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Genetic diversity and conservation strategies for endangered medicinal plants of Rajasthan

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Abstract
Rajasthan, known for its diverse ecosystems ranging from arid deserts to semi-arid grasslands and forested hills, hosts a wide array of medicinal plant species with therapeutic and commercial value. However, increasing anthropogenic pressures, climate change, overharvesting, and habitat degradation are threatening the survival of many of these valuable species. This review explores the genetic diversity of endangered medicinal plants in Rajasthan, their ecological significance, and the current and emerging conservation strategies needed to ensure their survival. The paper advocates for an integrative and sustainable framework for conserving these natural resources by emphasizing in-situ and ex-situ approaches, biotechnology applications, and community involvement.

Keywords: Genetic diversity, medicinal plants, endangered species, conservation strategies, climate change, habitat degradation

Introduction

Rajasthan, the largest state of India, is known for its desert landscape, dry climate, and diverse ecosystems. Despite its harsh environment, Rajasthan is home to a rich variety of plants, many of which are used in traditional medicine (*Gehlot et al*., 2016) [9].

People in this region, especially tribal communities like the Bhils, Garasias, and Sahariyas, have used these plants for centuries to treat various illnesses. Medicinal plants like *Commiphora wightii* (Guggal), *Withania somnifera* (Ashwagandha), and *Chlorophytum borivilianum* (Safed Musli) are not only important for local healthcare but are also used widely in Ayurvedic and herbal industries across India and the world (Shekhawat *et al., 2012*) [33].

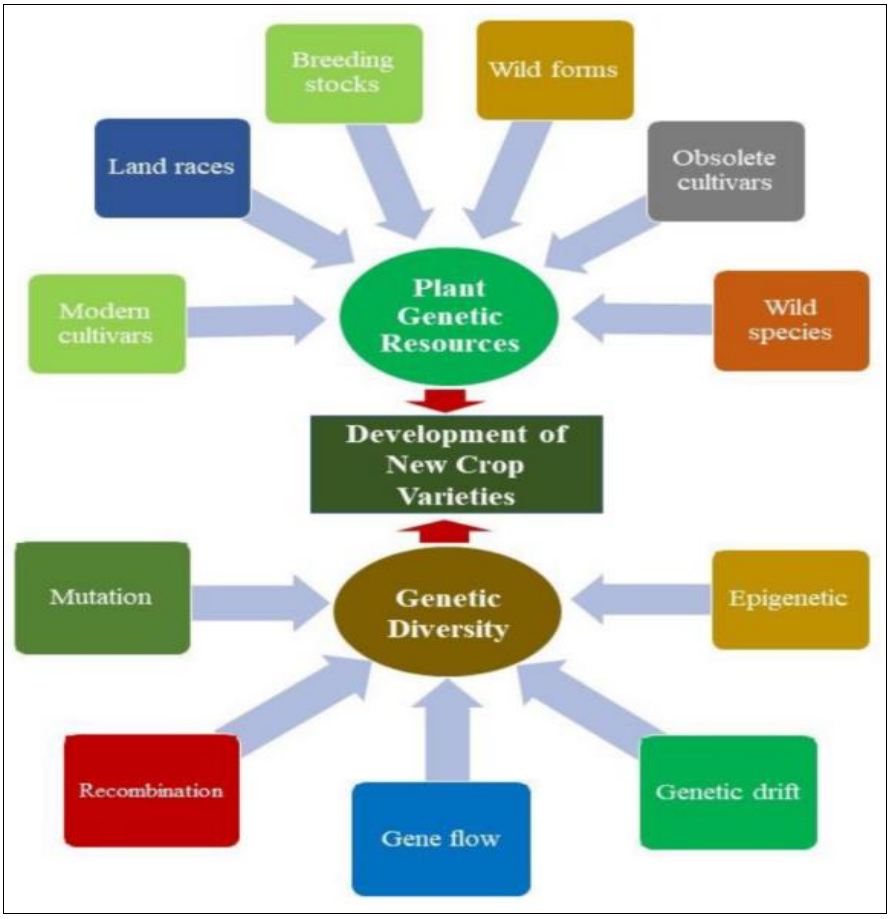

Fig 1: A plan of Genetic Diversity and conservation (Salgotra, & Chauhan, 2002) [29]

However, many of these valuable plants are now under threat. Due to reasons such as overharvesting, destruction of natural habitats, climate change, and overgrazing, the population of several medicinal plants has dropped sharply (Rawat, 2008) [25]. Some have even become endangered, meaning they are at risk of disappearing from the wild completely. This is a serious problem, not only because these plants are useful for medicine, but also because they are part of the natural ecosystem and cultural heritage of the region (Reddy, *2008*) [26].

One of the most important ways to help protect these plants is by conserving their genetic diversity. Genetic diversity means the variety of genes within a species. It allows plants to adapt to changing environments, resist pests and diseases, and maintain their health over time (Narain, 2000) [18]. Without enough genetic diversity, plants become weaker and more likely to die out. This is especially true for endangered species that already have small populations (Neel, 2008) [19].

To save these plants, we need smart and effective conservation strategies. These include protecting plants in their natural habitats (in-situ conservation), growing and storing them in botanical gardens or laboratories (ex-situ conservation), using modern tools like tissue culture for mass propagation, and involving local people in the process. It is also important to record and respect traditional knowledge about how these plants are used (*Braverman, 2014*) [6].

This review paper will explore the importance of genetic diversity in Rajasthan's medicinal plants, the major threats they face, and the different conservation methods being used or proposed. By combining traditional knowledge, scientific research, and community participation, we can help preserve these plants for future generations while supporting sustainable healthcare and biodiversity in the region.

Importance of Medicinal Plants in Rajasthan

Rajasthan is home to several endangered medicinal plants listed in the Red Data Book due to overexploitation, habitat loss, and harsh climatic conditions. Notable species include *Commiphora wightii* (Guggal), *Chlorophytum borivilianum* (Safed Musli), *Gloriosa superba* (Kalihari), and *Withania somnifera* (Ashwagandha) (Sharma *et al*., 2017) [31]. These plants possess valuable therapeutic properties and are widely used in Ayurveda and traditional healing systems. Their decline poses a threat to biodiversity and traditional knowledge systems. Conservation efforts through in-situ and ex-situ strategies, along with public awareness and sustainable harvesting practices, are crucial to preserving these vital medicinal resources for future generations (Nishteswar, 2014) [21]. Medicinal plants found in Rajasthan are shown in Table 1.

Table 1: Plants with medicinal values found in Rajasthan

S. No.	Botanical Name	Common Name	Medicinal Properties	Major Secondary Metabolites	Reference
1.	*Commiphora wightii*	Guggal	Anti-inflammatory, anti-obesity, cholesterol-lowering	Guggulsterones, essential oils, terpenoids	Sharma, & Zafar, 1996 [32]
2.	*Withania somnifera*	Ashwagandha	Adaptogenic, anti-stress, anti-inflammatory	Withanolides, alkaloids, sitoindosides	Singh, *et al*.,2011 [35]
3.	*Chlorophytum borivilianum*	Safed Musli	Aphrodisiac, immune booster, anti-diabetic	Saponins, alkaloids, steroids	Kothari & Singh, 2003 [15]
4.	*Boswellia serrata*	Salai guggul	Anti-arthritic, anti-inflammatory, wound healing	Boswellic acids, terpenoids	Ammon, 2010 [2]
5.	*Tecomella undulata*	Rohida	Hepatoprotective, anti-microbial, anti-cancer	Flavonoids, tannins, alkaloids	Bhandari, 1990 [5]
6.	*Aloe vera*	Ghritkumari	Skin healing, laxative, anti-diabetic	Aloin, barbaloin, anthraquinones	Surjushe *et al*., 2008 [37]
7.	*Cassia angustifolia*	Senna	Laxative, purgative, digestive stimulant	Sennosides, flavonoids	Mowrey, 1994 [187
8.	*Calotropis procera*	Aak	Anti-inflammatory, analgesic, anti-microbial	Cardiac glycosides, flavonoids, triterpenoids	Kumar *et al*., 2010 [16]
9.	*Azadirachta indica*	Neem	Anti-bacterial, anti-viral, blood purifier	Azadirachtin, nimbin, quercetin	Subapriya, & Nagini, 2005 [36]
10.	*Tinospora cordifolia*	Giloy	Immunomodulator, anti-diabetic, antioxidant	Tinosporine, berberine, glycosides	Saha, *et al*., 2011
11.	*Asparagus racemosus*	Shatavari	Reproductive tonic, galactagogue, anti-ulcer	Saponins, flavonoids, polyphenols	Pandey& Gupta, 2010 [22]
12.	*Tribulus terrestris*	Gokhru	Diuretic, aphrodisiac, enhances male fertility	Saponins, alkaloids, flavonoids	Neychev & Mitev, 2005 [20]
13.	*Emblica officinalis*	Amla	Antioxidant, liver tonic, immune booster	Ascorbic acid (Vitamin C), tannins, flavonoids	Scartezzini & Speroni, 2000 [30]
14.	*Terminalia bellirica*	Baheda	Digestive, laxative, anti-microbial	Tannins, gallic acid, chebulinic acid	Baliga, 2010 [4]
15.	*Terminalia chebula*	Harad	Laxative, antioxidant, detoxifier	Chebulinic acid, gallic acid, tannins	Saleem, *et al*., 2002 [28]

The Red Data Book serves as a critical scientific document that records endangered and threatened species, including medicinal plants, highlighting their risk of extinction. For Rajasthan, where several medicinal plant species are facing increasing threats due to overharvesting, habitat loss, and climate change, the inclusion of these species in the Red Data Book is essential (Rao *et al*., 2003) [24]. It provides formal recognition of their endangered status, drawing attention to their ecological and pharmacological importance. This listing acts as a basis for prioritizing conservation actions, enforcing protective regulations, and directing research and funding towards their preservation. Few significant plant included in Red Data book are from Rajasthan shown in the Table 2.

Table 2: Some significant Red Data Book medicinal plants in Rajasthan

S. No.	Botanical Name	Common Name	Red List Status
1.	*Commiphora wightii*	Guggal	Critically Endangered
2.	*Withania somnifera*	Ashwagandha	Vulnerable
3.	*Chlorophytum borivilianum*	Safed Musli	Endangered
4.	*Boswellia serrata*	Indian Frankincense	Near Threatened
5.	*Tecomella undulata*	Rohida	Vulnerable
6.	*Gloriosa superba*	Kalihari, Flame Lily	Endangered
7.	*Mucuna pruriens*	Kaunch	Vulnerable
8.	*Nardostachys jatamansi*	Jatamansi	Critically Endangered
9.	*Rauvolfia serpentina*	Sarpagandha	Endangered
10.	*Saussurea costus*	Kuth	Critically Endangered
11.	*Asparagus racemosus*	Shatavari	Vulnerable
12.	*Aconitum heterophyllum*	Atis	Endangered

IUCN. (2018) [12]

Genetic Diversity and Its Role in Conservation

Genetic diversity refers to the variety of genes within a species. It is the foundation of biodiversity and plays a crucial role in the survival and adaptability of plant species, especially endangered medicinal plants (Duffy, 2009) [8]. High genetic diversity allows species to adapt to changing environmental conditions, resist pests and diseases, and maintain healthy reproduction. In contrast, low genetic diversity makes plants more vulnerable to extinction, especially under stress caused by habitat destruction, climate change, or overharvesting (Alho, 2008) [1].

For medicinal plants, genetic diversity ensures the availability of important biochemical compounds that have therapeutic properties. Different genotypes within a species may produce varying levels of active ingredients, making it essential to conserve the full genetic range. This diversity is also key to future breeding and biotechnological research for developing improved plant varieties (Briskin, 2000) [7].

Conservation strategies must focus on preserving this genetic variation. In-situ conservation (protecting plants in their natural habitats) and ex-situ conservation (like seed banks, tissue culture, and botanical gardens) are essential methods. Additionally, using molecular tools such as DNA markers helps identify genetically diverse populations and monitor genetic erosion. By maintaining genetic diversity, we not only protect the plant species themselves but also safeguard the ecological and medicinal value they offer to humanity (*Heywood & Dulloo, 2005*) [11].

Table 3: Conservation strategy and techniques for Endangered plant species

S.No.	Conservation Type	Technique	Description
1.	In-situ	Protected Areas (Wildlife Sanctuaries, National Parks)	Natural habitats where species grow and evolve under natural conditions.
2.		Medicinal Plant Conservation Areas (MPCAs)	Special zones designated for the protection of native medicinal species.
3.		Sacred Groves and Community Forests	Traditional sites preserved by local communities, rich in native plant diversity.
4.	Ex-situ	Botanical Gardens	Cultivation of endangered species outside their natural habitat for education and research.
5.		Seed Banks	Long-term storage of seeds under controlled conditions to preserve genetic material.
6.		Field Gene Banks	Living collections of plants maintained in fields for future use.
7.		Tissue Culture and Micropropagation	Rapid multiplication of plantlets in sterile lab conditions; useful for rare or slow-growing species.
8.	Molecular & Biotechnological	DNA Barcoding	Identifies plant species and their genetic variation for better conservation planning.
9.		Molecular Markers (RAPD, AFLP, SSR)	Track genetic diversity and monitor genetic erosion over time.
10.		Cryopreservation	Ultra-low temperature storage of plant tissues, seeds, or cells for long-term conservation.
11.		Genomic Mapping and Gene Banks	Cataloging genes for future breeding, restoration, and biotechnological studies.

Threats to Genetic Diversity in Rajasthan's Medicinal Plants

The following factors are major threats to the genetic diversity of Rajasthan's medicinal flora:

1. **Overharvesting:** Unsustainable collection of roots, bark, and entire plants from the wild leads to population depletion and poor regeneration.
2. **Habitat Destruction:** Land-use changes for agriculture, mining, urbanization, and infrastructure development are reducing natural habitats.
3. **Climate Change:** Rising temperatures, irregular rainfall, and desertification negatively affect plant growth and seed germination.
4. **Grazing Pressure:** Overgrazing by livestock in forest and scrubland areas damages young saplings and herbs.
5. **Lack of Regeneration:** Many medicinal plants have poor natural regeneration due to low seed viability and predation.

These threats have resulted in the categorization of several medicinal species as critically endangered, endangered, or vulnerable in the IUCN Red List and the Indian Red Data Book.

Policy and Institutional Support

1. National level

Medicinal plants listed in the Red Data Book require robust policy and institutional support to ensure their conservation and sustainable use. At the national level, policies such as the National Medicinal Plants Board (NMPB) under the Ministry of AYUSH play a vital role by promoting the conservation, cultivation, and sustainable management of medicinal plants (Kala *et al*., 2007) [14]. The Wildlife Protection Act, 1972, and the Biological Diversity Act, 2002, provide legal frameworks to protect endangered species and regulate access to biological resources (Prathapan *et al*., 2002) [23]. In Rajasthan, state forest departments and biodiversity boards are actively involved in identifying and conserving threatened medicinal species through Medicinal Plant Conservation Areas (MPCAs) and community-based forest management programs (Shukla *et al*., 2006) [34]. Additionally, schemes like the National AYUSH Mission (NAM) offer financial and technical assistance for the cultivation and marketing of medicinal plants, especially those recognized as endangered (Ghate *et al*., 2012) [10]. Institutions such as the Botanical Survey of India (BSI) and various research universities contribute through field surveys, seed banking, and tissue culture initiatives. Collaborative efforts between government bodies, NGOs, and local communities are essential to enhance monitoring, improve habitat restoration, and ensure the implementation of conservation action plans for Red Data Book species.

2. State Level

Rajasthan has implemented several policy and institutional frameworks to support the conservation of endangered medicinal plants listed in the Red Data Book. The State Medicinal Plants Board (SMPB), Rajasthan, under the guidance of the National Medicinal Plants Board (NMPB), plays a key role in identifying, documenting, and conserving medicinal plant species (Anonymus, 2008). Policies such as the Rajasthan State Biodiversity Strategy and Action Plan and the Forest Policy of Rajasthan emphasize the protection of medicinal flora, especially those at risk of extinction. Institutions like the Forest Department, State Biodiversity Board, and Herbal Mandis work together to regulate sustainable harvesting practices and promote cultivation of threatened species through financial incentives and technical support. Several Vanaspati Van (herbal forests) and Medicinal Plant Conservation Areas (MPCAs) have been established in biodiversity-rich regions such as Mount Abu, Sariska, and Jaisamand. These efforts are complemented by community-based conservation initiatives, involvement of Joint Forest Management Committees (JFMCs), and integration of traditional knowledge systems.

Challenges in Medicinal Plant Conservation

Medicinal plant conservation in Rajasthan faces several critical challenges that threaten the survival of many endangered species. One of the foremost issues is overharvesting, driven by increasing demand for herbal medicines and lack of sustainable harvesting practices. Habitat degradation, due to urbanization, mining, overgrazing, and deforestation, further reduces the natural habitats of medicinal plants. Climate change, including rising temperatures and erratic rainfall patterns, affects the growth, reproduction, and distribution of many sensitive species.

Another major challenge is the loss of traditional knowledge, as younger generations move away from indigenous practices, leading to disconnect between communities and their botanical heritage. There is also a lack of accurate population data and comprehensive field assessments for many species, making it difficult to prioritize conservation efforts. Weak enforcement of existing policies, limited funding, and insufficient coordination among government agencies, researchers, and local stakeholders hinder effective implementation of conservation programs. Additionally, limited awareness among local communities and absence of proper training in sustainable harvesting and cultivation practices further complicate efforts.

Future Prospects and Recommendations

To ensure sustainable conservation of endangered medicinal plants in Rajasthan, the following steps are recommended (Kala, 2005) [13]:

1. **Integrative Conservation Models:** Combine in-situ, ex-situ, and community-based approaches for holistic preservation.
2. **Geo-referenced Mapping:** Use GIS tools to identify and monitor hotspots of genetic diversity.
3. **Participatory Research:** Engage local healers and farmers in research to validate traditional practices and improve cultivation.
4. **Value Addition and Market Linkages:** Establish herbal processing units, certification systems, and marketing support to enhance economic value.
5. **Climate Resilience Studies:** Investigate adaptive traits in native species to develop climate-resilient varieties.
6. **Educational Programs:** Introduce biodiversity and conservation modules in schools and colleges to create awareness from a young age.

Conclusion

The medicinal plant wealth of Rajasthan is a valuable natural heritage that must be protected for ecological balance, traditional healthcare systems, and future pharmaceutical discoveries. Genetic diversity is the cornerstone of plant survival, and its preservation is critical for the long-term sustainability of medicinal flora. By integrating scientific innovation with traditional wisdom, and involving local communities as stewards of biodiversity, Rajasthan can set a model for medicinal plant conservation across arid and semi-arid landscapes.

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