providing a backup against the loss of genetic diversity due to environmental changes or catastrophic events. Seed banks are particularly effective for long-term conservation, as they allow for the storage of large quantities of genetic material in a controlled environment, ensuring the viability and vigor of seeds over extended periods.

Gene banks also play a crucial role in ex situ conservation by maintaining living collections of tea plants. These collections serve as a resource for research, breeding, and restoration efforts, enabling the reintroduction of genetic material into natural populations when necessary (Raven and Havens, 2014). Advances in cryopreservation and other biotechnological methods have further enhanced the capacity of gene banks to conserve genetic resources, especially for species with recalcitrant seeds that cannot be stored using conventional methods (Coelho et al., 2020). These technologies ensure that a wide range of genetic diversity is preserved, supporting future breeding programs and adaptation to changing environmental conditions (Pence et al., 2020).

4.3 Community-led conservation initiatives

Community-led conservation initiatives are increasingly recognized as effective strategies for preserving tea plant genetic resources. These initiatives empower local communities to take an active role in the conservation and sustainable management of their natural resources. By fostering a sense of ownership and responsibility, community-led approaches can lead to more effective and enduring conservation outcomes. Such initiatives often involve the development of community-based nurseries, where local varieties of tea plants are propagated and distributed, ensuring the preservation of traditional knowledge and practices.

Furthermore, community-led conservation can enhance the resilience of tea plant populations by promoting agroforestry systems and sustainable land-use practices that integrate tea cultivation with biodiversity conservation. These systems not only conserve genetic resources but also provide economic benefits to local communities, reducing the reliance on unsustainable practices that threaten biodiversity (Pritchard et al., 2014). By aligning conservation goals with community needs, these initiatives can create a win-win scenario that supports both environmental and socio-economic objectives.

5 Role of Biotechnology in Genetic Preservation

5.1 Genetic characterization and molecular markers

Genetic characterization using molecular markers is essential for understanding the genetic diversity and structure of tea plant populations. Techniques such as next-generation sequencing and restriction-site-associated DNA sequencing (RAD-seq) allow for precise transcriptome profiling, which helps identify genes involved in important biosynthetic pathways (Niazian, 2019). These molecular markers are invaluable for assessing genetic diversity, which is critical for conservation efforts and breeding programs aimed at improving tea plant varieties.

The use of molecular markers also aids in the detection of genetic variations that may occur during *in vitro* culture and cryopreservation processes. Ensuring genetic integrity is vital, as any alterations could affect the plant's characteristics and its ability to adapt to environmental changes. Therefore, molecular markers serve as a tool for monitoring and maintaining the genetic stability of preserved tea plant germplasm.

5.2 Cryopreservation and tissue culture techniques

Cryopreservation is a pivotal technique for the long-term conservation of tea plant genetic resources. It involves storing plant tissues at ultra-low temperatures, typically in liquid nitrogen, to halt metabolic activities and preserve genetic material over extended periods (Białoskórska et al., 2024). This method is particularly beneficial for plants that do not produce viable seeds or propagate vegetatively, as it ensures the preservation of genetic diversity without the risk of genetic drift (Jiroutova and Sedlák, 2020).

Tissue culture techniques complement cryopreservation by providing a platform for the initial multiplication and maintenance of plant material under aseptic conditions. These methods allow for the rapid propagation of tea plants, ensuring a steady supply of material for cryopreservation (Cruz-Cruz et al., 2013). However, challenges such as oxidative stress and genetic variations during the freeze-thaw cycle must be addressed to ensure the successful regeneration of true-to-type plants (Bettoni et al., 2020; Wang et al., 2021).