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PLANT GENETIC RESOURCES: THE BACKBONE OF FUTURE FOOD SECURITY

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Introduction

Plant genetic resources (PGR) constitute a fundamental component of agro-biodiversity and are scientifically defined as the genetic material of plants possessing actual or potential value for present and future generations. It is the product of the recombination of genetic material (DNA) during the inheritance process, mutations, gene flow, and genetic drift (Brown et al 1983). These resources encompass a wide spectrum of diversity, including landraces, wild relatives, and cultivated varieties, which collectively serve as indispensable reservoirs of genetic variability. Such diversity is critical for ensuring the development of resilient, high-yielding, and climate-adaptive crop varieties, thereby safeguarding global food and nutritional security.

The Indian subcontinent represents one of the richest repositories of plant biodiversity, recognized as one of the primary centres of origin and diversity, and accounting for approximately 11.9% of the world's flora. This immense diversity is distributed across varied agro-ecological zones and includes numerous endemic species that contribute significantly to the global genetic pool. Traditional varieties or landraces, in particular, exhibit unique adaptive traits such as differential maturity periods, tolerance to specific edaphic conditions, and resilience against diverse biotic and abiotic stresses. These inherent characteristics underscore their pivotal role in contemporary crop improvement programs, especially in the context of climate change and sustainable agricultural development. Thus, the conservation, characterization, and effective utilization of plant genetic resources remain central to advancing modern plant breeding strategies and ensuring long-term agricultural sustainability.

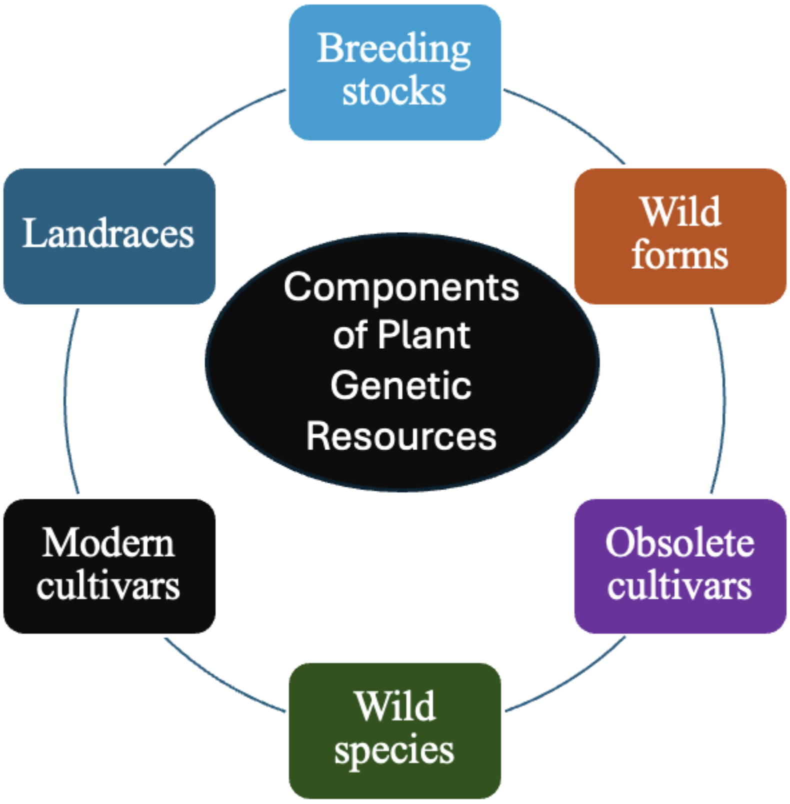

Fig. 1: Major Components of Plant Genetic Resources (PGR)

Evolution and Institutional Framework of Plant Genetic Resources Conservation in India

The organized conservation of plant genetic resources (PGR) in India originated with the pioneering efforts of Dr. B. P. Pal in 1941 at the Indian Agricultural Research Institute (IARI), who proposed the systematic assembly of global germplasm under phytosanitary conditions to the Indian Council of Agricultural Research (ICAR). This led to the initiation of the "Plant Introduction" scheme in 1946 within the Botany Division of IARI, facilitating structured acquisition and evaluation of germplasm.

The framework was further strengthened in 1956 with the establishment of the "Plant Introduction and Exploration Organization," which was later reorganized in 1961 as an independent Division of Plant Introduction. A major institutional advancement occurred in 1976 with the establishment of the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, under ICAR, following recommendations of a High-Level Committee. NBPGR currently serves as the nodal agency for the conservation, characterization, and utilization of PGR in India through integrated *in situ* and *ex situ* strategies, forming the backbone of crop improvement and sustainable agriculture.

Plant Genetic Resources Conservation in India

The National Bureau of Plant Genetic Resources (ICAR–NBPGR) functions as the apex nodal institution for the management of plant genetic resources (PGR) in India, supported by a network of regional stations across diverse phyto-geographical zones. It is mandated for the acquisition, conservation, characterization, and documentation of both indigenous and exotic germplasm for agricultural use. Additionally, it undertakes research and capacity building to ensure sustainable utilization of genetic resources. The National Genebank, operated under NBPGR, currently conserves over 4.4 lakh germplasm accessions, serving as a critical repository for crop improvement and biodiversity conservation.

Functions of NBPGR

- Ensures efficient management and facilitated access to plant genetic resources for crop improvement programmes.
- Acts as the central authority for issuing import permits and phytosanitary certificates for germplasm exchange.
- Conducts rigorous quarantine screening of seeds and vegetative propagules, including transgenic materials, to prevent entry of exotic pests and pathogens.
- Undertakes acquisition, conservation, characterization, evaluation, and documentation of indigenous and exotic germplasm.
- Maintains and coordinates a robust national network comprising regional stations, ICAR institutes, and State Agricultural Universities (SAUs).
- Supports research, training, and human resource development for sustainable utilization of plant genetic resources.
- Manages the National Genebank for long-term conservation of germplasm accessions.

Key Components and Management of National Genebank

The National Genebank integrates multiple conservation systems to ensure long-term preservation and utilization of plant genetic resources:

- **Seed Gene Banks**: Conserve orthodox seeds (desiccation-tolerant, stored at low moisture) and recalcitrant seeds (moisture-sensitive, limited storage).
- **Field Gene Banks**: Maintain perennial and vegetatively propagated crops such as fruit trees under field conditions.
- **Cryopreservation Units**: Store germplasm, including pollen and recalcitrant species, at ultra-low temperatures for long-term security.
- **In vitro Gene Banks**: Preserve clonal and horticultural crops under controlled tissue culture conditions for short- to medium-term storage.

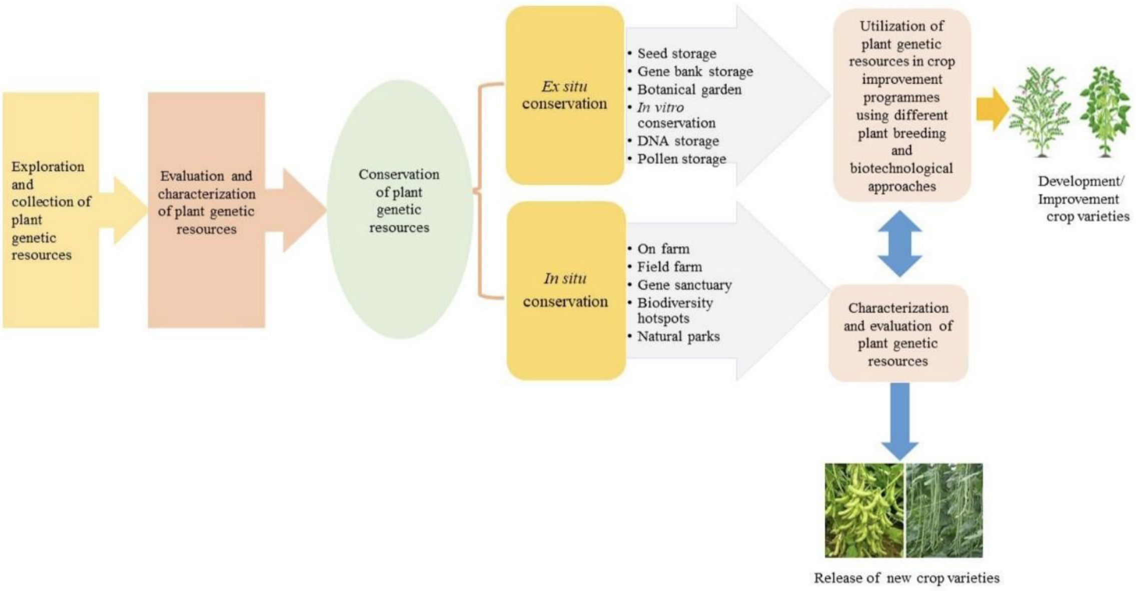

Fig. 2: Strategies for Conservation of Plant Genetic Resources (Salgotra et al 2023)

Essential Parameters for Effective Conservation

- **Uniqueness**: Avoid duplication to maintain genetic distinctiveness.
- **Seed Quality**: Adequate sample size as per crop type (self-, cross-pollinated, wild species).
- **Viability**: Minimum germination threshold (~85%) for storage.
- **Seed Health**: Pest- and disease-free material ensured through quarantine measures.
- **Passport Data**: Comprehensive documentation for traceability and utilization.

Utilization of Plant Genetic Resources in Crop Improvement

- **Genetic Diversity Source:** Landraces and wild relatives possess higher genetic variability compared to modern cultivars.

- **Trait Improvement:** PGRs provide genes for yield, disease and pest resistance, stress tolerance, and nutritional enhancement.
- **Parent Selection:** Diverse germplasm is used by breeders in hybridization programs to develop improved varieties.
- **Breeding Duration:** Development of new varieties takes ~8–11 years with a cultivation span of 5–6 years.
- **Role of Wild Relatives:** Wild species and landraces serve as reservoirs of novel alleles for biotic and abiotic stress resistance.

Breeding Applications of PGRs

- Development of pre-breeding materials for use in conventional breeding
- Creation of genetic stocks for resistance and quality traits
- Identification of male sterility sources for hybrid development
- Transfer of desirable genes to develop improved cultivars

Additional Uses

- Broadening genetic base of breeding populations
- Overcoming genetic bottlenecks
- Development of hybrids, composites, and synthetic varieties

Genomic Tools for Efficient Utilization of Plant Genetic Resources

Modern biotechnological tools, including NGS, HTS, and HTP, have greatly enhanced the efficient utilization of plant genetic resources in crop improvement. DNA-based molecular markers such as RFLP, RAPD, AFLP, ISSR, DArT, SSR, and SNPs are widely used for genetic diversity analysis due to their stability and independence from environmental effects (Cao et al 2022), with SSRs being commonly employed for genotype characterization. Advances in high-throughput sequencing have led to increased use of SNP markers and facilitated QTL identification using biparental populations (Bhat et al 2019). Molecular markers also support breeding strategies such as parental selection, heterosis analysis, MARS, MABB, gene pyramiding, and genomic selection, enabling the introgression of desirable traits (Salgotra et al 2015). Overall, integration of advanced genomic and phenotyping tools is essential for sustainable PGR utilization and future food security.

Conclusion

Effective management of plant genetic resources (PGR) requires coordinated global efforts due to interdependence among nations for germplasm exchange and conservation. The integration of complementary in situ and ex situ conservation strategies is essential to ensure long-term preservation of genetic diversity. Furthermore, enhancing awareness across stakeholders, including policymakers, scientists, and farmers, is critical for the sustainable utilization and protection of PGR for future crop improvement.

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