Transferring traits from non-adapted materials

Aim of the module

At the end of the module, we should be able to:

- discuss the various issues regarding the use of exotic germplasm for breeding
- describe the genepool concept
- discuss the difficulties associated with trait transfer from within the species, from different species, from different genera, and from outside the immediate genepool
- describe the principal methods and technologies employed in transferring a range of traits from non-adapted materials into better adapted material

Issues hampering the use of exotics in plant breeding

- Lack of pre-breeding programs is the single most limiting factor
- Unmanageable number of accessions in genetic banks -- overwhelming genetic diversity
- Lack of the information required by breeder, such as traits for adaptation to stresses
- Lack of information on crossing ability and patterns of genetic diversity between crops and their wild related taxa, particularly for tropical crops
- Number of generations needed for exotic germplasm to become sources of parental material for the conventional breeding pool

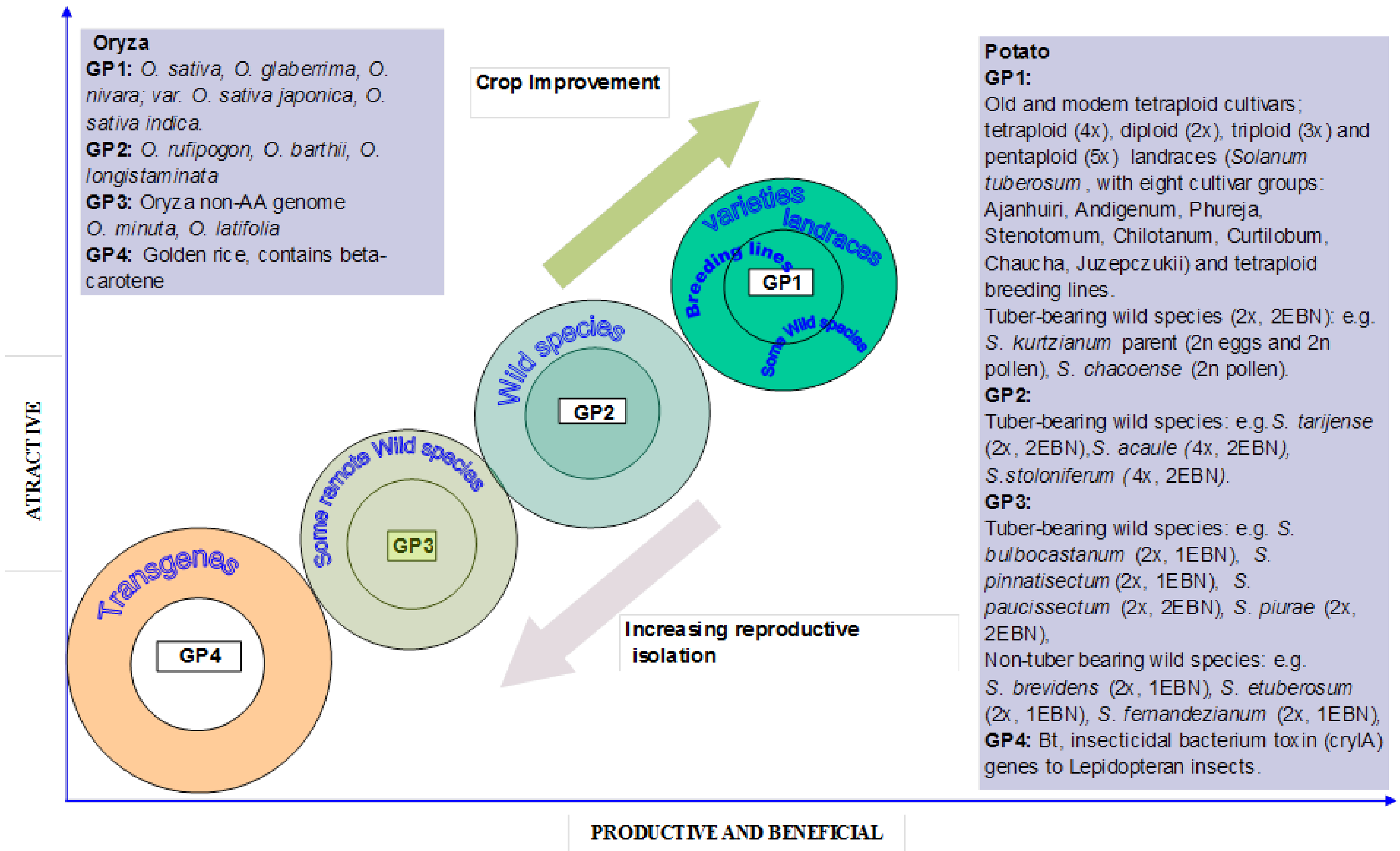
Genepool Concept

- Gene pool is the total genetic variation in the breeding population of a species and closely related species capable of crossing with it.
- Primary gene pool (GP1)
  - The total genetic variation in the breeding population of a crop and closely related taxa with which gene transfer is easy, since they commonly interbreed or can be routinely crossed.
- Secondary gene pool (GP2) -
  - The total genetic variation in the population of less closely related taxa with which gene transfer to the crop is possible but may be difficult to accomplish using conventional breeding techniques. Gene transfer and combination may encounter barriers due to some problems of F1 infertility.

Genepool Concept

- Tertiary gene pool (GP3)-
  - The total genetic variation in the population of a more distant taxa with which gene transfer to the crop is impossible or, if possible, requires somatic fusion or in-vitro techniques such as embryo rescue for F1 generation and viability. Severe F1 sterility constitutes a barrier to gene transfer.
- Quaternary gene pool (GP4) –
  - The immense genetic variation derived from unrelated plant species or other organisms. Gene transfer is impossible by pollination or tissue culture methods, requiring genetic engineering techniques.

Explaining the Gene Pool Concept with two examples



The taxon group concept

- Applications of the gene pool concept have been limited because of
  - a lack of information on crossing ability and
  - patterns of genetic diversity between crops and their wild related taxa,
  - especially for many under-researched tropical crops.
- An alternative pragmatic approach to the gene pool concept is the taxon group concept
  - assumes a positive relationship between taxonomic and genetic distance

The taxon group concept

- This concept can provide a classification system for the relationship between crops and their wild relatives as follows:
  - Taxon group 1a – crop
  - Taxon group 1b – same species as crop
  - Taxon group 2 – same series or section as crop
  - Taxon group 3 – same sub-genus as crop
  - Taxon group 4 – same genus but different sub-genus or species from crop
  - Taxon group 5 – same tribe but different genus from crop
- Is subjective, making the genepool concept take precedence, especially where hybridization information exist

Main difficulties associated with gene transfer

- Most successful hybridization restricted to GP1 and thus reduced genetic variability
- Pre-breeding activities need to access GP2 or GP3
- Barriers to interspecific hybridization are the main constraints and they act preventing:
  - the fusion of male and female gametes,
  - the development of a fertilized ovule into a viable seed, or
  - the effective utilization of the hybrids for gene introgression.
- Reproductive barriers are distinguished by the time they occur and can be grouped into pre- and post fertilization barriers

Pre-fertilization barriers

Understanding mechanisms involved in pre-fertilization barriers

- Male sterility
  - Genic male sterility – and restorer genes
  - Cytoplasmic male sterility
- Incompatibility systems
  - Self-incompatibility
  - Cross incompatibility

Pre-fertilization barriers

Circumventing the barriers

- Differences in flowering time -- pollen storage
- Overcoming pollen germination on the stigma: Try
  - Crosses in different environments and at different times of the day to determine the optimal time of pollination
  - Mechanical removal of the stigma or cutting styles, and pollinate the cut end.
  - Adding growth regulators e.g. auxins, cytokinins and gibberellins.
  - Applying mentor pollen.
  - Applying immunosupressors e.g. amino-n-caproic acid, salicylic acid, or acriflavin,

Pre-fertilization barriers

Overcoming pollen failure to grow down the style

- Check differences in the length of the style of the two parents. If there is a difference, use the longer style as male parent.
- Otherwise, some incompatibility system?

Pre-fertilization barriers

Overcoming incompatibility systems

- Attempt reciprocal directions of the cross.
- Select cross-compatible genotypes.
- Test different accessions of both the parents and select matching accessions if there are any.
- pollinate a large number of female accessions with a pollen mixture from many male accessions.
- Try also
  - mentor pollen
  - bridging lines

Pre-fertilization barriers

Overcoming incompatibility systems: Somatic hybridization

- producing new hybrids by bringing together hitherto incompatible reproductively isolated species, using protoplast fusion.
- Interspecific or intergeneric
- The cells of leaf mesophyll, young hypocotyls and/or calli are generally suitable for protoplast isolation.
- One of two methods of protoplast fusion:
  - Chemical fusion:
  - Electrofusion

Post-fertilization barriers

Take effect after successful fertilization and are attributed to mechanisms that reduce the viability or reproductive potential of the hybrid

- Seed (embryo) abortion
- Weakness or sterility of F1 hybrids
- Hybrid breakdown
- Linkage drag

Post-fertilization barriers

Circumventing the barriers

- Ploidy manipulation
  - Haploidization
  - Polyploidization
- Embryo rescue
- Ovary culture
- Ovule culture
- Somatic hybridization

Post-fertilization barriers

Overcoming F1 sterility, hybrid breakdown and linkage drag

- Artificial somatic doubling of chromosome number
- Repeated backcrossing
- Reversion of hybrid breakdown -- Repeated intercrossing among interspecific hybrids
- Promoting homoeologous chromosome pairing
- Mitigation of linkage drag
  - Use of molecular marker technology
  - Advanced backcross QTL analysis

Summary

Methods for transferring traits from non-adapted materials

- **Introgression**: a practice that involves the **backcrossing** into adapted stocks of genes controlling specific important traits from non-adapted materials.
- **Incorporation**: a practice consisting of the large-scale development of locally adapted populations good enough to introduce into the adapted genetic bases of the crop. Its overriding objective is to **broaden the genetic base** of the crop and provide a wide range of new parents