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Ecological Distribution, Phytochemical Profiling, and Ex-Situ Conservation Strategies for Lesser-Known Medicinal Plants in the Agra District, India

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Abstract

India represents one of the world's most significant mega-diversity centers, holding a vast reservoir of medicinal and aromatic plants that have formed the foundation of traditional healthcare systems for millennia. However, escalating urbanization, industrialization, and habitat loss, which currently depletes forest cover by 1-2% annually, pose severe threats to these invaluable botanical resources. This study undertakes a comprehensive ecological and phytochemical investigation of lesser-known medicinal herbs across diverse habitats (industrial, urban, suburban, rural, and wetland) within the Agra district of Uttar Pradesh, India. A total of 17 indigenous medicinal species, including Abutilon indicum, Boerhavia diffusa, Tribulus terrestris, and Barleria prionitis, were identified and meticulously documented through the establishment of a localized herbarium. Ecological assessments utilizing the Jaccard Similarity Index indicated high spatial homogeneity in plant distribution (index > 0.9375), though subtle micro-environmental variations influenced specific population densities. Preliminary phytochemical screenings of aqueous and methanolic extracts revealed a dominant presence of flavonoids and tannins, suggesting high antioxidant and anti-inflammatory potential, while alkaloids were largely absent, barring specific species like Tribulus terrestris and Ruellia tuberosa. Furthermore, an ex-situ conservation experiment conducted at a botanical garden demonstrated statistically significant improvements in reproductive capacity and seedling survivorship ($p < 0.05$), particularly in species like Barleria prionitis. The integration of morphological profiling, ecological mapping, and controlled cultivation highlights the urgent necessity for formalized conservation frameworks to protect these biological assets, ensuring their sustainable integration into modern pharmacological research and mitigating the pressures on wild populations.

Keywords*:* Biodiversity Conservation, Phytochemistry, Ex-situ Cultivation, Medicinal Plants, Jaccard Similarity Index, Pharmacognosy

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Introduction

Recognized globally as one of the twelve megadiverse nations, India harbors an exceptional wealth of biological resources, characterized by an intricate tapestry of ecosystems and microclimates. Among its most valuable biological assets are medicinal and aromatic plants, which have been continuously utilized in traditional medicine systems for thousands of years. The historical reliance on medicinal flora is deeply woven into the cultural fabric of the subcontinent, with early documentation dating back to the Atharvaveda around 2000 BCE. Pioneering historical figures, notably Maharishi Charaka, who is frequently heralded as the principal founder of Ayurvedic medicine, systematically cataloged the therapeutic efficacy of native flora. Charaka imparted extensive botanical knowledge to communities across the subcontinent, advocating for the integration of specific herbs into daily dietary practices to prevent physical and physiological ailments, and emphasizing seasonal herbal regimens to fortify the human body against environmental extremes.

In contemporary times, the global paradigm has shifted significantly toward natural and holistic healthcare. The international market for products derived from medicinal plants is expanding at a robust rate of approximately 7% annually, reflecting a surging demand for plant-based therapeutics, dietary supplements, and functional foods. Despite this immense economic and therapeutic potential, the biological sources of these materials are under unprecedented threat. The absence of a rigorously defined and successfully implemented strategy for the conservation of wild medicinal plants is a matter of profound global concern. Natural habitats, particularly forests that serve as primary repositories for wild medicinal herbs, are diminishing at an alarming pace. Recent macro-ecological survey reports indicate that regional forest cover is contracting by 1% to 2% annually, primarily driven by land-use changes, agricultural expansion, and infrastructural development.

This rapid habitat degradation directly results in the loss of critical ecosystems for countless species, placing intense survival stress on wild populations and pushing several high-value therapeutic plants to the brink of localized extinction. While substantial institutional efforts have been directed toward the conservation of prominent, highly commercialized medicinal species, lesser-known herbs that possess equivalent pharmacological potential often remain neglected in broad conservation agendas. Furthermore, the reproductive capacity of these plant species—a fundamental determinant of population dynamics and survival—is frequently overlooked in standard botanical inventories. Understanding and documenting the specific reproductive mechanisms, seed biology, and germination potential of these plants is an absolute prerequisite for formulating viable long-term conservation protocols.

In response to these interconnected ecological and pharmacological challenges, this research study was conducted within the Agra district of Uttar Pradesh, India. The primary objective was to survey, document, and analyze lesser-known medicinal herb species distributed across a gradient of environmental disturbances, ranging from heavy industrial zones to protected wetlands. By integrating ecological distribution mapping, detailed morphological characterization, qualitative phytochemical screening, and controlled ex-situ propagation experiments, this study aims to provide a comprehensive framework for understanding the therapeutic potential and conservation imperatives of native flora. Through the extraction of bioactive compounds and the analysis of seedling survivability under controlled conditions, this research bridges the gap between traditional ethnobotanical knowledge and modern scientific conservation, laying the groundwork for the sustainable utilization of these invaluable biological resources.

Materials and Methods

Study Area and Site Selection- The field investigations were conducted in the Agra district, situated in the semi-arid region of Uttar Pradesh, India. To ensure a comprehensive representation of diverse micro-ecosystems and varying degrees of anthropogenic disturbance, five distinct primary sampling sites were meticulously selected: Dayalbagh (representing a peri-urban/suburban matrix), Bichpuri Rural (representing an agricultural and rural landscape), Keetham Wetlands (a protected, moisture-rich ecological reserve), Chhalesar Rural (a secondary rural and pastoral zone), and the Sikandra Industrial Are a (characterized by high urbanization and industrial pollution). Additionally, the Botanical Garden at R.B.S. College was established as an auxiliary site for controlled ex-situ observations and conservation experiments.

Field Survey and Herbarium Preparation- Extensive field surveys were executed across the selected locations to identify and collect native medicinal plant species. The collection protocol prioritized lesser-known herbaceous taxa exhibiting local ethnobotanical significance. Upon collection, fresh specimens were subjected to a rigorous preservation process to establish a permanent herbarium for future taxonomic reference and educational utility. The harvested plants were methodically dried in the field to allow for the gradual evaporation of cellular moisture content, utilizing controlled air-exposure techniques to arrest decomposition and microbial degradation.

Following complete desiccation, the specimens were subjected to mechanical pressing to enhance long-term physical stability and facilitate subsequent handling. The pressed plants were systematically mounted onto standard, acid-free herbarium sheets, with careful attention paid to the orientation of leaves, stems, and reproductive structures to ensure the structural integrity and visibility of key morphological diagnostic features. Each herbarium sheet was meticulously labeled with standardized tags denoting essential metadata, including binomial nomenclature, date of collection, precise geographic coordinates of the collection site, and specific ecological field notes regarding the habitat.

Ecological and Morphological Assessment- To quantify plant distribution patterns across the varying environments, frequency charts were constructed to visually represent species abundance at each of the five survey sites. Furthermore, ecological similarity between the discrete habitats was statistically evaluated utilizing the Jaccard Similarity Index, a standard biomathematical metric ranging from 0 (indicating complete ecological dissimilarity) to 1 (indicating identical species composition). Concurrently, extensive morphological characterization was performed on seven high-priority species: Barleria prionitis, Ocimum basilicum, Tribulus terrestris, Rumex dentatus, Ruellia tuberosa, Sonchus arvensis, and Xanthium strumarium. Parameters measured included root architecture (taproot versus fibrous systems), branching typologies, shoot metrics, leaf venation, and detailed floral and fruit traits (e.g., inflorescence architecture, fruit typologies such as capsules, schizocarps, or achenes).

Phytochemical Screening- To validate the therapeutic potential of the targeted plants, preliminary qualitative phytochemical analyses were conducted to isolate and identify major classes of secondary metabolites. Both aqueous and methanolic solvent extraction methods were utilized to ensure the mobilization of compounds across differing polarities. The extracts were subjected to standardized chemical assays to detect the presence of flavonoids, tannins, alkaloids (specifically utilizing Hager's reagent and Mayer's reagent), steroidal complexes, proteins, amino acids, and carbohydrates. This biochemical profiling is critical for elucidating physiological activity and facilitating subsequent advanced pharmacological synthesis aiming for high efficacy and reduced toxicity.

Ex-Situ Conservation Protocols- An ex-situ conservation trial was initiated within the controlled micro-environment of the Botanical Garden at R.B.S. College. Germplasm (seeds and vegetative propagules) from the collected specimens was cultivated under standardized edaphic and hydrological conditions. The specific objectives were to assess the intrinsic reproductive capacity, seed germination dynamics (including the presence of physical or physiological dormancy), and the comparative survivability of seedlings when removed from the environmental stressors inherent to their wild habitats.

Results

Species Distribution and Ecological Abundance- The comprehensive field surveys culminated in the identification and cataloging of 17 distinct medicinal plant species across the study zones. The spatial distribution data revealed pronounced ecological preferences among specific taxa. Abutilon indicum (locally known as Kanghi) demonstrated a high tolerance for moisture-rich and rural soils, recording maximum abundance at the Keetham Wetlands (28 occurrences) and Bichpuri Rural (21 occurrences), while showing constrained populations within the controlled Botanical Garden setting (14 occurrences). Conversely, Achyranthus aspera dominated the agrarian landscape of Bichpuri Rural (28 occurrences) but exhibited a sharp demographic decline in urbanized and heavily disturbed zones (15 occurrences). Boerhavia diffusa (Gadha-cand) thrived robustly in suburban and managed environments, particularly at the Botanical Garden (25) and Dayalbagh (20), but struggled under the specific environmental stressors of the Sikandra Industrial sector, recording only 10 occurrences. Notably, Barleria prionitis displayed a unique resilience profile, establishing abundant populations in the highly polluted Sikandra Industrial Area (19 occurrences) and the Botanical Garden (20), while remaining conspicuously scarce at the Dayalbagh site (2 occurrences). These varied distribution frequencies underscore the profound impact of localized environmental variables—including soil chemistry, ambient pollution, and hydrological regimes—on the survivability of indigenous medicinal flora.

Habitat Similarity Indexing- Application of the Jaccard Similarity Index to the spatial presence-absence data provided crucial insights into ecosystem connectivity. The analysis indicated a remarkably high baseline of species overlap across the study area, yielding general similarity coefficients surrounding 0.9375. A perfect ecological congruence (Jaccard Index = 1.0) was calculated between the Dayalbagh suburban site and the Bichpuri Rural site, indicating identical species assemblages capable of transitioning across the rural-suburban gradient. However, comparative matrices involving the ex-situ Botanical Garden location yielded slightly depressed similarity values (ranging from 0.875 to 0.9375). This statistical divergence confirms that highly manipulated, urban-adjacent garden environments select for slightly altered plant communities compared to natural wetland or strictly rural habitats.

Qualitative Phytochemical Profiling- The phytochemical screening of aqueous and methanolic extracts derived from the seven primary target species unveiled significant therapeutic markers. The most ubiquitous secondary metabolites were flavonoids and tannins, which were consistently detected across the majority of the tested species in both solvent mediums. This widespread presence strongly suggests that these local flora possess high intrinsic antioxidant, antimicrobial, and anti-inflammatory properties. Interestingly, alkaloid compounds were largely absent across the spectrum; standardized applications of both Hager's and Mayer's tests returned predominantly negative results. However, highly specific exceptions were noted: Tribulus terrestris and Ruellia tuberosa registered positive reactions for specific alkaloid fractions under Mayer's test.

Species-specific profiles further differentiated the medicinal utility of the flora. Methanolic extracts frequently confirmed the presence of vital primary metabolites, including proteins, amino acids, and complex carbohydrates. Barleria prionitis and Ocimum basilicum (Basil) presented a rich biochemical matrix consisting of flavonoids, tannins, amino acids, and proteins. Rumex dentatus mirrored this profile but added distinct steroidal components. Conversely, Tribulus terrestris lacked detectable flavonoids but contained carbohydrates and proteins alongside its unique alkaloid signature. Sonchus arvensis displayed a highly balanced multi-metabolite composition, whereas Xanthium strumarium exhibited a notably restricted secondary metabolite profile, indicating comparatively lower broad-spectrum medicinal potential.

Morphological and Reproductive Traits- Detailed morphological profiling revealed specialized anatomical adaptations facilitating survival in the semi-arid regional climate. Root architecture varied systematically; species such as Abutilon indicum possessed deep-penetrating taproots enabling drought resistance, while others like Achyranthus aspera and Amaranthus viridis utilized extensive fibrous root systems to rapidly harvest shallow moisture. Floral morphology directly correlated with distinct pollination strategies. Species such as Barleria prionitis and Ocimum basilicum developed complex, visually prominent inflorescences (primarily racemose and panicle-type) adapted exclusively for entomophily (insect pollination). In contrast, Tribulus terrestris demonstrated a more opportunistic, dual reproductive strategy, utilizing both anemophily (wind) and insect vectors. The resulting fruiting bodies exhibited significant evolutionary divergence, ranging from the protective capsules of Barleria to the fragmented schizocarps of Tribulus and the dispersive achenes of Sonchus arvensis. Seed viability tests exposed high baseline fertility in several taxa, with Abutilon indicum achieving an exceptional 86% germination rate. Furthermore, the analysis confirmed varying strategies of seed dormancy across the taxa, with some exhibiting intense physiological dormancy to survive unfavorable seasons, while others expressed physical coat-driven dormancy or no dormancy at all.

Ex-Situ Conservation Efficacy- The controlled cultivation of these taxa within the ex-situ Botanical Garden environment yielded profoundly positive implications for conservation biology. Relieved from the intense competitive pressures, pathogenic loads, and hydrological uncertainties of the wild, the translocated germplasm exhibited marked physiological improvements. Cultivated populations demonstrated robust vegetative growth, generating significantly larger floral displays and higher subsequent fruit sets. Seedling survivorship metrics were vastly superior to wild demographic baselines. Statistical analyses confirmed these field observations; for instance, Barleria prionitis showed highly significant quantitative improvements in flower initiation, seed viability, and early-stage seedling survival under ex-situ conditions (p-value < 0.05). Parallel enhancements in reproductive vigor were recorded for Ocimum basilicum, Tribulus terrestris, and Rumex dentatus, confirming that artificially managed environments can effectively buffer vulnerable medicinal species against demographic collapse.

Discussion

The accelerating depletion of global forest cover, currently estimated at up to 2% annually, imposes an existential threat to wild botanical reserves. The findings of this study provide a critical, localized lens into the dynamics of medicinal plant ecology within the rapidly developing Agra district. The distinct spatial distribution patterns observed among the 17 identified species confirm that anthropogenic land-use heavily dictates floristic composition. The proliferation of Abutilon indicum in wetlands and the resilience of Barleria prionitis in heavily polluted industrial sectors highlight the immense adaptive plasticity of specific herbaceous taxa. These distribution variations, supported by the nuanced deviations in the Jaccard Similarity indices, emphasize that conservation strategies cannot rely on monolithic protected areas; rather, they must account for specific micro-ecological preferences and the reality of fragmented, human-dominated landscapes.

The phytochemical validations conducted herein firmly substantiate the ethnobotanical utility historically ascribed to these plants by Ayurvedic traditions. The widespread detection of flavonoids and tannins—bioactive compounds renowned for their free-radical scavenging, vascular protection, and anti-inflammatory mechanisms provides an empirical basis for the use of these plants in treating physiological ailments. The specific detection of alkaloids in Tribulus terrestris and Ruellia tuberosa points toward potent pharmacological pathways, as plant-derived alkaloids form the structural basis for numerous modern neuroactive and antispasmodic pharmaceuticals. Species like Boerhavia diffusa and Withania coagulans, while known for highly specific bioactive compounds such as punarnavine and withanolides respectively, were also highlighted as exceptional candidates for large-scale agricultural integration due to their robust adaptability.

Crucially, the success of the ex-situ conservation trials offers a highly actionable pathway for mitigating wild harvesting pressures. The statistically significant enhancement of reproductive capacity and seedling survivability in the controlled botanical garden environment proves that these lesser-known species can be successfully cultivated outside their native ranges. This approach accomplishes dual objectives: it safeguards genetic diversity against sudden environmental shocks or habitat destruction, while simultaneously generating a reliable, sustainable biomass supply for the burgeoning commercial pharmaceutical sector. By optimizing germination protocols and understanding inherent seed dormancy mechanisms, agronomists can transition these wild herbs into reliable cash crops.

Furthermore, the modern intersection of nutrition and phytochemistry suggests entirely novel utilization paradigms for these species. Recent gastronomic and nutritional research has seen an explosive demand for "microgreens" immature plant seedlings harvested shortly after cotyledon emergence. Prized by high-end culinary professionals and dietitians, microgreens are dense repositories of vitamins, ascorbic acid, tocopherols, carotenoids, folate, and complex phytochemicals like glucosinolates and anthocyanins. While clinical literature regarding the direct synergistic health impacts of microgreens remains in its infancy, the robust phytochemical profiles identified in the native Agra flora suggest that controlled cultivation of select medicinal species as functional microgreens could open highly lucrative, health-promoting agricultural markets.

Conclusion

This comprehensive investigation establishes a foundational inventory of lesser-known medicinal plants within the Agra district, elucidating their spatial ecology, structural morphology, and profound phytochemical value. The empirical data confirms that while urbanization and industrialization continually fracture natural habitats, specific native species possess both the ecological resilience and the biochemical complexity necessary for continued pharmacological exploitation. Most significantly, the research validates the immense efficacy of ex-situ conservation models. Controlled propagation not only ensures the survival of vulnerable germplasm but drastically amplifies reproductive output and seedling viability. By integrating rigorous traditional ethnobotanical knowledge with modern phytochemical analysis and controlled agricultural innovation, this study provides a sustainable, multi-dimensional framework designed to fulfill the escalating global demand for herbal therapeutics while staunchly defending regional biodiversity for future generations.

References

World Health Organization (WHO). (2019). WHO Global Report on Traditional and Complementary Medicine 2019. Geneva: World Health Organization.

Forest Survey of India (FSI). (2021). India State of Forest Report (ISFR) 2021. Ministry of Environment, Forest and Climate Change, Government of India.

Sharma, P. V. (1992). Charaka Samhita: Text with English Translation. Chaukhambha Orientalia, Varanasi, India.

Harborne, J. B. (1998). Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis (3rd ed.). Chapman and Hall, London.

Trease, G. E., & Evans, W. C. (2009). Pharmacognosy (16th ed.). Saunders Elsevier, Edinburgh.

Jaccard, P. (1912). The Distribution of the Flora in the Alpine Zone. New Phytologist, 11(2), 37-50.

Baskin, C. C., & Baskin, J. M. (2014). Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination (2nd ed.). Academic Press, San Diego.

Volis, S. (2016). How to conserve threatened Chinese plant species with extremely small populations? Plant Diversity, 38(1), 45-52.

Chhatre, S., Nesari, T., Somani, G., Kanchan, D., & Sathaye, S. (2014). Phytopharmacological overview of Tribulus terrestris. Pharmacognosy Reviews, 8(15), 45-51.

Khare, C. P. (2007). Indian Medicinal Plants: An Illustrated Dictionary. Springer Science & Business Media, New York.

Ebert, A. W., & Wu, T. H. (2019). Microgreens of local vegetables: A new crop for urban and peri-urban agriculture. Acta Horticulturae, 1240, 107-112.

Mishra, S., Aeri, V., Gaur, P. K., & Jachak, S. M. (2014). Phytochemical, therapeutic, and ethnopharmacological overview for a traditionally important herb: Boerhavia diffusa Linn. BioMed Research International, 2014, 808302.

Khatoon, M., Islam, E., Abu Sayeed, M., & Aminul Islam, M. (2019). Phytochemical screening and pharmacological activities of Barleria prionitis Linn. Journal of Pharmacognosy and Phytochemistry, 8(3), 209-214

Jha, V., & Jha, A. (2020). Urbanization and its impact on biodiversity: A review of the Indian scenario. International Journal of Ecology and Environmental Sciences, 46(2), 143-152.

Tiwari, R., & Rana, C. S. (2015). Plant secondary metabolites: A review. International Journal of Engineering Research and General Science, 3(5), 261-271.