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Diversity, Ethnobotany, and Conservation of Cactus Species at the Himalayan Botanical Garden, Nainital, Uttarakhand

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Abstract: ***The Himalayan Botanical Garden (HBG), Nainital, maintains a curated collection of 50 cactus and succulent species representing the plant family Cactaceae and associated succulent taxa. This paper documents the species diversity, ethnobotanical uses, ornamental value, and conservation potential of these arid-adapted plants in a temperate Himalayan context. The collection includes both native and exotic species, with significant ecological, horticultural, and economic value. The study underlines the role of ex-situ conservation in promoting awareness and sustainable utilization of succulents, especially in changing climatic regimes.***

Keywords: Botanical garden, Cactus, Ethnobotany, Ex-situ conservation, Ornamental plants, Himalayan region

1. Introduction

Cacti, members of the family Cactaceae, represent a fascinating group of succulent plants primarily adapted to survive in arid and semi-arid ecosystems. With over 1,800 species across more than 130 genera, the family is almost exclusively native to the New World, particularly the deserts of North and South America, including the southwestern United States, Mexico, and parts of South America (Anderson 2001). A few species such as *Rhipsalis baccifera* are exceptions, occurring naturally in parts of Africa and Sri Lanka. The evolutionary adaptations of cacti, including CAM (Crassulacean Acid Metabolism) photosynthesis, thick cuticles, reduced leaves, and specialized water-storing tissues, have made them highly resilient to harsh environmental conditions (Nobel 1988).

Beyond their ecological adaptations, cacti hold significant ethnobotanical and economic value. In countries such as Mexico, *Opuntia* species (commonly known as prickly pear) are widely consumed, with both the cladodes (nopalitos) and fruits (tunas) forming integral parts of local diets and traditional medicine. These species are known for their high content of antioxidants, vitamins, and dietary fiber (Sáenz 2000). Similarly, *Agave* species are cultivated not only for their fibers and sugars but also for their role in traditional medicine and cultural practices (Gentry 1982). In arid parts of India, certain *Opuntia* and *Agave* species have naturalized and are being explored for fodder, fuel, and anti-erosion purposes (Singh *et al*. (2014).

Botanical gardens play a crucial role in the ex-situ conservation, public education, and scientific study of plant biodiversity. The Himalayan Botanical Garden (HBG) in Nainital serves as a high-altitude center for the conservation of both native and exotic plant species, including arid-zone taxa like cacti and succulents. While cacti are not native to the Indian Himalayas, their cultivation in controlled environments such as glasshouses or rockeries allows for both conservation and education in regions where such species would otherwise be ecologically excluded.

This paper presents a comprehensive inventory of 50 cactus and succulent species maintained at the HBG, along with their known ethnobotanical uses and ornamental value. It seeks to highlight the importance of maintaining such collections in the Himalayan region, both for conservation and for promoting awareness of xerophytic plant diversity. Through this study, we also emphasize the potential role of cactus species in sustainable horticulture, landscape design, and alternative agriculture under the growing impacts of climate change.

2. Materials and Methods

1) Study Site

The study was conducted at the Himalayan Botanical Garden (HBG), located in Nainital, Uttarakhand, India, situated at an altitude of approximately 1700-2100 meters above sea level in the Kumaon Himalaya. The region falls under a temperate montane climate zone, experiencing cool summers and cold

winters with occasional snowfall. The botanical garden is administered by the Forest Department of Uttarakhand and serves as a center for plant conservation, education, and horticultural research.

To accommodate cactus and succulent species- naturally adapted to arid and semi-arid conditions- a dedicated Dome section has been developed within HBG. This specialized facility ensures optimal temperature regulation, drainage, and sunlight exposure for successful growth of non-native xerophytic species.

2) Data Collection

An inventory survey of all cactus and succulent species currently maintained in the HBG collection was conducted between 2009- 2024. The following methodological steps were followed:

a) **Field Identification:** Each specimen was examined in situ, with initial identification performed based on morphological features such as stem form, areole arrangement, spination, flower type, and growth habit.

b) **Procurement from Nurseries:** To enrich h the diversity of the garden and overcome limitations in local species availability, selected species were sourced from plant nurseries and cactus growers. All nursery-acquired plants were:
- Quarantined for pests and diseases upon arrival
- Acclimatized under semi-controlled polyhouse conditions before field planting.
- Documented with source information and tagged accordingly.

c) **Taxonomic Verification:** Species identification was confirmed using standard taxonomic keys from regional floras and authoritative references including Anderson 2000 and Hunt *et al*. (2006). Where necessary, online databases such as The Plant List, Tropicos, and Plants of the World Online were consulted for accepted nomenclature and synonyms.

3) Documentation Parameters

For each species, the following information was recorded and compiled:
- Scientific name
- Common uses (ethnobotanical, ornamental, medicinal, or culinary)
- Growth form and habit
- Ecological origin (native range and habitat preference)

Data on ethnobotanical uses were compiled from literature reviews, including peer-reviewed journals, ethnobotanical databases, and medicinal plant compendiums. Particular emphasis was placed on uses relevant to Indian, Mexican, and Mediterranean contexts where cactus species are traditionally utilized.

4) Cultivation and Maintenance Practices

Cactus and succulent species at HBG are maintained under horticultural supervision with attention to the following cultivation practices:
- **Soil Medium:** A custom substrate mix composed of coarse sand (40%), perlite (20%), loam soil (30%), and organic compost (10%) was used to mimic arid-zone soil profiles and ensure adequate drainage.
- **Watering Regime:** Plants were irrigated sparingly, with seasonal adjustments—once weekly during summer and biweekly or less during winter to prevent root rot.
- **Pest and Disease Management:** Routine inspections and biological control measures (e.g., neem oil spray) were employed to manage mealybugs, spider mites, and fungal infections.
- **Propagation:** Select species were propagated via offset division, stem cuttings, and seed sowing, depending on species-specific viability.

5) Data Analysis

Species were categorized according to their primary use: ornamental, medicinal, edible, or multipurpose. Descriptive statistics (frequencies and percentages) were used to assess species distribution across usage categories. Using Excel software for record-keeping and educational use within the garden.

3. Results and Discussion

1) Species Diversity and Composition

A total of 50 cactus and succulent species representing over 15 genera were documented at the Himalayan Botanical Garden (Table 1 and Fig.1). These species, though primarily native to arid and semi-arid regions of the Americas and Africa, have been successfully acclimatized and cultivated in the controlled environments of the garden. The collection includes representatives from major genera such as *Agave*, *Opuntia*, *Kalanchoe*, *Mammillaria*, *Crassula*, *Sedum*, *Cotyledon*, and *Ferocactus*, among others.

The majority of the species—over 75% (n = 38)—are maintained for ornamental purposes, highlighting the aesthetic value and landscape potential of cacti and succulents in garden design. Species like *Echinocactus grusonii*, *Senecio rowleyanus*, and *Lithops lesliei* are particularly valued for their distinctive morphology and color, making them popular among visitors and home gardeners alike.

2) Ethnobotanical and Economic Relevance

In addition to ornamental applications, 12 species (24%) possess notable ethnobotanical or economic value. For instance:
- *Opuntia microdasys* is widely used in Mexico and parts of India for its edible cladodes and fruit. The fruit is rich in vitamin C and antioxidants, while the pads serve as a vegetable or forage crop in arid zones (Sáenz 2000).
- *Agave americana* and related species are traditionally cultivated for fiber (sisal) and medicinal purposes, including treatment of digestive issues, wounds, and infections (Gentry 1982).
- *Kalanchoe luciae* and K. synsepala are employed in traditional medicine for their anti-inflammatory and antimicrobial properties, supporting their inclusion in ethnobotanical studies (Reddy *et al*. 2010).

This diversity reflects the multifunctional role of cactus species—not only as resilient ornamentals but also as resources for food, fiber, medicine, and cultural use. The potential for these plants in climate-smart agriculture, especially in water-scarce regions of India, is significant.

3) Adaptation and Cultivation Success at HBG

Despite their origin in xeric habitats, the cactus species at HBG have demonstrated high adaptability to high-altitude temperate conditions when grown under controlled environments such as rockeries and glasshouses. Key factors supporting this success include:

- Well-drained soil media mimicking desert soils
- Controlled watering regimes to prevent root rot
- Temperature regulation during the winter months using polyhouse and glasshouse techniques
- Proper sunlight exposure aided by shade netting to balance light and frost protection

Propagation trials conducted using stem cuttings and offsets showed good success rates in *Crassula*, *Kalanchoe*, and *Opuntia* species. However, seed germination remained low, likely due to the absence of pollinators and temperature fluctuations in Nainital's environment.

These observations align with earlier research suggesting that vegetative propagation is more effective for exotic succulents in non-native gardens (Hunt *et al*. (2006)).

4) Conservation and Educational Value

The cactus section at HBG serves as an important educational and conservation resource. It provides:

- Exposure to exotic xerophytes for students, researchers, and the public
- Opportunities for ex situ conservation of rare or economically valuable species
- A living laboratory for climate-resilient horticultural practices

Given the increasing demand for low-water landscaping and ornamental xerophytes, HBG's cactus collection has the potential to contribute to horticultural innovation, green tourism, and plant-based livelihoods in nearby regions.

5) Challenges and Future Directions

Several challenges were noted:

- Cold sensitivity of some species during winter months
- Pest infestations, particularly mealybugs, in dense plantings
- Lack of structured propagation programs for genetic diversity conservation

Future work should include:

- Expanding the collection to include endangered and endemic xerophytes
- Incorporating QR-coded labeling and digital databases for public learning
- Establishing partnerships with arid-zone research centers for plant exchange and joint conservation

4. Conclusion

The present study documents and evaluates the rich diversity of 50 species of cactus and succulents maintained at the Himalayan Botanical Garden (HBG), Nainital, highlighting their ornamental, medicinal, and ethnobotanical significance. Despite being native to arid and semi-arid regions of the Americas and Africa, these species have been successfully cultivated and conserved in the unique temperate conditions of the Kumaon Himalaya through careful horticultural management and environmental control.

The study reveals that a majority of the species (76%) are maintained for ornamental purposes, underlining their aesthetic and landscape value. At the same time, a noteworthy proportion of species demonstrate valuable traditional uses, including nutritional, medicinal, and agro-industrial applications. This multifunctionality reinforces the importance of these plants in sustainable horticulture, biodiversity education, and climate-adaptive landscaping.

The successful acclimatization of these exotic xerophytes in a high-altitude environment like Nainital offers valuable insights for future conservation strategies, especially in the context of water scarcity, climate change, and habitat loss. Furthermore, the cactus collection at HBG serves not only as a center for plant conservation but also as a platform for public education, scientific research, and ecotourism.

To build upon this foundation, future efforts should aim at expanding species diversity, developing propagation and seed banking programs, and integrating digital documentation tools for enhanced learning and conservation outreach. The study underscores the critical role that regional botanical gardens can play in preserving and promoting plant species that are often overlooked yet hold immense potential for ecological and economic resilience.

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Sulcorebutia rauschii | *Echinocactus grusonii*

Mammillaria tetrancistra | *Agave americana*

Figure 1: Cactus Maintained at Himalayan Botanical Garden

Table: HBG maintained 50 spp. of cactus listed below

S. No.	Cactus species	Uses
1	*Agave Americana*	Sometimes grown as a hedge. Its leaves are sometimes used medicinally or grown for their fibres
2	*Agave medinensis*	Agave has been taken by mouth for constipation, indigestion, flatulence, jaundice, cancer, and diarrhoea, and to promote urine production
3	*Agave schidigera*	Help to maintain blood sugar level
4	*Agave Victoria*	Ornamental
5	*Alluaudia humbertii*	Ornamental
6	*Stenocactus multicostatus*	Excellent plant for container growing.
7	*Cotyledon orbiculata* var *oblonga*	Fleshy parts of leaves is applied to warts and corns
8	*Cotyledon tomentosa*	Houseplant
9	*Crassula conjuncta*	Ornamental
10	*Crassula ovata* (Jade plant)	Ornamental
11	*Crassula ovate* (Gollum jade)'	Ornamental
12	*Delosperma congestum*	Ornamental
13	*Echeveria imbricate*	Ornamental
14	*Echinocactus grusonii*	Ornamental
15	*Echinopsis chamaecereus*	Ornamental
16	*Faucaria britteniae*	Ornamental
17	*Ferocactus cylindricus*	Ornamental
18	*Acanthocereus tetragonus*	Ornamental
19	*Gasteria glomerata*	Ornamental
20	*Cleistocactus winteri*	Ornamental
21	*Graptoveria opalina*	Ornamental
22	*Kalanchoe fedtschenkoi*	Ornamental
23	*Kalanchoe laxiflora*	Ornamental
24	*Kalanchoe luciae*	Used to treat ailments such as infections, rheumatism
25	*Kalanchoe synsepala*	Used to treat viral infections, bacterial infections

26	*Kalanchoe tomentosa*	Ornamental
27	*Lithops lesliei*	Ornamental
28	*Malephora crocea*	Ornamental
29	*Mammillaria bocasana*	Ornamental
30	*Mammillaria microthele*	Ornamental
31	*Mammillaria prolifera*	Ornamental
32	*Mammillaria pulmosa*	Ornamental
33	*Mammillaria tetrancistra*	Ornamental
34	*Didierea trollii*	Ornamental
35	*Esposto lanata*	Ornamental
36	*Opuntia microdasys*	Fruit raw , cooked o dried for later use
37	*Opuntia polyacantha*	Ornamental
38	*Opuntia rufiada minima*	Ornamental
39	*Pachyphytum compactum*	Ornamental
40	*Pilosocereas azureus*	Ornamental
41	*Sedum Burrito*	Ornamental
42	*Sedum panchyphyllum*	Ornamental
43	*Sedum tubrotinctum*	Ornamental
44	*S. tectorum*	Ornamental
45	*Sencio mandaliscae*	Ornamental
46	*Senecio rowleyanus*	Ornamental
47	*Sulcorebutia rauschii*	Ornamental
48	*Tephrocactus articulatus*	Ornamental