

UNIT ONE: Definition and Significance Of Plant Breeding

- ☛ **Plant Breeding/Improvement** is a branch of agriculture that focuses on *manipulating plant heredity* to develop new and improved plant performance for use by society
- ☛ Plant variation is natural, humans with special expertise (plant breeders) create some of it
- ☛ Generally, also, there is a perception that such creations derive from crossing different plants.
- ☛ The changes made in plants are permanent and heritable
- ☛ Plant breeding can also define as an **Art, a Science and Technology** of improving the genetic make-up of plants in relation to their economic use for the man kind

Why Breed Plants?

- 1) Improved yield and quality are usually the primary breeding goals
- 2) Improving health of the plant
- 3) Breeding for increased tolerance to drought, extremes of temperature, salinity etc.
- 4) Breeding for lodging resistance

The Strategy of Plant Breeding

- 1) To identify the morphological, physiological, and pathological traits in a cultivated plant species that contributes to its adaptation, health, productivity, and suitability for food, fiber, or industrial products
- 2) To search out new genes that encode for desired traits in different strains of the cultivated species and their close relatives
- 3) To combine genes for the desired traits into an improved cultivar through traditional breeding or new biotechnology procedures
- 4) To assess performance of the improved breeding lines in the local environment in comparison with present cultivars
- 5) To distribute as new cultivars breeding lines superior to cultivars currently grown

The Art and Scientific nature of Plant Breeding

- ❑ The **art** of plant breeding lies in the breeder's skill in observing plants with unique economic, environmental, nutritional, or aesthetic characteristics.
- ❑ Before plant breeders possessed the scientific knowledge that is available to them today, they relied solely on skill and judgment in selecting novel plants which could be propagated through seeds or vegetative parts.
- ❑ The successful plant breeders were keen observers, quick to recognize variant plants of the same species which would improve performance in the field.
- ❑ Selection became the earliest form of plant breeding

The Art and Scientific nature of Plant Breeding

- ❑ Hybridization then became the principal plant breeding procedure
- ❑ Through systematic cross-pollination, particular combinations of genes for different meritorious traits could be combined into a single plant cultivar.
- ❑ Plant breeding became more of a science and less of an art
- ❑ More recently, the science of molecular genetics proposes to advance plant breeding to an even higher level of sophistication
- ❑ According to the new technology, the DNA (gene) encoding for a desired trait would be identified, cloned, and inserted into the DNA of a plant reproductive cell line

How Plant Breeding Began?

- ✓ Plant breeding began when prehistoric man and woman learned to look for superior plants to harvest
- ✓ The seed-bearing spikes of the primitive wheat were brittle and easily broken apart, causing seeds to shatter and fall to the soil surface as they ripened
- ✓ Over long periods of time, perhaps 5,000 to 10,000 years, mutant forms of wheat gradually emerged in which seeds were held firmly until harvest
- ✓ These new forms of wheat were gathered as they were easier to harvest and to prepare for food. Eventually, they became the wheat cultivated by prehistoric people

Plant Breeding Before Mendel

- ❑ In 1856, a Frenchman, Louis Leveque de Vilmorin, utilized the **Progeny test** to increase the sugar content in the wild sugar beet
- ❑ The progeny test evaluates the breeding value of a single plant by the performance of its progeny
- ❑ Pioneering accomplishments in breeding for **disease resistance** were reported by William Allen Orton in 1898, who was breeding for wilt resistance in cotton
- ❑ Henry Luke Bolley in 1901, who was breeding for wilt resistance in flax(linseed)
- ❑ Both subjected mixed populations of plants to a natural epidemic of the disease by growing the plants in soil infested with the wilt organism and then selecting surviving plants.
- ❑ **Sex in plants** was established with certainty as early as 1694 through research by the German botanist, Rudolf Jakob Camerarius, the details of gamete fusion and double fertilization were not known until the late 1800s

The Contributions of Gregor Mendel in plant breeding

- Mendel cross-pollinated alternative forms of the common garden pea and studied the ratios of the different forms through successive generations
- Mendel established a few fundamental "Laws of Inheritance" which remain valid today and form the basic rules that plant breeders follow

Plant Breeding After Mendel

- In 1904 George Harrison Shull started to inbreed open-pollinated corn at the Station for Experimental Evolution, Cold Spring Harbor, New York
- Hybrid corn proved to be so successful that it replaced the "open-pollinated" Corn
- Norman Ernest Borlaug Crosses between short "semi dwarf" wheat from Italy and Japan and locally cultivated wheat subsequently led to the development of short, profusely tillering, and highly productive wheat cultivars that lifted wheat yields to a new high

Modern/Molecular Plant Breeding

- Molecular breeding/rDNA use of molecular markers/indirect selection in conjunction with linkage maps and genomics, to select plants with desirable traits on the basis of genetic assays
- Molecular markers are used in plant breeding in various ways
 1. Gaining a better understanding of breeding
 2. Rapid introgression of simply inherited traits
 3. Early generation testing
 4. Unconventional problem-solving
 5. Plant cultivar identification

Objectives in plant breeding

1. Yield increase
2. Resistance to Plant Disease and insect pest
3. Enhancement of compositional traits
4. Crop adaptation
5. Maturity
6. Resistance to Lodging & Shattering
7. Winter Hardiness
8. Heat and Drought Resistance
9. Soil Stress

Objectives in plant breeding

Lodging causes yield losses in small grains

1. The plant lodges before it is ripe and the seeds do not fill properly
2. The fallen plant is not picked up in the harvest operation
3. The fallen plants provide a favorable environment for the development of disease (rust, mildew) or for multiplication of insect pests

Resistance to lodging

- 1) Short, stiff, sturdy stems or stalks,
- 2) Vigorous, strong root systems that anchor the plant firmly in the soil,
- 3) More resilient straw that will bend but not break in the wind, and
- 4) Resistance to disease and insects that weaken the stem or the root system

THANK YOU FOR YOUR ATTENTION

Chapter 2. Plant Domestication and Crop Evolution

- ❑ Evolution is concerned with the effect of changes in the frequency of alleles within a gene pool of a population
- ❑ Such changes leading to changes in genetic diversity and the ability of the population to undergo evolutionary divergence
- ❑ Evolution is a population phenomenon
- ❑ As Darwin stated, variation is a feature of natural populations
- ❑ The individuals with the best genetic fitness for the specific environment will survive and reproduce more successfully
- ❑ Scientists have been able to identify relationships between modern cultivars and their wild and weedy progenitors

Crop Evolution

- Scientists collect, process, and store this natural variation in germplasm banks for use by breeders in their breeding programs
- Darwin's theory of evolution through natural selection can be summed up in three principles that are at the core of plant breeding
 1. **Variation.** Variation in morphology, physiology, and behavior exist among individuals in a natural population
 2. **Heredity.** Offspring resemble their parents more than they resemble unrelated individuals.
 3. **Selection.** Some individuals in a group are more capable of surviving and reproducing than others (i.e., more fit)

Crop Evolution

- Induced mutation and hybridization for recombination are major sources of variation
- Once variation has been assembled, the breeder imposes a selection pressure (**artificial selection**) to discriminate among the variation to advance only desired plants
- Conceptually, breeding and evolution are the same, a key difference being the duration of the processes
- Plant breeding has been described as evolution directed by humans
- Compared to evolution, a plant breeding process is completed in a *twinkle of an eye!*

Domestication

- ❑ Domestication is the process by which genetic changes (or shifts) in wild plants are brought about through selection process imposed by humans
- ❑ It is an evolutionary process in which selection (**Natural and artificial**) operates to change plants genetically, morphologically, and physiologically
- ❑ Species that become completely domesticated often are unable to survive when reintroduced into the wild
- ❑ Because the selection process that drives domestication strips plants of natural adaptive features and mechanisms that are critical for survival in the wild, but undesirable according to the needs of humans

Concepts of domestication

- ❑ Two categories of crop plants are identified, with respect to domestication, as primary crops or secondary crops
- ❑ **Primary crops** are those whose wild progenitors were deliberately cultivated by humans, genetic changes occurring in their new environments
- ❑ **Secondary crops** are those that evolved from weeds that arose in cultivated fields
- ❑ The domestication of vegetables, root and tuber crops, and most fruit trees is described as gradual domestication
- ❑ This is because it is difficult to use a single characteristic to differentiate between wild and cultivated species of these horticultural plants
- ❑ These crops are commonly vegetative propagated, hence evolution under cultivation would occur mainly from variation originating from somatic mutations
- ❑ Seed crops have the advantage of genetic recombination through sexual reproduction to create new variability more rapidly

Centers of origin of crop plants

- De Candolle was the first to suggest in 1886 that a crop plant originates from the area where its wild progenitor occurs
- Vavilov, on his plant explorations around the world in the 1920s and 1930s, noticed that extensive genetic variability within a crop species occurred in clusters within small geographic regions separated by geographic features such as mountains, rivers, and deserts
- This view was disputed because some crops had more than one center of diversity
- EXAMPLE found different forms of diploid, tetraploid, and hexaploid species of wheat in the Middle East, he observed that only hexaploid cultivars were grown in Europe and Asia
- He defined the **center of origin of a crop plant** as the geographic area(s) where it exhibits maximum diversity (i.e., where the greatest number of races and botanical varieties occur)

Centers of origin of crop plants

- The centers where **maximum diversity** occurs primary centers, and the places where types migrate to, the secondary centers

1)Primary center of origins: are the original home of the crop plants which are generally un cultivated areas like mountains, hills river valleys forests and etc.

Main features of primary center of diversity are:

- They have wide genetic diversity
- Have large number of dominant genes
- Mostly have wild characters
- Exhibit less crossing over
- Natural selection operates

Centers of origin of crop plants

2) **Secondary center of diversity:** Vavilov suggested that valuable form of crop plants are found far from their primary center of origin, which he called secondary center of diversity or origin

Main features of secondary center of diversity are:

- Have lesser genetic diversity than the primary center
- Have large number of recessive alleles
- Mostly have desirable characters
- Exhibit more crossing over
- Both natural and artificial selection operates

Centers of origin of crop plants

Vavilov, identified **eight** major centers of diversity and three sub-centers

1.Chinese center: bean, millet, naked oat, sesame, soybean

2.Indian center: rice bean, chickpea, cotton, jute, finger millet, mung bean, rice, sugarcane, taro, yam

2a.Indomalayan center: banana, coconut, sugarcane, yam

3.Central Asiatic center: chickpea, flax, lentil, pea, rye, safflower, sesame, bread wheat

4.Near Eastern center: alfalfa, barley, chickpea, flax, lentil, melon, red oat, pea, rye, sesame

5.Mediterranean center: broad bean, cabbage, lettuce, hulled oat, durum wheat

6.Ethiopian (formerly Abyssinian) center: barley, chickpea, flax, lentil, finger millet, sesame, teff, tetraploid wheat

7. South Mexican and Central American center: common bean, corn, upland cotton, cucurbits (gourd, squash, pumpkin), sisal hemp

8. South American (Peruvian-Ecuadorian-Bolivian) center: lima bean, sea-island cotton, potato, sweet potato, tobacco, tomato

8a.Chiloé center: potato

8b. Brazilian-Paraguayan center: cacao, manioc, peanut, pineapple, rubber tree

THANK YOU FOR YOUR ATTENTION

Chapter 3. Germplasm, Plant Introduction and Acclimatization

- ❑ **Plant germplasm** is living genetic source material used by plant breeders to develop new cultivars
- ❑ Plant germplasm is one of our most important natural resources and must be managed properly
- ❑ Farmer-selected cultivated forms, called **landraces**, originally evolved from wild plant populations
- ❑ Progress in breeding, often by selection and purification of these heterogeneous landraces, inevitably led to more **uniformity** and **less genetic variability** within the improved cultivars than was present in the original landraces
- ❑ One of the consequences of successful plant breeding is an increased erosion or reduction in genetic variability for the crop undergoing selection

Plant Germplasm

- Proper management of germplasm resources by the breeder includes introducing new germplasm resources on a regular basis to develop new recombinants and hence increase genetic variability
- The breeder must carefully evaluate breeding materials being discarded during the selection process so that erosion of the genetic base does not deteriorate beyond recovery
- The landraces that did not acquire broad genetic diversity during evolutionary period eventually succumbed to the ravages of disease, drought, cold, competition with weeds, or other unfavorable environmental stresses
- Obviously, not all of the myriad/innumerable of plant genotypes found in nature can be conserved in germplasm collections, but those species that may be useful to plant breeders need to be sampled and stored before the natural habitats in which they are now found are destroyed

Importance of Germplasm to Plant Breeding

- ❑ Germplasm is the lifeblood of plant breeding without which breeding is impossible to conduct
- ❑ Breeders generate new variability by using a variety of methods such as crossing parents, mutagenesis (inducing mutations), and more recently, gene transfer
- ❑ When breeders need to improve plants, they have to find a source of germplasm that would supply the genes needed to undertake the breeding project
- ❑ To facilitate the use of germplasm, certain entities (germplasm banks) are charged with the responsibility of assembling, cataloguing, storing, and managing large numbers of germplasm

Sources of Germplasm for Plant Breeding

- o Components of genetic resources: various plant materials which constitute gene pool or germplasm are known as components of genetic resources
- o There are **seven** major components of gene pool or germplasm
- 1. Landraces:** are primitive genotypes which were selected and cultivated by farmers for many generation or years

Main features of landraces

- Landraces were not deliberately bred like modern cultivars
- Landraces have high level of variability which provides high degree of resistance to biotic and abiotic stresses
- They have recognizable morphological trait and farmers have names for them, and different landraces are known to differ in adaptation to soil type, time of seeding, date of maturity, height and nutritive value
- The main drawbacks of landraces are that they are less uniform and low yielders

Sources of Germplasm for Plant Breeding

2. Obsolete cultivars: These are the improved varieties which were popular earlier and now have been replaced by new varieties

3. Modern cultivars: this refers to the currently cultivated high yielding varieties

- o These varieties have high yield potential and uniformity as compared to obsolete cultivars

- o However, modern cultivars have narrow genetic base and low adaptability as compared with landraces

4. Advanced breeding lines: refers to pre-released plant materials that have been developed by plant breeders for use as modern cultivars

Sources of Germplasm for Plant Breeding

5. Wild forms of cultivated species: Such materials have genetically high degree of resistance to biotic and abiotic stresses

- They can easily cross with cultivated species
- However, wild forms of many crop species are extinct

6. Wild relatives: naturally occurring plant species which have common ancestry with crops and can cross with species is known as wild relatives

- They are important sources of resistance gene for biotic and abiotic stresses
- However, they are used as the last resort in crop improvement program because their use in crossing leads to:
 1. Hybrid sterility
 2. Hybrid inviability and
 3. Transfer of several undesirable genes to the cultivated crop species

Sources of Germplasm for Plant Breeding

7. Mutants: are genotypes that have unusual and less frequent individuals

- o Mutation breeding is used when the desirable characters is not found in the genetic stock of cultivated species and their wild form and wild relatives

- o Mutation do occurs naturally as well as can be induced through the use of physical and chemical mutagens

Some important features of plant genetic resources or gene pool

- 1) Gene pool represents the entire genetic variability or diversity available in a crop species
- 2) Germplasm consists of landraces, modern cultivars, obsolete cultivars, breeding stocks and wild forms
- 3) Germplasm includes both cultivated and wild species
- 4) Germplasm is collected from the center of diversity, gene banks, gene sanctuary /shelter, farmers plots, markets and seed companies

Classification of gene pool

Gene pool can be classified on the basis of:

1) Area of collection

- A. Indigenous germplasm
- B. Exotic germplasm

2) Domestication

- a. Cultivated
- b. Wild

Classification of gene pool

3) Duration of Conservation

a) Base Collections

- These collections are not intended for distribution to researchers, but are maintained in long-term storage systems
- They are the most comprehensive collections of the genetic variability of species
- Storage conditions are low humidity at subfreezing temperatures (-10 to -18°C) or cryogenic (-150 to -196°C), depending on the species

b) Active collections

- Active collections usually comprise the same materials as in base collections; however, the materials in active collections are available for distribution to plant breeders or other patrons upon request
- They are stored at 0°C and about 8% moisture content, and remain viable for about 10–15 years
- To meet this obligation, curators of active collections at germplasm banks must increase the amount of germplasm available to fill requests expeditiously
- Because the accessions are more frequently increased through field multiplication, the genetic integrity of the accession may be jeopardized

Duration of conservation

c) Working or breeders' collections

- Breeders' collections are primarily composed of elite germplasm that is adapted
- They also include enhanced breeding stocks with unique alleles for introgression into these adapted materials
- In these times of genetic engineering, breeders' collections include products of rDNA research that can be used as parents in breeding programs

Classification of gene pool

4) Cross ability in the breeding program

1) Primary gene pool (GP1). GP1 consists of biological species that can be intercrossed easily (inter fertile) without any problems with fertility of the progeny

- That is, there is no restriction to gene exchange between members of the group
- This group may contain both cultivated and wild progenitors of the species

2) Secondary gene pool (GP2). Members of this gene pool include both cultivated and wild relatives of the crop species

- They are more distantly related and have cross ability problems
- Nonetheless, crossing produces hybrids and derivatives that are sufficiently fertile to allow gene flow
- GP2 species can cross with those in GP1, with some fertility of the F1, but more difficulty with success

3) Tertiary gene pool (GP3). GP3 involves the outer limits of potential genetic resources

- Gene transfer by hybridization between GP1 and GP3 is very problematic, resulting in lethality, sterility, and other abnormalities
- To exploit germplasm from distant relatives, tools such as embryo rescue and bridge crossing may be used to nurture an embryo from a wide cross to a full plant and to obtain fertile plants

Genetic Erosion: Causes and Implications

- Genetic erosion defined as the decline in genetic variation in cultivated or natural populations largely through the action of humans
- Loss of genetic variation may be caused by natural factors, and by the actions of crop producers, plant breeders, curators of germplasm repositories, and others in society at large

The following are the causes of genetic erosion

- A. Natural factors
- B. Action of farmers
- C. Action of breeders
- D. Problems with germplasm conservation
- E. General public action

Germplasm Collection and Conservation

- Collection refers to tapping of genetic diversity from various sources and assembling the same at one place.
- Collection is essential to reduce loss of genetic diversity which is taking place due to genetic erosion and extinction.
- The collection of plant genetic resources is highly scientific processes, and this process takes place into account five important items. These are:

1) Sources of collection i.e. where to collect?

A. Center of diversity

B. Gene banks (Gene banks are also known as germplasm banks or gene pools. Gene banks are organizations where genetic diversity is maintained in living state.

C. Gene sanctuaries : are protected areas of great genetic diversity under natural conditions

D. Seed companies

E. Farmers' fields

F. Markets

G. Collections can be made by local exploration trips to the regions of crop diversity

Germplasm Collection

2) Priority of collection .i.e. what to collect:

Endangered areas and species should be given top priority

3) Agencies of collection i.e. who would collect?

- a) Agricultural research
- b) Universities or
- c) Institute of plant genetic resources or
- d) International plant genetics resources institute/IPGRI

Germplasm Collection

4) Methods of collection i.e. how to collect: Germplasm collection is made in four principal ways. These are:

- The expedition to the area or regions of high genetic diversity
- Personal visit to the gene bank
- Correspondence
- Exchange of materials

5) Methods of sampling i.e. who to sample? Sample size i.e. how much to collect?

There are two sampling methods for collection of germplasm from the regions of diversity.

1.Random sampling: - is effective in capturing of alleles for biotic and abiotic stresses

2.Biased sampling or non-random sampling: is useful in collection of morphologically distinct genotypes

Germplasm Collection

Sample size or how much to sample?

- oThe sample size should be such that 95% of the total genetic variability can be captured from the area of collection
- oTo achieve this goal, 50 to 100 individuals should be collected per site with 50 seeds per plant