Safeguarding Plant Genetic Resources: Biodiversity Laws, ABS, and Biopiracy Prevention

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Abstract. Plant genetic resources support sustainable agriculture, global food security, and biodiversity, yet they are often targets of biopiracy and illegal trade, leading to biodiversity loss. This review examines the critical role of biodiversity laws and Access and Benefit-Sharing (ABS) frameworks in safeguarding genetic resources. It discusses the legal mechanisms designed to protect biodiversity and ensure the equitable sharing of benefits from the use of genetic material. However, biodiversity conservation and sustainable use warrant harmonized policies that balance biodiversity preservation with scientific research and commercial interests and foster global cooperation to combat and prevent biopiracy. The review also highlights the challenges posed by biopiracy, emphasizing the need for stronger international and national regulations to prevent unauthorized exploitation.

Keywords : Access and Benefit-Sharing (ABS) ; Biodiversity Loss ; Biopiracy ; Conservation ; Plant Genetic Resources ; Sustainable Utilization.

1 Introduction

Plant genetic resources (PGR), encompassing domesticated crops, landraces, wild relatives, and wild plants used for food, fiber, and medicinal purposes, are considered an important pillar of sustainable food production, agriculture, and global ecological stability [1, 2]. They are also a source of crop improvement, including pest and disease resistance, higher yields and nutritional content, and adaptation to environmental changes. Other agricultural innovations using PGR, such as plant growth-promoting rhizobacteria (PGPR)-based products, biopesticides, and plant storage, have depended heavily on the genetic variability available in PGR. In this context, the conservation and sustainable utilization of PGR have become central to biodiversity governance at the national and global levels [3].

The erosion of PGR is occurring for multiple reasons, including habitat destruction, overexploitation of plants, illegal access to and sale of PGR, genetic depletion, and changes in environmental conditions. There is concern that the greater economic value of certain plant traits and associated traditional knowledge may lead to unauthorized use and theft of biological resources. Consequently, access to genetic resources, equitable benefit sharing, and the prevention of biopiracy have been legislated and regulated through international and national conventions and legislation, respectively. International conventions such as the Convention on Biological Diversity (CBD) and the Nagoya Protocol, and domestic acts such as India's Biological Diversity Act, are vital instruments for addressing this issue [4-6].

2 Biodiversity Laws and Wild Crop Protection

India has several legal frameworks that support the conservation of wild crop relatives and other plant genetic resources. The Wildlife (Protection) Act, 1972; the Forest Conservation Act, 1980; and the Biological Diversity Act, 2002 help conserve threatened plant species and their ecosystems [7]. The Biological Diversity Act ensures the conservation and sustainable use of biodiversity and the equitable distribution of benefits derived from biological resources. It regulates access to biological resources and associated indigenous knowledge by establishing the National Biodiversity Authority (NBA), State Biodiversity Boards, and Biodiversity Management Committees [6, 8].

At the international level, the CBD recognizes each state's sovereignty over its biological resources, the need to conserve them, the need for sustainable use, and the sharing of benefits [4]. The Nagoya Protocol advances the Convention's goals by establishing procedures for accessing biological resources and for sharing benefits from genetic resources [5]. These international conventions play a vital role in protecting wild crop

relatives, medicinal plants, and indigenous species, which are rich sources of traits for crop improvement. Various global biodiversity guidelines and Sustainable Development Goals underscore the need to protect plant genetic resources for future agriculture [9, 10].

3 Access and Benefit Sharing (ABS)

ABS provides a mechanism for using PGRs to deliver equitable benefits to provider countries and communities. The Nagoya Protocol has defined two principles: Prior Informed Consent (PIC) and Mutually Agreed Terms (MAT) [5, 11].

PIC allows users to obtain permission to access genetic resources, and MAT outlines the terms for benefit-sharing. Benefits may include monetary compensation, technology transfer, capacity building, collaborative research, and the sharing of research results. These measures promote transparency and accountability in research on biodiversity and its commercial use.

In agriculture, ABS is of great importance due to the widespread use of PGRs in crop improvement, biotechnology, and the drug and nutraceutical industries [12, 13]. The debate among international organizations over the last few years has highlighted the importance of ABS systems, which would protect the rights of biodiversity custodians while maintaining space for innovative research and technology development. However, there are numerous operational challenges, including valuing traditional knowledge, tracking resource use, identifying rights holders, and fairly distributing benefits among the local community [13]. This has led to an increased need for capacity building, stakeholder involvement, and cooperation among nations.

4 Biopiracy Prevention

Biopiracy is the illegal acquisition, patenting, or commercialization of biological resources and traditional knowledge without proper consent and equitable benefit-sharing [14, 15]. Among bioresources, plant genetic resources are the most vulnerable because indigenous agriculture, traditional crop varieties, and medicinal practices have significant market value. India has developed an effective legal framework to counter biopiracy through the Biological Diversity Act, its Rules, and associated regulations. The Traditional Knowledge Digital Library (TKDL) serves as a defense by systematically codifying traditional plant knowledge and making it available to patent offices worldwide to prevent the issuance of unmeritorious patents [14].

Significant instances of biopiracy involving turmeric, neem, and basmati helped secure the protection of plant genetic resources and traditional knowledge, as these disputes revealed that patents could be canceled when their novelty was challenged by prior knowledge [15]. These patent disputes have greatly increased international awareness of indigenous rights and the equitable distribution of benefits. Continued global cooperation among governments, scientists, communities, and NGOs is needed to combat biopiracy. Table 1 lists some global biopiracy cases and the measures implemented to safeguard them.

Table 1. Major plant-related biopiracy cases and preventive measures

Year	Plant Resource/ Traditional Knowledge	Country/ Community of Origin	Applicant/ Opposing Party	Patent/ Case No.	Issue(s)	Outcome/ Significance	References
1995	Ayurveda: Turmeric (*Curcuma longa*) – wound healing	India	University of Mississippi Medical Center, USA	US Patent No. 5,401,504	Patent claimed medicinal use already documented in traditional knowledge	Patent revoked after India demonstrated prior art from traditional sources and scientific literature. Landmark biopiracy case.	[16]
1994–2000	Neem (*Azadirachta indica*) – pesticidal & fungicidal properties	India	W.R. Grace & USDA, USA	European Patent EP0436257	Traditional agricultural knowledge was patented without recognition of prior use.	European Patent Office revoked the patent due to a lack of novelty and prior traditional use.	[16]
1997–2002	Basmati Rice (*Oryza sativa*)	India & Pakistan	RiceTec Inc., USA	US Patent No. 5,663,484	Claims over basmati rice lines and characteristics	Several claims were withdrawn or restricted following challenges from India.	[16]
1999–2008	Enola Bean (*Phaseolus vulgaris*)	Mexico	Pod-Ners LLC, USA	US Patent No. 5,894,079	Patent on a traditionally cultivated bean variety	Patent invalidated after opposition; highlighted concerns regarding farmers' rights and seed sovereignty.	[17]
Ancient Texts (Documented 2001 onwards)	Ayurveda & other traditional texts: *Charaka Samhita* & *Sushruta Samhita*	India	Multiple international patent applicants	-	Prior-art disputes; Traditional medicinal plant knowledge used in patent applications	Classical texts became evidence for challenging patents claiming existing traditional knowledge.	[18, 19]
2001–Present	Traditional Knowledge Digital Library (TKDL)	India	Patent offices worldwide	-	Part of "Preventive mechanism": Need to prevent misappropriation of traditional plant-based knowledge	TKDL documents Ayurveda, Siddha, Unani, and other knowledge systems, helping prevent wrongful patent grants.	[20]
2024	World Intellectual Property Organization (WIPO) Genetic Resources and Associated Traditional Knowledge GRATK Treaty (2024)	Global	WIPO Member States	-	Lack of transparency regarding the origin of genetic resources used in inventions	First international treaty requiring disclosure of the origin of genetic resources and associated traditional knowledge in patent applications, helping prevent future biopiracy.	[21]

5 Illegal Trading, Biodiversity Loss, and Biodiversity Conservation Strategies

Illegal trade in flora poses a profound threat to biodiversity. Thus, efforts must be made to safeguard plant genetic resources, which are essential to maintaining food security and biodiversity. These illegal trades primarily involve the extraction of wild plants from their natural habitats, which harbor high commercial and/or cultural value. These illicit trades involve numerous rare wild-collected orchids, medicinal plants, tropical timber, etc., leading to genetic erosion or extinction, loss of biodiversity or genetic diversity, population declines, and ecosystem imbalance, thereby affecting crucial adaptive potential and long-term survival [22-24]. Additionally, these issues extend to aquatic plants growing in wetlands and freshwater bodies, whose disruption affects water quality and habitat preservation [22]. Furthermore, plants from biodiversity hotspots, such as the Galápagos Islands, are vulnerable due to trade loopholes [25].

Due to "plant blindness," plants have been neglected under the Wildlife Trade Regulations (WTR) [26]. Various international legal and regulatory frameworks are now in place to curb illegal trade, promote sustainable sourcing, and support the conservation of biodiversity and genetic diversity, aligning with the Sustainable Development Goals (SDGs). The Convention on International Trade in Endangered Species (CITES) helps regulate international trade in endangered plant species. It prevents overexploitation by imposing strict monitoring and controls on trade permits [25, 27]. The Nagoya Protocol on Access and Benefit-Sharing (ABS) provides fair and equitable benefit-sharing for the use of genetic resources (GR). ABS fosters conservation incentives in biodiversity-rich countries, supporting GR protection [28-30]. However, this can affect both noncommercial and commercial botanical research. Hence, it warrants

careful balance to avoid hindering critical scientific research [29, 31]. Under the Botanic Gardens Conservation International (BGCI), the Illegal Plant Trade Coalition (IPTC), partnering with the United Nations Environment Program's (UNEP's) World Conservation Monitoring Center (UNEP-WCMC) and Global Enforcement Partners (GEP), focuses specifically on plants and their trade. FloraGuard is an organization funded by the UK Economic and Social Research Council (ESRC). It combines cross-disciplinary and innovative methods to analyze online trading platforms and trace illegal trade in endangered flora, assisting existing law enforcement in identifying and investigating illicit trade [24, 32]. The Cartagena Protocol on Biosafety complements ABS by overseeing the risks associated with the transboundary movement of genetically modified organisms (GMOs), thereby indirectly safeguarding the genetic integrity of native plant populations [33]. The Kunming-Montreal Global Biodiversity Framework (KMGBF) was adopted by the CBD in 2022. It includes 2030 targets to stop biodiversity loss. This supports an integrated approach to preserving genetic diversity and the sustainable utilization of plant genetic resources (PGR) [34]. SDGs also play an important role in conserving floral biodiversity. SDG 2.5 aims to maintain genetic diversity in food production systems. It is associated with the conservation of both plant and animal genetic resources, as well as SDG indicator 2.5.1, which supports medium- and long-term conservation facilities. This indicator monitors the plant genetic resources held in gene banks, seed banks, and plant tissue culture collections globally and serves as a vital safeguard against illegal harvesting and biodiversity loss [35-37]. Moreover, SDGs 14 and 15 emphasize the sustainable use and conservation of biodiversity in aquatic and terrestrial ecosystems, respectively [38, 39]. The Agenda 2030 framework also integrates these biodiversity goals into sustainable development [29, 38].

6 Challenges and Future Directions

Illegal trade in plants continues to hamper the conservation of plant genetic resources [40]. The implementation of the Nagoya Protocol has hindered noncommercial research vital to biodiversity conservation and monitoring. This highlights the need to adopt adaptive governance that fosters a scientific temperament [29, 31]. Advances in technologies, such as DNA barcoding and Digital Sequence Information (DSI), may aid species identification and tracking. These genetic technologies would enable stronger enforcement of laws against illegal flora trade and promote policies on benefit-sharing and the maintenance of genetic sovereignty [35, 36].

7 Conclusion

In conclusion, effective biodiversity laws and ABS frameworks are important pillars for protecting and sustainably utilizing plant genetic resources. The reinforcement of legal policies at the international and national levels is vital to preventing biopiracy and ensuring equitable distribution of benefits. Moreover, harmonized policies that balance biodiversity conservation and utilization, promote scientific innovation, and safeguard floral biodiversity should be incorporated into future policies and regulatory frameworks. Thus, continued global cooperation and policy reinforcement will be the key to preserving plant genetic biodiversity for future generations.

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