



AGRI MAGAZINE

(International E-Magazine for Agricultural Articles)

Volume: 03, Issue: 02 (February, 2026)

Available online at <http://www.agrimagazine.in>

© Agri Magazine, ISSN: 3048-8656

Role of Plant Genetic Resources in Sustainable Agriculture

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Plant genetic resources (PGRs) refer to the genetic material of plants that is of actual or potential value for food and agriculture. This includes seeds, fruits, roots and other plant parts, as well as the genetic information stored in these materials. PGRs are essential for the development of new crop varieties, as they contain valuable genetic traits such as disease resistance, drought tolerance and improved nutritional content. PGRs are crucial for global food security and the sustainable development of agriculture. However, many of these resources are at risk of being lost due to various threats, such as climate change, land use changes and the loss of traditional farming practices (Berry *et al.*, 2020). Therefore, the conservation and sustainable use of PGRs are essential to ensure the long-term availability of genetic diversity for agriculture. The importance of PGRs has been recognized globally, and several international agreements and initiatives have been established to support their conservation and use. For example, the International Treaty on Plant Genetic Resources for Food and Agriculture was adopted by the United Nations Food and Agriculture Organization (FAO) in 2001, which aims to ensure the conservation and sustainable use of PGRs, as well as the fair and equitable sharing of benefits arising from their use.

Recent studies have highlighted the urgent need for action to conserve and use PGRs. For example, a study published in *Nature Plants* found that more than 75% of crop wild relatives, which are important sources of genetic diversity for crop improvement, are under threat of extinction (Khoury *et al.*, 2020). Another study published in *Environmental Research Letters* found that climate change is likely to significantly reduce the availability of PGRs in some regions, particularly in sub-Saharan Africa (Becker Reshef *et al.*, 2019). Efforts to conserve and use PGRs are ongoing and various strategies and approaches are being developed and implemented. These include in situ conservation, which involves conserving PGRs in their natural habitats, as well as ex situ conservation, which involves storing PGRs in gene banks and other facilities. Additionally, the development of new crop varieties using PGRs is being supported through research and breeding programs. Various strategies and approaches are being developed and implemented to conserve and utilize PGRs. In situ conservation, which conserves PGRs in their natural habitats and ex situ conservation, which stores PGRs in gene banks and other facilities, are two important strategies for PGR conservation. Additionally, research and breeding programs supporting the development of new crop varieties utilizing PGRs are being carried out.

History of PGR Conservation and Utilization

The conservation and utilization of PGRs have a long history, dating back to ancient times when farmers selected and saved seeds from plants with desirable traits for the next planting season. However, the formal conservation and utilization of PGRs began in the 20th century, with the establishment of gene banks and the development of international agreements and policies for PGR management. The first gene bank was established in Leningrad (now St. Petersburg), Russia, in 1926, followed by the establishment of the International Rice Research Institute's gene bank in the Philippines in 1960. The establishment of these gene banks marked the beginning of a new era in the conservation of PGRs, enabling the long-term

preservation of plant genetic diversity. In the 1980s, the importance of PGRs for food security and sustainable agriculture became increasingly recognized, leading to the establishment of several international initiatives aimed at promoting their conservation and utilization. The International Board for Plant Genetic Resources (IBPGR), now known as the International Plant Genetic Resources Institute (IPGRI), was established in 1974 to coordinate international efforts for PGR conservation and utilization. One of the most significant international agreements for PGR management is the International Treaty on Plant Genetic Resources for Food and Agriculture, adopted by the United Nations Food and Agriculture Organization (FAO) in 2001. The Treaty aims to ensure the conservation and sustainable use of PGRs and the equitable sharing of benefits arising from their use.

Classifications of PGRs

Plant genetic resources are conserved and utilized through a range of methods that include seed banks, field collections, in vitro conservation, and cryopreservation (Agrawal et al., 2019; Ren et al., 2020). Each of these methods has its advantages and limitations and is used to conserve different types of PGRs. Seed banks are the most commonly used method for PGR conservation and involve storing seeds in low-temperature conditions to maintain their viability over a long period. Seed banks are useful for conserving a wide range of plant species and are relatively easy to establish and maintain (Thormann and Engels, 2015). Examples of seed banks include the Svalbard Global Seed Vault in Norway and the Millennium Seed Bank in the UK. Field collections involve the conservation of plant species in their natural habitats. This method is particularly useful for conserving wild relatives of crops, as they often have traits that are valuable for crop improvement. Field collections also provide opportunities for studying plant populations in their natural environment (Thormann and Engels, 2015). The European Cooperative Programme for Crop Genetic Resources Networks (ECPGR) maintains several field collections across Europe.

In vitro conservation involves the use of tissue culture techniques to maintain PGRs in sterile conditions. This method is particularly useful for conserving PGRs that cannot be conserved through seed banks or field collections, such as vegetatively propagated plants. In vitro conservation also enables the maintenance of genetic purity and the elimination of pathogens (Sharma et al., 2020). The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) maintains an in vitro gene bank for chickpea. Cryopreservation involves the storage of plant tissues, such as shoot tips or embryos, at ultra-low temperatures, usually below -150°C . This method is particularly useful for conserving PGRs that cannot be conserved through seed banks, field collections or in vitro conservation. Cryopreservation also enables the long-term storage of PGRs with high genetic diversity (Halder and Ghosh, 2020). The USDA National Plant Germplasm System maintains several cryopreservation facilities across the United States.

Global Initiatives and Policies for PGR Conservation and Utilization

Plant genetic resources (PGRs) are crucial for global food security and sustainable agriculture. To ensure their conservation and utilization, several global initiatives and policies have been established, including the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). The ITPGRFA, which was adopted in 2001, aims to promote the conservation and sustainable use of PGRs and to ensure their fair and equitable sharing of benefits. It establishes a multilateral system for access to PGRs that are important for food and agriculture and provides guidelines for their collection, conservation, and utilization (Reed, 2004). In addition to the ITPGRFA, several other initiatives and policies have been established to promote PGR conservation and utilization. The Global Crop Diversity Trust, for example, was established in 2004 to support the conservation of crop diversity and to provide funding for the establishment and maintenance of gene banks (Priyanka et al., 2021). The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, which was adopted in 2010,

aims to ensure the fair and equitable sharing of benefits from the utilization of genetic resources (Buck and Hamilton, 2011).

Impact of Climate Change on PGRs and Their Conservation

Climate change is expected to have a significant impact on PGRs and their conservation. Climate change induced changes in temperature, rainfall patterns and extreme weather events are likely to affect the distribution, diversity and adaptation of plant species, including those that are important for food security and agriculture (FAO, 2019). Several recent studies have demonstrated the impact of climate change on PGRs. For example, a study by Khoury et al., (2014) found that 52% of the 29,402 crop wild relatives they assessed are likely to be threatened with extinction due to climate change. Similarly, a study by Jarvis et al., (2008) found that climate change is likely to have a significant impact on the distribution and genetic diversity of several major crops, including wheat, rice and maize. The impact of climate change on PGRs underscores the importance of their conservation. Effective conservation strategies are needed to ensure that PGRs are able to adapt to changing climatic conditions and continue to contribute to food security and sustainable agriculture. Conservation efforts should focus on both in situ and ex situ conservation strategies, such as the establishment of seed banks, field collections, in vitro conservation and cryopreservation (FAO, 2019). In addition to conservation efforts, mitigating climate change is also essential for protecting PGRs. Reducing greenhouse gas emissions and implementing measures to adapt to changing climatic conditions can help to ensure the continued availability and accessibility of PGRs (Watson et al., 2019).

Genetic Diversity and its Importance in Crop Improvement

Genetic diversity is the variation in genetic traits within and among populations of the same species. In crops, genetic diversity is crucial for crop improvement; as it allows breeders to select for desirable traits such as disease resistance, yield and quality. Genetic diversity can be found at different levels, including within individual plants, populations and species. Recent studies have highlighted the importance of genetic diversity in crop improvement. For example, a study by Chen et al. (2021) showed that genetic diversity is a key factor in determining the yield potential of maize. The study found that accessions with higher genetic diversity had higher yields and were more resilient to environmental stresses such as drought and heat. Another study by Aubry (2019) emphasized the importance of genetic diversity in maintaining resilient food systems. The study found that increasing the genetic diversity of crops and livestock can help to increase their resilience to environmental and socio-economic stresses, such as climate change, disease outbreaks and market fluctuations. Conservation of genetic diversity is also important for crop improvement. In situ conservation, which involves conserving crop genetic resources in their natural habitats, can help to maintain genetic diversity and promote adaptation to changing environmental conditions (FAO, 2019). Ex situ conservation, including the establishment of seed banks and field collections can also help to preserve genetic diversity for future crop improvement efforts.

Constraints in Using of PGRs

Plant genetic resources (PGRs) have great potential to contribute to sustainable agriculture, but their utilization is often limited by several constraints.

1. Lack of knowledge: A lack of knowledge and understanding about PGRs, their potential and how to use them effectively is one of the most significant constraints in their use. Farmers, breeders and policymakers need to be educated about PGRs and their significance to unlock their full potential in agriculture (de Haan, 2021).

2. Insufficient infrastructure: Effective conservation and use of PGRs require adequate infrastructure such as seed banks, in vitro conservation facilities and field gene banks. However, many developing countries lack such infrastructure, making it difficult to conserve and utilize PGRs effectively (Canton, 2021).

3. Policy and legal frameworks: The lack of appropriate policy and legal frameworks for PGRs, including intellectual property rights, can limit access to and sharing of PGRs. This can hinder research and development, as well as the use of PGRs for commercial purposes (Kiehn et al., 2021).

4. Inadequate funding: Limited financial resources can make it challenging to invest in the conservation and utilization of PGRs, and can also hinder research and development on PGRs. There is a need for adequate funding for PGR research, development and conservation (Canton, 2021).

5. Limited diversity: The genetic diversity of PGRs is declining due to various factors such as climate change, land-use change and urbanization. This loss of genetic diversity hinders the development of new crop varieties that can adapt to changing environments and provide resilience to pests and diseases (Shukla et al., 2019).

Applications of PGRs in Crop Improvement

Plant genetic resources have numerous applications in crop improvement, including breeding, biotechnology and genetic engineering. PGRs can be used to introduce desirable traits such as disease resistance, yield and quality into crops.

Utilizing PGRs to Achieve Progress in Multiple Crop Species

Plant genetic resources have a crucial role in the genetic improvement of various crop species, enabling the development of new varieties with improved yield potential, quality and resilience to biotic and abiotic stresses. The use of PGRs has the potential to achieve significant progress in multiple crops, contributing to global food security and sustainable agriculture (Hajjar et al., 2008).

Opportunities for PGR Conservation and Utilization for Developing Countries

Developing countries also have several opportunities for PGR conservation and utilization. For instance, traditional knowledge and practices related to PGRs can inform conservation and utilization efforts. Traditional seed saving and exchange practices, for example, can help maintain genetic diversity (Galluzzi et al., 2010). Collaborative efforts between developing and developed countries can help to address the challenges facing PGR conservation and utilization. This can involve capacity building, information sharing and joint research and development initiatives. Advances in technology, such as genomic sequencing and gene editing, can also enhance the conservation and utilization of PGRs. For example, genomic sequencing can facilitate the identification of important genes for crop improvement, while gene editing can help introduce desirable traits into crops (Gao, 2021). Developing countries can benefit from the market opportunities associated with the conservation and utilization of PGRs. This includes the development of value-added products and the sale of seeds and other plant materials (Galluzzi et al., 2010).

Future Perspectives on PGRs and their Role in Sustainable Agriculture

Plant genetic resources are essential for sustainable agriculture, as they provide genetic diversity for crop improvement and adaptation to changing environmental conditions. The global population is expected to reach 9.7 billion by 2050, increasing the demand for food and agricultural products and highlighting the need for sustainable agriculture practices that can ensure food security for current and future generations. In this context, PGRs have a significant role to play in shaping the future of sustainable agriculture. One key future perspective is the integration of PGRs into sustainable agriculture systems. This approach involves using diverse and resilient crop varieties that can withstand biotic and abiotic stressors, reducing the reliance on chemical inputs and promoting ecological balance. This approach has been shown to increase yields, enhance soil health and biodiversity and reduce environmental impacts (Srivastav et al., 2020). For example, the adoption of intercropping, agro forestry, and other diversified farming systems that incorporate PGRs has been shown to improve soil fertility, enhance pest and disease control, and promote carbon sequestration (Altieri et al., 2015). Another future perspective is the use of advanced technologies to conserve and utilize PGRs. This includes the use of genomics, proteomics and other omics

technologies to characterize and understand the genetic diversity of PGRs, as well as the development of high-throughput phenotyping methods to screen large collections for desirable traits. Additionally, advances in gene editing and other biotechnologies can help to introduce desirable traits into crops, increasing their resilience to environmental stressors and improving their nutritional quality (Khush, 2013).

Conclusion

Plant genetic resources have tremendous potential in contributing to sustainable agriculture, food security, and achieving the Sustainable Development Goals (SDGs). Utilizing PGRs has led to significant progress in multiple crop species, including wheat, rice, maize, potato, tomato and legumes, by improving yield potential, quality, resistance to pests and diseases, and tolerance to biotic and abiotic stresses. The integration of PGRs into sustainable agriculture systems and the use of advanced technologies to conserve and utilize PGRs can further enhance their potential to shape the future of sustainable agriculture. However, there are also constraints that must be addressed, including inadequate funding and infrastructure for conservation efforts, insufficient awareness and education, and legal and policy barriers to access and benefit-sharing. Addressing these challenges requires collaborative efforts from governments, research institutions, and other stakeholders. Overall, the conservation and sustainable use of PGRs are essential for achieving global food security, sustainable agriculture, and the SDGs.