plant breeders to develop new, resilient tea varieties (Engels et al., 2024). However, the increasing complexity of access and benefit-sharing policies has posed challenges to the free exchange of germplasm, necessitating a more streamlined and transparent system (Ebert et al., 2023).

To address these challenges, a multilateral system has been proposed to facilitate the sharing of plant genetic resources, including tea. This system aims to harmonize access conditions and ensure equitable benefit-sharing, thereby reducing legal uncertainties and transaction costs for conservers and users of genetic resources (Ebert et al., 2023). By improving access to genetic diversity and related data, this approach supports the development of new tea varieties that can withstand environmental stresses and meet consumer demands.

7.3 Capacity building and knowledge exchange

Capacity building and knowledge exchange are integral to the successful preservation and utilization of tea plant genetic resources. Collaborative efforts between countries and institutions enhance the capabilities of researchers and breeders, enabling them to effectively manage and utilize genetic resources. For example, Japan's National Agriculture and Food Research Organization has leveraged international collaborations to enhance its genetic resource management and breeding programs for tea.

Knowledge exchange initiatives, such as workshops, training programs, and joint research projects, facilitate the dissemination of best practices and innovative techniques in genetic resource management. These initiatives help build a global community of experts who can collectively address the challenges facing tea cultivation and contribute to the development of improved tea varieties. By fostering a culture of collaboration and learning, capacity building efforts ensure the long-term sustainability and resilience of tea plant genetic resources.

8 Future Directions and Challenges

8.1 Integrating new technologies in conservation

The integration of new technologies in the conservation of tea plant genetic resources is crucial for enhancing the efficiency and effectiveness of preservation efforts. Recent advancements in biotechnologies, such as genomic selection and cryopreservation, offer promising avenues for improving the management of genetic resources. Genomic selection can significantly increase genetic gains in tea breeding programs by enhancing selection accuracy and reducing breeding cycles. Cryopreservation, which involves storing plant genetic resources at ultra-low temperatures, provides a reliable method for long-term conservation, ensuring the stability and viability of germplasm. Additionally, automation in genebank management and the development of routine cryopreservation procedures for various species are evolving to address the challenges posed by recalcitrant-seeded and vegetatively propagated species.

8.2 Addressing socio-economic barriers

Socio-economic barriers present significant challenges to the conservation of tea plant genetic resources. The economic implications of emerging science and the need for prioritization in collection and conservation efforts are critical considerations (Gollin, 2020). In many low- to middle-income countries, where tea is predominantly grown, limited resources and low selection accuracy hinder the implementation of advanced breeding programs. Addressing these barriers requires a focus on equitable benefit-sharing arrangements and the involvement of local communities in conservation efforts. The Convention on Biological Diversity highlights the importance of sustainable use and equitable sharing of benefits derived from genetic resources, which can help overcome socio-economic challenges.

8.3 Vision for sustainable tea genetic resource management

A sustainable vision for managing tea genetic resources involves a holistic approach that integrates both in situ and ex situ conservation methods. In situ conservation, which involves preserving species in their natural habitats, is essential for maintaining genetic diversity and allowing for natural evolutionary processes (Yadav et al., 2024). Ex situ methods, such as gene banks and tissue culture, provide a controlled environment for preserving genetic material and ensuring its availability for future use. The development of in vitro genetic banks and microclonal reproduction techniques can further support the conservation of rare and endangered tea plant species. By