REVIEW ARTICLE

Exploring India's angiosperm diversity: A comprehensive review

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India's remarkable botanical legacy is exemplified by its vast array of angiosperms or flowering plants, thriving within its multifaceted landscapes. This extensive review begins on a thorough exploration of the nation's angiosperm diversity, scrutinizing their distribution, ecological contributions and evolutionary heritage across various ecosystems. By integrating a wealth of existing literature, historical narratives and recent scientific advances, the study provides a nuanced and comprehensive portrayal of India's angiosperm flora.

The review places particular emphasis on endemic species and their conservation status, as well as their integral roles in traditional medicine and cultural practices. Additionally, it investigates the hurdles and prospects for safeguarding India's angiosperm diversity, considering the impacts of habitat degradation, climate change and anthropogenic pressures. By underscoring the critical importance of preserving this botanical treasure trove, the review highlights the pressing need for ongoing research and strong conservation initiatives to protect the ecological balance and cultural heritage of this biodiverse hotspot.

Key Words: *Angiosperm; Biodiversity; Forest; Plant species*

INTRODUCTION

India boasts a rich blend of biological and cultural diversity, standing as one of the 17 mega-biodiverse nations worldwide. Its landscape is inhabited by a plethora of tribal, nomadic, farming and fishing communities, each holding unique nature-based livelihoods and a wealth of traditional knowledge. In contemporary times, the utilization of traditional knowledge has expanded beyond the day-to-day activities of these communities. There is a rising international appetite for natural, herbal and organic products crafted through traditional methods, fueling the growth of industries such as herbal medicine, cosmetics and personal care.

This expanding market demand for bio-resources and associated traditional knowledge presents indigenous and local communities with fresh methods for income generation and economic empowerment. However, the surge in biopiracy and the unprincipled use of traditional knowledge has become a growing concern. The chief factor behind this misappropriation is the unregulated access to traditional knowledge within local communities and the absence of adequate documentation of this invaluable resource [1].

India is a treasure trove of biodiversity, presenting an extraordinary range of ecosystems that span the country's varied topography. The great Himalayan ranges, capped in eternal snow, give way to lush sea-level plains, meandering lowland swamps and complex mangrove networks. This diverse landscape also includes dense tropical rainforests, fertile alluvial plains, vast arid deserts and cold, high-altitude deserts.

The nation's climate is equally diverse, with tropical and subtropical zones characterizing the Indo-Gangetic plains and the Peninsular region, while the northern reaches of the country experience temperate to arctic conditions across the expansive Himalayan region.

These rich biogeographic and climatic conditions cement India's reputation as a global hotspot of biodiversity, emphasizing the critical need for conservation initiatives. Safeguarding this unique ecological heritage is imperative for preserving the wealth of plant and animal life that inhabits these varied ecosystems.

LITERATURE REVIEW

Biogeographically, India is a unique convergence of two major areas-the Palearctic and Indo-Malayan and encompasses five principal forest biomes: Tropical evergreen and semi-evergreen forests, tropical deciduous forests, tropical thorn forests, montane forests and littoral and swamp forests. Reflecting the vast diversity across its landscapes, Balakrishnan delineates the country into eleven phytogeographic zones such as: North-West Himalayas; Indo-Gangetic Plains; Eastern Himalayas (Arunachal Pradesh and Sikkim); Assam (North-Eastern India excluding Arunachal Pradesh and North Bengal); Central India; Arid zone; Northern Western Ghats and northern West Coast; Southern Western Ghats, southern West Coast and Lakshadweep; Deccan; Eastern Ghats and Coromandel coast and Andaman and Nicobar Islands [2]. India, with a geographical expanse of approximately 3,287,263 Km^2, ranks as the world's seventh-largest country. It spans from latitudes 8°4'N to 37°6'N and longitudes 68°7' E to 97°25'E. The nation's forest cover has been estimated at 7,13,789 km^2, constituting 21.71% of its total geographic area. This encompasses 99,779 km^2 of very dense forest, 306,890 km^2 of moderately dense forest, 307,120 km^2 of open forest and 46,539 km^2 of scrubland (Forest Survey of India Report, 2021-22). India's varied topography and climate nurture rich ecological zones and complex forest ecosystems, underscoring the importance of preserving its abundant natural resources and extensive biodiversity.

India is rich in biological diversity largely due to its prevailing varied physical environment, latitude, altitude, geology and climate. Observing the country's rich plant diversity, Hooker commented that 'The Flora of British India is more varied than that of any other country of equal area in the eastern hemisphere, if not on the globe' [3]. The Indian flora represents taxa occurring in different countries including Afghanistan, Bhutan, Bangladesh, China, Nepal, Pakistan, Myanmar, Malaysia, Indonesia, Thailand, Vietnam, Laos and Cambodia. There are even the representatives from African, American, Australian and European countries. Though the geographical area cover of India represents only about 2.4% of the world's total landmass, the country harbours collectively a total of 55,048 taxa belonging to 21,984 angiosperms, 82 gymnosperms, 1314 pteridophytes, 2800 bryophytes, 2989 lichens, 15602 fungi, 9008 algae and 1269 microbes representing approximately 11.4% of total so far recorded species of the world and about 25% of vascular plants that occur in India are endemic to the country [4].

India's floral diversity is predominantly centered around four globally recognized biodiversity hotspots: The Himalayas, Western Ghats and Sri Lanka, Northeast India and the Andaman Islands (Indo-Burma) and the Nicobar Islands (Sundaland). These hotspots are among the 36 recognized worldwide and hold an exceptional concentration of endemic plant species. However, these regions also face significant challenges such as habitat loss and a high incidence of threatened plant species.

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In total, India is home to 4,303 flowering plant taxa across 977 genera in 154 families, deemed to be strictly endemic within the country's current political borders. The endemic flora is dominated by dicotyledons, comprising 3,170 taxa (72%) spread across 723 genera from 127 families. In contrast, monocotyledons contribute 1,133 taxa (26%) from 254 genera in 27 families.

Estimates suggest that approximately 10% of India's flowering plant species are under threat of extinction. This calls for heightened conservation efforts to protect the nation's vast and precious floral heritage, which plays an important role in maintaining ecological balance and supporting local biodiversity.

Northeast India, with its rich botanical heritage, stands as a cradle of flowering plants boasting over 130 species of primitive angiosperms [5]. Moreover, India is recognized as one of the world's 12 Vavilovian Centers of Origin and diversification of cultivated plants, known as the Hindustan Center of Origin of Crop Plants [6]. At least 167 species of significant agri-horticultural crops and 320 species of their wild relatives, spanning 116 genera and 48 families have their roots here [7].

The country's agricultural wealth extends to its diverse landraces, such as the 50,000 to 60,000 varieties of rice, as well as other economically vital crops like wheat, sugarcane, legumes, sesame, eggplant, citrus, banana, mango, jute, ginger, turmeric, pepper, cinnamon and cardamom. This area is a haven for genetic diversity, critical for the resilience and productivity of these staple crops.

Moreover, India's extensive medicinal flora comprises around 3,000 angiosperm species with potential therapeutic qualities. Of these, approximately 1,300 species play a central role in traditional medicinal practices such as Ayurveda, siddha, unani and even modern allopathy. Additionally, the region is home to an array of primitive angiosperm genera, including *Alnus*, *Aspidocarya*, *Betula*, *Decaisnea*, *Euptelea*, *Exbucklandia*, *Haematocarpus*, *Holboellia*, *Houttuynia*, *Magnolia*, *Manglietia*, *Pycnarrhena* and *Tetracentron* [8].

Angiosperms, the most significant group of land plants, encompass over 300,000 species and represent 89.4% of embryophytes [9,10]. Their sudden emergence during the early Cretaceous and subsequent dominance in the later part of that era is considered one of Darwin's "abominable mysteries" [11]. The rapid rise and proliferation of this plant group transformed the planet's landscape and established the structural framework for most terrestrial ecosystems [10,12]. The diversification of angiosperms also facilitated the coevolution of various new organisms in the animal kingdom, including insects and contributed to the diversification of ferns [13,14].

Although there remain debates regarding the origin and lineage of this plant group, their emergence is generally accepted to have occurred in the early cretaceous [15-19].

Angiosperms have been identified across a multitude of geographic locations during the early cretaceous period, but their existence in India during this epoch remains uncertain [19,20]. Sahni reported a vesselless fossil wood designated homoxylon from the Rajmahal region, associating it with vesselless angiosperms [21]. However, Bose et al., reexamined the affinity of homoxylon sahni, situating it within *Bennettitales* and establishing a novel genus, *Sahnioxylon* [22].

In subsequent years, Sharma described Lesqueria Crane and Dilcher, while Banerji identified a fruiting body as sonajoricarpon and a flower-like structure from the Rajmahal formation [23,24]. Banerji drew parallels between sonajoricarpon and the fruits of the extant Fabaceous genus *Butea* Roxb [24]. Despite these early observations suggesting an angiosperm connection, further detailed scrutiny clarified that these fossils were not angiosperms but instead belonged to the gymnosperms [25].

According to Shankar, the Indian subcontinent is home to 34 species of Magnolia, including nine introduced species and hybrids [26]. This richness in biodiversity, both in terms of endemic plants and diverse crop varieties, positions India as a vital global repository of natural heritage, demanding rigorous conservation efforts to safeguard its ecological treasures.

India's political boundaries have shifted several times since the colonial era, affecting the classification and documentation of its rich biodiversity. Sarkar provided an early comprehensive account of endemic genera in India, listing 142 genera, of which four were also found in Bhutan and one extended into southern Tibet [27]. Subsequent reports varied in their listings of endemic genera, with Nayar reporting 147 genera, Ahmedullah reporting 140 and Mitra et al., reporting 121 [28-30]. These reports were based on the distribution information available at the time, but many genera initially considered endemic have since undergone taxonomic revisions with some being merged with parent or allied genera. According to Karthikeyan, there are 2,991 genera found in India, but a critical examination of literature and plant database websites reveals that only 49 genera are truly endemic to India [31]. These 49 genera belong to 22 families and include 80 taxa.

The endemic genera, 40 are confined to Peninsular India, four to the Himalayas and three to the Andaman and Nicobar Islands. The genus *Bentinckia* exhibits a disjunct distribution. *Hardwickia* is common throughout the dry deciduous forests of Peninsular and North India, except for the Northeast.

The families Poaceae, Apiaceae, Asteraceae and Orchidaceae account for approximately 51% of India's generic endemism, with Poaceae alone making up 27%. These genera encompass 34 herbaceous, 12 arborescent and three shrubby species. A total of 165 species (158 angiosperms, 5 gymnosperms and 1 pteridophyte) belonging to 142 genera and 57 families are recorded from the campus of Sangat Sahib Bhai Pheru Khalsa Senior Secondary School Faridkot, Punjab, India from July 2022 to April 2023. Out of 57 families, grass family Poaceae is dominant with represented with 15 species. Ninety-five documented as a weed species, 67 species are cultivated and 3 species both cultivated as well as wild species. Eighty-five species are annual and 80 are perennials.

An initial study in the Subansiri region of the eastern Himalayas uncovered substantial levels of plant endemism. As part of a comprehensive effort to sample different forest types and map biologically rich areas, the study assessed the observed species to determine their endemic status within this significant global biodiversity hotspot. The research included documenting the count of individuals, species, genera and families across both natural and semi-natural forest types. The investigation involved random sampling of 122 plots in different forest types and cataloged 764 plant species, with 59 of them found to be unique to the region. The overall species endemism rate was calculated at 13 per hectare. These 59 endemic species were distributed across 27 families and 46 genera. Interestingly, half of the endemic species were concentrated in just five families: Rubiaceae, Lauraceae, Acanthaceae, *Magnoliac*eae and Rosaceae. Analysis of the stem size class distribution of the most abundant endemic tree species across three primary forest types offered insight into their quantitative status. The study adopted a proportional stratified random sampling method across various vegetation types and utilized satellite remote sensing data to map the region. The discovery of numerous primitive genera and families pointed to a long evolutionary history, underscoring the region's deep-seated botanical heritage and notable species endemism [32].

Rawat et al., conducted a study in the Kandi region of Hoshiarpur, India, documenting an extraordinary collection of 176 plant species spanning 57 distinct families and 133 genera [33]. This remarkable breadth underscores the region's exceptional botanical diversity. Among the species, 175 were angiosperms and one was a gymnosperm, reflecting the overwhelming dominance of flowering plants in the area. Within the angiosperms, dicotyledons constituted a striking 78.3% (137 species across 105 genera), while monocotyledons represented 21.7% (38 species across 27 genera).

DISCUSSION

The study showcased Poaceae as the most prominent family, comprising 30 species across 21 genera. Other significant families included Papilionaceae, Caesalpiniaceae, Euphorbeaceae, Apocynaceae, Acanthaceae and Mimosaceae. Trees emerged as the dominant life form, accounting for 36.9% of the species, followed by shrubs (22.7%), grasses (17.1%), herbs (13.6%), climbers (8.5%) and sedges (1.1%).

The investigation identified 33 plant species from 21 families employed by the local populations of Satrod Khurd and Dabra villages for treating a range of gastrointestinal disorders, including diarrhea and indigestion, as well as skin afflictions. The Fabaceae family emerged as the most prominent, contributing four species, while Lamiaceae followed closely with three species. Other families such as Amaranthaceae, Rutaceae, Meliaceae, Asclepiadaceae, Myrtaceae, Euphorbiaceae and Moraceae each offered two species.

Notable botanical families like Crassulaceae, Cannabaceae, Boraginaceae, Solanaceae, Menispermaceae, Rhamnaceae, Poaceae, Papaveraceae and Combretaceae each provided one species. Important plant components such as leaves, seeds, fruits, bark, roots, twigs and flowers were utilized to treat conditions like diarrhea, dysentery, blood purification and various skin disorders. Several versatile plants, including *Calotropis procera*, *Argemone mexicana*, *Datura metel* and *Azadirachta indica*, exhibited therapeutic efficacy across multiple ailments. The collected data was carefully compared with established literature, peer-reviewed research papers and reputable online sources to ensure its validity and reliability. This comprehensive approach underscored the extreme ethnobotanical knowledge and practices inherent to the region [34].

This comprehensive analysis of the region's forest flora reveals invaluable insights into its rich species diversity, the prominence of particular plant families and the varied composition of life forms. The study highlights the ecological richness and significance of the Kandi region, emphasizing its importance as a center of biodiversity.

In a comprehensive 2023 study conducted by Singh et al., an intriguing assortment of twenty-five angiosperm wild species was identified across 23 genera and 14 families as weeds in crops, gardens and waste areas in Faridkot, Punjab, India [4]. The Asteraceae family emerged as the most prominent, with five distinct species, followed by Poaceae and Solanaceae, each showcasing three species. Brassicaceae, Malvaceae and Scrophulariaceae each presented two species, while the remaining families each held a single species. Of the 23 genera, only two *Solanum* and *Veronica* featured two species apiece, while the rest were monotypic, emphasizing the diverse botanical landscape. Among the 25 species identified, 22 were dicots, highlighting their dominance, while the remaining three were monocots. This study sheds light on the remarkable biodiversity of the region and its dynamic exchange with agricultural and natural ecosystems.

Kaur et al., documented an extraordinary collection of 294 plant species, surround 288 angiosperms, 3 gymnosperms and 3 pteridophytes, across 232 genera and 79 families from Bassi Umar Khan and Atwarapur in the Bhunga block of district Hoshiarpur, Punjab [35]. The Fabaceae family was most prevalent, trailed by notable families such as Poaceae, Asteraceae, Cucurbitaceae and Solanaceae. Of the 294 species, 142 were herbaceous, 66 were trees, 52 were shrubs and 34 were climbers. Among these, 78 species were traditionally utilized in medicinal formulations, representing 26.5% of the overall flora in the study area. Herbs dominated traditional use in various medicinal preparations, followed by trees, shrubs and climbers. The study highlighted that 25 plants were frequently used to treat gastrointestinal disorders, while 16 species were found effective in controlling diabetes. This analysis underscores the region's rich floristic diversity and the extreme traditional knowledge held within the study area.

An extensive study of angiosperm diversity in the Doaba region of Punjab, India, revealed a remarkable total of 464 species across 337 genera and 99 families. Among these species, 88% were dicots, while the remaining 12% were monocots. The data included wild, cultivated and ornamental species. Fabaceae was the most dominant family with 60 species, followed by Asteraceae (33 species), Poaceae (29 species), Euphorbiaceae (20 species), Amaranthaceae (18 species) and Cucurbitaceae and Solanaceae (17 species each).

Out of the total species recorded, 255 were herbs, 65 were shrubs, 85 were trees and 59 were climbers. Additionally, the study identified six species new to the flora of Punjab. This investigation emphasizes the Doaba region's rich angiosperm diversity and underscores the urgent need for its documentation and conservation [36].

The emergence of angiosperms on Earth took place during the Jurassic period. The oldest known angiosperm, *Florigerminis jurassica* Cui et al., (also known as the 'Jurassic flower bud'), dates back approximately 164 million years to the Jurassic period and was unearthed in Inner Mongolia, China, in 2022 [37].

During the early Cretaceous, angiosperms were limited to regions situated between latitudes 45° N and 45° S. These flowering plants gradually began to supplant the non-flowering vegetation of the Jurassic era, establishing a firm presence in the northern hemisphere only in the late Cretaceous period.

Hallier theorized that this plant group originated on a continent located in the southern Pacific Ocean; however, no such continent has ever been found [38]. Nonetheless, researchers like Bailey, Axelrod and Thorne all concurred that the cradle of angiosperms was located in the southern or western Pacific region [39-41]. This extensive area spans from Assam in the west to Australia and the Fiji Islands in the east, surround regions such as Myanmar, southern China, Japan, Malaysia, New Zealand and New Caledonia. While fossil evidence does not specify the precise origin, it does confirm that angiosperms arose within the tropical belt before gradually expanding to higher latitudes.

Within this broad area, known as the Southwest Pacific Basin, primitive angiosperms thrive in abundance. Many early families are isolated to this region and primitive representatives of other families can also be found here.

The paleobotanical record of seed plants remains incomplete. Plants with affinities to ranalian and amentiferous species rank among the oldest of paleobotanical finds. Seed-bearing pteridosperms, possessing fern-like foliage, appear to provide the most plausible evolutionary link to flowering plants, including the seed pod and the cupule that encloses the seed.

According to Cronquist, the subclass Magnoliidae encompasses the most ancient and primitive angiosperms still in existence today [42]. This subclass comprises several time-honored plant families, such as water lilies (Nymphaeaceae), buttercups (Ranunculaceae) and *magnolias* (Magnoliaceae). The Magnoliaceae family showcases distinct primitive traits, including: Large, striking flowers adorned with numerous tepals; abundant spirally arranged free stamens at the base of a cone-like receptacle, which bears numerous spirally arranged free carpels.

As the plant matures, the carpel-bearing section transforms into a woody, cone-like aggregate composed of seed-bearing follicles. Each seed is ensconced within a fleshy, red outer layer known as an aril and is connected to its follicle by a slender, thread-like funiculus.

Additional primitive floral attributes comprise actinomorphic (radially symmetrical) flowers that are perfect (both male and female reproductive structures) and complete (possessing all four floral organs) along with an elongated floral axis or receptacle. These characteristics are prominently displayed in both the flowers and fruits of the Magnolia species, serving as a testament to the ancient lineage of this family.

The Angiosperm Phylogeny Group IV (APG IV) system of classification recognizes the clade Magnoliids as a collection of ancient angiosperms, consisting of four orders: *Canellales*, Laurales, *Magnoliales* and *Piperales*. The *Canellales* order, with families Canellaceae and Winteraceae, is absent in India. However, India hosts a notable presence of other orders: The Laurales order, represented by Hernandiaceae and Lauraceae families; the *Magnoliales* order, surround Myristicaceae, Magnoliaceae and Annonaceae families and the *Piperales* order, which includes the Saururaceae, Piperaceae and Aristolochiaceae families.

CONCLUSION

A key component of India's ecological richness is the diversity of its angiosperms, which are a reflection of the vast range of habitats and climatic conditions found throughout the nation. The critical need to preserve this botanical variety is emphasized in this review, since it is essential to the health of ecosystems and the advancement of fields like environmental science, pharmacology and agriculture. However, there are significant risks to this biodiversity due to the increasing degradation of ecosystems, as well as the consequences of climate change and human activity.

In order to address these issues, a thorough strategy is needed. This entails using cutting-edge genetics, conservation biology and ecosystem management studies, as well as implementing strict conservation laws. Furthermore, educating the local population and implementing sustainable livelihood initiatives might be important in ensuring the protection of these species.

India's angiosperms have enormous potential for upcoming scientific discoveries and advancements. It is imperative that this biodiversity be preserved and used responsibly on a worldwide scale. We can guarantee the preservation of this priceless natural resource for the benefit of both the current and future generations by encouraging cooperation between scientific domains and policy efforts.

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