**Plant genetic resources for plant breeding**

**Importance of germplasm to plant breeding**

**Germplasm** is the lifeblood of plant breeding without which breeding is impossible to conduct. It is the genetic material that can be used to perpetuate a species or population. It not only has reproductive value, but through genetic manipulation (plant breeding), germplasm

can be improved for better performance of the crop. Germplasm provides the materials (parents) used to initiate a breeding program. Sometimes, all plant breeders do is to evaluate plant germplasm and make a selection from existing biological variation. Promising genotypes that are adapted to the production region are then released to producers.

**Centers of diversity in plant breeding**

Whereas the existence of centers of crop origin or domestication is not incontrovertible, the existence of natural reservoirs of plant genetic variability has been observed to occur in certain regions of the world. These centers are important to plant breeders because they represent pools of diversity, especially wild relatives of modern cultivars. Plant breeding may be a victim of its own success. The consequence of selection by plant breeders in their programs is the steady erosion or reduction in genetic variability, especially in the highly improved crops. Modern plant breeding tends to focus on a small amount of variability for crop improvement.

**Sources of germplasm for plant breeding**

The major sources of variability for plant breeders may be categorized into three broad groups:

***Domesticated plants*:** Domesticated plants are those plant materials that have been subjected to some form of human selection and are grown for food or other uses. There are various types of such material:

1. **Commercial cultivars:** There are two forms of this material: **current cultivars** and **retired cultivars**. These are products of formal plant breeding for specific objectives. It is expected that such genotypes would have superior gene combinations, be adapted to a growing area, and have a generally good performance. The retired cultivars were taken out of commercial production because they may have suffered a set back (e.g., susceptible to disease) or higher performing cultivars were developed to replace them.
2. **Breeding materials:** Ongoing or more established breeding programs maintain variability from previous projects. These intermediate breeding products are usually genetically narrow-based because they originate from a small number of genotypes or populations. For example, a breeder may release one genotype as a commercial cultivar after yield tests. Many of the genotypes that made it to the final stage or have unique traits will be retained as breeding materials to be considered in future projects. Similarly, genotypes with unique combinations may be retained.
3. **Landraces:** Landraces are farmer-developed and maintained cultivars. They are developed over very long periods of time and have coadapted gene complexes. They are adapted to the growing region and are often highly heterogeneous. Landraces are robust, having developed resistance to the environmental stresses in their areas of adaptation. They are adapted to unfavorable conditions and produce low but relatively stable performance. Landraces, hence, characterize subsistence agriculture. They may be used as starting material in mass selection or pure-line breeding projects.
4. **Plant introductions:** The plant breeder may import new, unadapted genotypes from outside the production region, usually from another country (called plant introductions). These new materials may be evaluated and adapted to new production regions as new cultivars, or used as parents for crossing in breeding projects.
5. **Genetic stock**. This consists of products of specialized genetic manipulations by researchers (e.g., by using mutagenesis to generate various chromosomal and genomic mutants).

***Undomesticated plants***

When desired genes are not found in domesticated cultivars, plant breeders may seek them from wild populations. When wild plants are used in crosses, they may introduce wild traits that have an advantage for survival in the wild (e.g., hard seed coat, shattering, indeterminacy) but are undesirable in modern cultivation. These undesirable traits have been selected against through the process of domestication. Wild germplasms have been used as donors of several important disease- and insectresistance genes and genes for adaptation to stressful environments. The cultivated tomato has benefited from such introgression by crossing with a variety of wild *Licopersicon* species.

***Other species and genera***

Gene transfer via crossing requires that the parents be cross-compatible or cross-fertile. As previously stated, crossing involving parents from within a species is usually successful and unproblematic. However, as the parents become more genetically divergent, crossing (wide crosses) is less successful, often requiring special techniques (e.g., embryo rescue) for intervening in the process in order to obtain a viable plant. Sometimes, related species may be crossed with little difficulty.

**Concept of gene pools of cultivated crops**

J. R. Harlan and J. M. J de Wet proposed a categorization of gene pools of cultivated crops according to the feasibility of gene transfer or gene flow from those species to the crop species. Three categories were defined, primary, secondary, and tertiary gene pools:

1. **Primary gene pool (GP1):** GP1 consists of biological species that can be intercrossed easily (interfertile) 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 crossability 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. Genetransfer techniques enable breeders to transfer genes beyond the tertiary gene pool. Most crop plants have a GP2, which consists primarily of species of the same genus. Some crop plants have no secondary gene pools (e.g., barley, soybean, onion, broad bean).

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**Conservation of plant genetic resources**

Plant breeders manipulate variability in various ways – for example, they assemble, recombine, select, and discard. The preferential use of certain elite genetic stock in breeding programs has narrowed the overall genetic base of modern cultivars. As already noted, pedigree analysis indicates that many cultivars of certain major crops of world importance have common ancestry, making the industry vulnerable to disasters (e.g., disease epidemics, climate changes). National and international efforts have been mobilized to conserve plant genetic resources.

**Why conserve plant genetic resources?**

There are several reasons why plant genetic resources should be conserved:

1. Plant germplasm is exploited for food, fiber, feed, fuel, and medicines by agriculture, industry, and forestry.
2. As a natural resource, germplasm is a depletable resource.
3. Without genetic diversity, plant breeding cannot be conducted.
4. Genetic diversity determines the boundaries of crop productivity and survival.
5. As previously indicated, variability is the life blood of plant breeding.

**Genetic erosion**

**Genetic erosion** may be 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.

1. ***Natural factors*:** Genetic diversity can be lost through natural disasters such as large-scale floods, wild fires, and severe and prolonged drought. These events are beyond the control of humans.
2. ***Action of farmers*:** Right from the beginnings of agriculture, farmers have engaged in activities that promote genetic erosion. These include clearing of virgin land in, especially, germplasm-rich tropical forests, and the choice of planting material. Farmers, especially in developed economies, primarily grow improved seed, having replaced most or all landraces with these superior cultivars. Extending grazing lands into wild habitats by livestock farmers, destroys wild species and wild germplasm resources.
3. ***Action of breeders*:** Farmers plant what breeders develop. Some methods used for breeding (e.g., pure lines, single cross, multilines) promote uniformity and a narrower genetic base. When breeders find superior germplasm, the tendency is to use it as much as possible in cultivar development. In soybean most of the modern cultivars in the USA can be traced back to about half a dozen parents. This practice causes severe reduction in genetic diversity.

**Approaches to germplasm conservation**

There are two basic approaches to germplasm conservation – *in situ* and *ex situ*.

1. ***In situ* conservation:** This is the preservation of variability in its natural habitat in its natural state (i.e., on site). It is most applicable to conserving wild plants and entails the use of legal measures to protect the ecosystem from encroachment by humans. These protected areas are called by various names (e.g., nature reserves, wildlife refuges, natural parks).
2. ***Ex situ* conservation:** In contrast to *in situ* conservation, *ex situ* conservation entails planned conservation of targeted species (not all species). Germplasm is conserved not in the natural places of origin but under supervision of professionals off site in locations called germplasm or gene banks. Plant materials may be in the form of seed or vegetative materials. The advantage of this approach is that small samples of the selected species are stored in a small space indoors or in a field outdoors, and under intensive management that facilitates their access to breeders. However, the approach is prone to some genetic erosion (as previously indicated) while the evolutionary process is halted.

**Types of plant germplasm collections**

1. **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. Entries are maintained in the original form. Storage conditions are low humidity at subfreezing temperatures (−10 to −18°C) or cryogenic (−150 to −196°C), depending on the species. Materials may be stored for many decades under proper conditions.
2. **Backup collections:** The purpose of backup collections is to supplement the base selection. In case of a disaster at a center responsible for a base collection, a duplicate collection is available as insurance.
3. **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.
4. **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.

**Managing plant genetic resources**

The key activities of curators of germplasm banks include regeneration of accessions, characterization, evaluation, monitoring seed viability and genetic integrity during storage, and maintaining redundancy among collections. Germplasm banks receive new materials on a regular basis. These materials must be properly managed so as to encourage and facilitate their use by plant breeders and other researchers.

1. **Regeneration:** Germplasm needs to be periodically rejuvenated and multiplied. The regeneration of seed depends on the life cycle and breeding system of the species as well as cost of the activity. To keep costs to a minimum and to reduce loss of genetic integrity, it is best to keep regeneration and multiplication to a bare minimum. It is a good strategy to make the first multiplication extensive so that ample original seed is available for depositing in the base and duplicate or active collections.

**A major threat to genetic integrity of accessions during regeneration is:**

1. Contamination which can change the genetic structure.
2. Differential survival of alleles or genotypes within the accession.
3. Random drift.

**The isolation of accessions during regeneration is critical, especially in cross-pollinated species, to maintaining genetic integrity. This is achieved through:**

1. Proper spacing
2. Caging
3. Covering with bags
4. Hand pollination
5. Other techniques.

**Regeneration of wild species is problematic because of:**

1. High seed dormancy.
2. Seed shattering.
3. High variability in flowering time.
4. Low seed production.
5. Some species have special environmental requirements.
6. **Characterization:** Users of germplasm need some basic information about the plant materials to aid them in effectively using these resources. Curators of germplasm banks characterize their accessions, an activity that entails a systematic recording of selected traits of an accession. Traditionally, these data are limited to highly heritable morphological and agronomic traits. However, with the availability of molecular techniques, some germplasm banks have embarked upon molecular characterization of their holdings. **Passport data** are included in germplasm characterization. These data include an accession number, scientific name, collection site (country, village), source (wild, market), geography of the location, and any disease and insect pests.
7. **Evaluation:** Genetic diversity is not usable without proper evaluation. Preliminary evaluation consists of readily observable traits. Full evaluations are more involved and may include obtaining data on cytogenetics, evolution, physiology, and agronomy. More detailed evaluation is often done outside of the domain of the germplasm bank by various breeders and researchers using the specific plants. Traits such as disease resistance, productivity, and quality of product are important pieces of information for plant breeders. Without some basic information of the value of the accession, users will not be able to make proper requests and receive the most useful materials for their work. Monitoring seed viability and genetic integrity During storage, vigor tests should be conducted at appropriate intervals to ensure that seed viability remains high. During these tests, abnormal seedlings may indicate the presence of mutations.
8. **Exchange:** The ultimate goal of germplasm collection, rejuvenation, characterization, and evaluation is to make available and facilitate the use of germplasm. There are various computer-based genetic-resource documentation systems worldwide, some of which are crop-specific. These systems allow breeders to rapidly search and request germplasm information. There are various laws regarding, especially, international exchange of germplasm. Apart from quarantine laws, various inspections and testing facilities are needed at the point of germplasm.

**Germplasm storage technologies**

Once collected, germplasm is maintained in the most appropriate form by the gene bank with storage responsibilities for the materials. Plant germplasm may be stored in the form of pollen, seed, or plant tissue.

1. **Seed storage: s**eeds are dried to the appropriate moisture content before being placing in seed envelopes. These envelopes are then arranged in trays that are placed on shelves in the storage room. The storage room is maintained at −18°C, a temperature that will keep most seeds viable for up to 20 years or more.
2. **Field growing:** Accessions are regrown to obtain fresh seed or to increase existing supplies. To keep the genetic purity, the accessions are grown in isolation to ensure self-pollination.
3. **Cryopreservation:** Cryopreservation or freeze-preservation is the storage of materials at extremely low temperatures of between −150 to −196°C in liquid nitrogen. Plant cells, tissue, or other vegetative material may be stored this way for a long time without loosing regenerative capacity. Whereas seed may also be stored by this method, cryopreservation is reserved especially for vegetatively propagated species that need to be maintained as living plants. Shoot tip cultures are obtained from the material to be stored and protected by dipping in a cryoprotectant (e.g., a mixture of sugar and polyethylene glycol plus dimethylsulfoxide).
4. **In vitro storage:** Germplasm of vegetatively propagated crops is normally stored and distributed to users in vegetative forms such as tubers, corms, rhizomes, and cuttings. However, it is laborious and expensive to maintain plants in these forms. In vitro germplasm storage usually involves tissue culture. There are several types of tissue culture systems (suspension cells, callus, meristematic tissues). Consequently, meristem cultures are favored for in vitro storage because they are more stable. The tissue culture material may be stored using the method of slow growth (chemicals are applied to retard the culture temperature) or cryopreservation.
5. **Molecular conservation:** The advent of biotechnology has made it possible for researchers to sequence DNA of organisms. These sequences can be searched for genes at the molecular level. Specific genes can be isolated by cloning and used in developing transgenic products.