.
- Can be combined with molecular markers for marker-assisted backcrossing.

Demerits:

- Less suitable for transferring many genes controlling complex quantitative traits.
- Several generations may be required.
- Selection is necessary to retain the target trait.
- Linkage drag may transfer undesirable genes near the target gene; additional selection may be needed.

COMPARISON OF PEDIGREE, BULK AND BACKCROSS METHODS

Feature	Pedigree	Bulk	Backcross
Main principle	Selection + ancestry records	Advance populations in bulk; select later	Repeated crossing to recurrent parent
Typical use	Self-pollinated crops; combine traits	Self-pollinated crops; advance segregants	Transfer one/few specific traits
Early selection	Strong	Limited	Target-trait selection
Records	Detailed pedigree	Minimal early records	Backcross generations recorded
Main advantage	Precise family/plant selection	Simple and economical	Retains elite parent background
Major limitation	Labour and records	Loss of rare genotypes possible	Less suitable for complex multi-gene improvement

EXAM-ORIENTED REVISION

- Define plant breeding and explain its aim, objectives and scope.
- Discuss the history of plant breeding in pre-Mendelian and post-Mendelian periods.
- Define plant introduction and explain its types and procedure.
- Write the merits and demerits of plant introduction.
- Explain acclimatization and distinguish it from breeding.
- Write about major plant genetic resource institutions in India.
- Define selection and compare mass selection with pure-line selection.
- Explain hybridization and distinguish intervarietal from distant hybridization.
- Describe the complete steps of artificial hybridization.
- Explain pedigree, bulk and backcross methods with procedures, merits and demerits.
- Why is the backcross method particularly useful for transfer of a single major gene?
- Why can natural selection affect the outcome of the bulk method?

CONCEPT MAP

Plant Breeding → Genetic variation → Introduction / Selection / Hybridization → Segregation & recombination → Selection → Evaluation → Stable improved variety or hybrid.

Easy memory: Mass = many plants together. Pure line = one plant → progeny → uniform line. Pedigree = selection + family history. Bulk = population advanced together. Backcross = repeatedly return to the elite/recurrent parent.

These notes are designed for M.Sc. Second Year study and examination preparation. Terminology may vary slightly among universities and textbooks.