

Intragenetic Diversity and Stenoendemism in *Garcinia*, *Humboldtia* and *Symplocos* in the Agasthyamala Biosphere Reserve, India

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Abstract: This study examines the high intragenetic diversity and significant stenoendemic representation (i.e., taxa with extremely narrow and restricted geographic distributions) within *Garcinia* (Clusiaceae), *Humboldtia* (Fabaceae-Caesalpinioideae), and *Symplocos* (Symplocaceae) in the Agasthyamala Biosphere Reserve (ABR), India. Taxonomic revisions reveal that the ABR supports a disproportionately high concentration of species in these genera, compared to the broader Western Ghats. In *Garcinia*, the ABR harbours 64% of the regional diversity, including three stenoendemic taxa. Similarly, nearly 55% of Indian diversity of *Humboldtia* is confined to the ABR, comprising four stenoendemic taxa. In *Symplocos*, the ABR harbours 42% of regional diversity, including nine stenoendemic taxa. These distributional patterns indicate that the ABR functions as an island-like phytogeographic unit, with the Shencottah Gap acting as a significant geographical barrier. The region's unique topography and stable ever-wet microclimate have facilitated its role as both an ecological refugium and an evolutionary ecotone, fostering the preservation of ancient lineages and allopatric speciation. These findings underscore the ABR's significance as a global centre of stenoendemism and emphasise the urgent need for targeted conservation measures.

Keywords: Caesalpinioideae, Clusiaceae, Evolutionary ecotone, island-like phytogeography, Shencottah Gap, Symplocaceae, Western Ghats.

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Introduction

The unique floristic diversity, high percentage of endemism, and exceptional number of stenoendemic taxa (i.e., those restricted specifically to localized geographic areas) in the Agasthyamala Biosphere Reserve (ABR) of the Western Ghats are attributed to its island-like (terrestrial landscapes isolated by physical, climatic, and geographical barriers) phytogeography, its role as a long-standing ecological refugium (a stable geographical area that buffers species against harsh regional climate shifts, allowing them to survive when wiped out elsewhere), and its status as an evolutionary ecotone (a transitional ecological community where intense environmental stress and natural selection accelerate divergent adaptation and speciation) (Ahmedullah & Nayar, 1986; Nayar, 1996; Mohanan & Sivadasan, 2002; Rajkumar *et al.*, 2022; Mohanan, 2025). Situated at the southernmost tip of the Western Ghats, the ABR is isolated from the contiguous mountain range to the north by the 7.5 km Shencottah Gap. This topographical break, combined with the low-altitude coastal plains bordering the remaining three sides, renders these high-altitude hills physiographically analogous to an island. Such unique topography acts as a significant barrier to species migration and gene flow to the north, while the southern terminus effectively halts terrestrial dispersal in all other directions. Consequently,

unlike other high-diversity regions of the Western Ghats, the ABR functions as an isolated refugium. As established by MacArthur and Wilson (1967), geographic isolation restricts outside species migration, forcing enclosed populations to evolve independently within confined spaces. This isolation has fostered allopatric speciation and distinct evolutionary trajectories over geological timescales, resulting in the high species richness and stenoendemism characteristic of true insular systems.

Over more than 30 years of floristic study within the Agasthyamala Biosphere Reserve (ABR), the author has identified a significant pattern among plant genera belonging to ancient lineages. These genera –characterized by cosmopolitan distributions, intercontinental affinities, and a predominantly arborescent habit– exhibit disproportionately high intrageneric diversity and stenoendemism within the ABR. To investigate this phenomenon, three representative genera were selected for comprehensive taxonomic revision across India. This comparative approach facilitates an evaluation of nationwide distribution patterns against the highly concentrated diversity within the ABR, correlating these findings with the reserve’s status as an island-like phytogeographic unit and a long-term refugium.

Materials and Methods

Study area

The Agasthyamala Biosphere Reserve (ABR), established in 2001 and recognized by the UNESCO World Network of Biosphere Reserves in March 2016 (UNESCO, 2016; MOEF, Government of India. 2017), is situated at the southern terminus of the Western Ghats, India, between 8°8' N–9°10' N and 76° 52' E–77°34' E. (Fig. 1) Spanning approximately 3,500 km², the reserve encompasses a diverse tropical forest ecosystem across the Thiruvananthapuram, Kollam, and Pathanamthitta districts of Kerala, and the Tenkasi, Tirunelveli, and Kanyakumari districts of Tamil Nadu. The Kerala sector

includes the Neyyar, Peppara, and Shendurney Wildlife Sanctuaries, alongside the Achencoil and Konni Forest Divisions. The Tamil Nadu sector comprises the Kalakkad–Mundanthurai Tiger Reserve and the Kanyakumari Wildlife Sanctuary. Topographically, the reserve follows a steep altitudinal gradient, rising from 300 m to 1,868 m above sea level at its highest peak, Agasthyarkoodam.

The ABR is characterized by a complex climatic regime influenced by both Southwest and Northeast monsoons. Due to its unique geographic and significant elevation range, the region receives substantial annual rainfall–ranging from 2,000 mm to over 5,000 mm– and maintains high humidity levels throughout the year. This ‘ever-wet’ microclimate, particularly within windward valleys and high-altitude shola-grassland complexes, creates an environmental buffer that has persisted despite regional climatic fluctuations. This long-term stability reinforces the ABR’s status as a critical ecological refugium.

Taxonomic scope and data sources

The Agasthyamala Biosphere Reserve hosts approximately 2,254 species of flowering plants, 400 of which are endemic to the Western Ghats (UNESCO, 2016; Rajkumar *et al.*, 2022). A recent enumeration (Mohanani, 2025) identified about 450 Western Ghats endemics within the reserve, 239 (53%) of which are stenoendemic to the ABR. This represents the highest concentration of stenoendemism among all biosphere reserves in India. Analysis of these stenoendemic taxa reveals that certain genera with ancient lineages exhibit both maximum species diversity and high localized endemism within the ABR. Among these, three representative genera–*Garcinia* L. (Clusiaceae), *Humboldtia* Vahl (Fabaceae-Caesalpinioideae), and *Symplocos* Jacq. (Symplocaceae)– were selected for present analysis. This selection is primarily based on the firsthand observations and concrete data gathered by the author over several years of

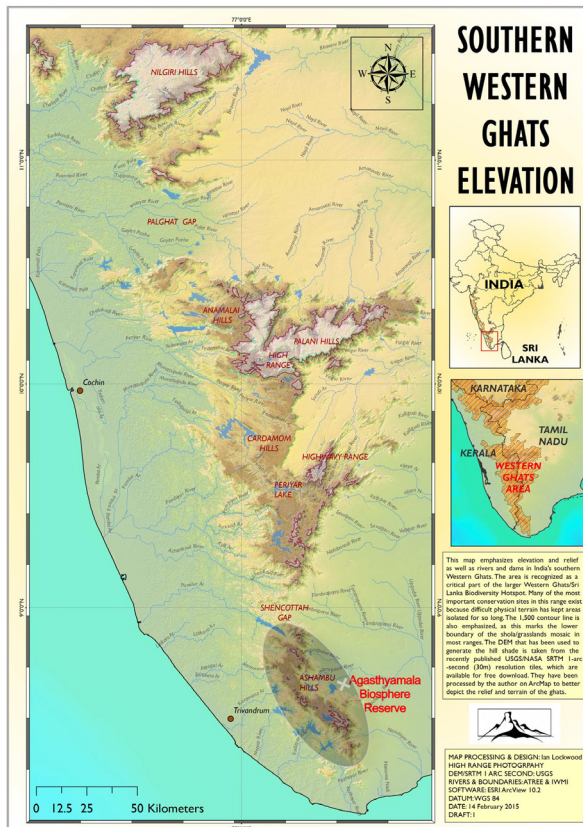


Fig. 1. Map of Southern Western Ghats showing the Agasthyamala Biosphere Reserve (ABR) and the Shencottah Gap. (© <https://ianlockwood.blog/tag/western-hats/page/2/>).

intensive research. While other species-rich genera such as *Eugenia* (Myrtaceae), *Memecylon* (Melastomataceae), and *Miliusa* (Annonaceae) are expected to exhibit a similar pattern, however, they were not included because comprehensive revisionary studies are currently lacking, and due to insufficient baseline data.

Data for *Garcinia* and *Symplocos* were derived from the comprehensive taxonomic revisions led by the author (Shameer *et al.*, 2016, 2017; Mohanani *et al.*, 2023; Stephan *et al.*, 2017, 2021a, 2021b; Stephan, 2023), whereas data for *Humboldtia* were integrated from existing revisionary studies (Sanjappa, 1986; Anoop *et al.*, 2016a, 2016b; Kumar *et al.*, 2022). Conservation statuses were updated based on the IUCN Red List (IUCN, 2025). These data were synthesized to analyze distributional patterns and test the hypothesis of the ABR as an island-like phytogeographic refugium and an evolutionary ecotone.

Results

Garcinia L.

The genus *Garcinia* exhibits a pantropical distribution. In the recent study (Mohanani *et al.*, 2023), 33 species and seven varieties are recognized native to India. As the genus is primarily adapted to semi-evergreen and evergreen habitats, its diversity is concentrated within three key phytogeographical zones: the Western Ghats, Northeast India, and the Andaman and Nicobar Islands.

Maximum diversity is found in Northeast India, where 15 species and three varieties are recorded, followed by the Western Ghats (11 species and two varieties) and the Andaman and Nicobar Islands (with 10 species and two varieties). With respect to endemism, the Western Ghats ranks first with nine species and two varieties, followed by Northeast India (three species, two varieties) and the Andaman and Nicobar Islands (three species, one variety). Notably, the Agasthyamala Biosphere Reserve has the highest concentration of *Garcinia* in the country. Despite its relatively small geographical area, the ABR supports seven species—approximately 64% of the total *Garcinia* diversity found in the Western Ghats. Furthermore, three of these are stenoendemics strictly restricted to the ABR. This high density of species and narrow-range endemics within the ABR provides strong evidence for its role as a specialized evolutionary refugium and a centre of allopatric speciation.

Humboldtia Vahl

Humboldtia is a genus endemic to the Western Ghats–Sri Lanka region, though it possesses clear evolutionary affinities with African lineages. *Humboldtia* comprises ten taxa (eight species and two varieties), nine of which are endemic to the Western Ghats; *H. laurifolia* Vahl, endemic to Sri Lanka, is the sole exception.

The distribution of *Humboldtia* in the Western Ghats exhibits a pattern of increasing spatial

restriction toward the south, with the genus as a whole confined to the region extending from southern Karnataka southward. Among these, *H. vahliana* Wight is the most broadly distributed, ranging throughout the Ghats of Kerala and Tamil Nadu. In contrast, two taxa (*H. brunonis* Wall. and *H. brunonis* var. *rakthapushpa* Udayan, Tushar & S.George) are restricted to southern Karnataka, northern Kerala, and the Nilgiris. Similarly, two species (*H. bourdillonii* Prain and *H. sanjappae* Sasidh. & Sujanapal) are restricted to the Idukki–Pathanamthitta ranges of Kerala. The remaining four taxa (*H. decurrens* Bedd., *H. ponmudiana* E.S.S.Kumar, Shareef & Raj Vikr., *H. unijuga* Bedd. var. *unijuga* and *H. unijuga* var. *trijuga* Joseph & Chandras.) are restricted to the southernmost tip of the Western Ghats. Thus, including the widely distributed *H. vahliana*, ABR harbors 5 taxa accounting for 55% of the Indian representation of the genus, four of which are stenoendemic to the region. This remarkable clustering of taxa highlights the ABR as a critical evolutionary node and a distinct refugium, where long-term isolation has fostered the diversification of the genus.

***Symplocos* Jacq.**

The genus *Symplocos* exhibits an amphi-pacific distribution, with a strong preference for evergreen habitats above 1000 m asl, occurring primarily within the montane forest types. In the recent study (Stephan, 2023), 46 species and four subspecies are recognized as native to India, distributed across three primary phytogeographical zones: the Western Ghats, the Himalayas (including Northeast India), and the Eastern Ghats. The Western Ghats harbor the highest diversity, with 35 taxa (32 species and three subspecies), followed by the Himalayas (16 species and two subspecies) and the Eastern Ghats (four species). Notably, endemism within this genus in India is restricted exclusively to the Western Ghats, where 29 out of the 35 taxa are endemic.

In the Agasthyamala Biosphere Reserve, 15 taxa are recorded, 14 of which are Western

Ghats endemics. Remarkably, nine of these 14 endemic taxa are stenoendemic to the ABR. This concentration represents the highest percentage of stenoendemism recorded for the genus within the country. The presence of such a high number of narrow-range endemics within the ABR further confirms its status as an island-like refugium that has facilitated intense speciation in high-altitude lineages (Table 1 & 2).

Discussion and conclusion

The collective data from the taxonomic revisions of *Garcinia*, *Humboldtia*, and *Symplocos* provide compelling empirical evidence for the status of the Agasthyamala Biosphere Reserve as a unique island-like phytogeographic region, a long-standing ecological refugium, and a significant evolutionary ecotone. The high intrageneric diversity and endemism observed here are likely driven by a synergistic combination of sharp topographical barriers, and long-term microclimatic stability. This localized phenomenon closely mirrors the macro-scale evolutionary dynamics observed in true oceanic islands like Madagascar, where extreme geographic isolation and fine-scale topographically-driven habitat fragmentation similarly act as a crucible for intense speciation within ancient floral lineages (Antonelli *et al.*, 2022; Liu *et al.*, 2024). Significantly, many of the stenoendemic taxa identified in this study are currently classified under IUCN Red List categories, such as Critically Endangered (CR), Endangered (EN), and Near Threatened (NT), pointing to their conservation priority.

These evolutionary processes are morphologically evident in certain taxa. In the genus *Humboldtia*, for instance, clear phenotypic divergence is manifested in the variation of leaflet numbers between *H. unijuga* var. *unijuga* and *H. unijuga* var. *trijuga*, as well as the distinct petiole structures distinguishing *H. decurrens* and *H. ponmudiana*. Conversely, in morphologically complex and plastic genera such as *Garcinia* and *Symplocos*, such clear-cut phenotypic relationships

Table 1. Distribution pattern of genera *Garcinia*, *Humboldtia* and *Symplocos* in India.

Genus	Total Taxa (India)	Taxa in WG (Endemic to WG)	Total Taxa in ABR	Stenoendemic Taxa to ABR
<i>Garcinia</i>	40 (33 sp. & 7 vars.)	13 (11 endemic)	7 sp.	3 sp.
<i>Humboldtia</i>	9 (7 sp. & 2 vars.)	9 (9 endemic)	5 (4 sp. & 1 var.)	4 (3 sp. & 1 var.)
<i>Symplocos</i>	50 (46 sp., 3 subsp. & 1 var.)	35 (29 endemic)	15 (13 sp. & 2 subsp.)	9 (8 sp. & 1 subsp.)

Note: WG: Western Ghats; ABR: Agasthyamala Biosphere Reserve; sp.: species; subsp.: subspecies; var.: varieties.

Table 2. Intrageneric diversity and distribution patterns of *Garcinia*, *Humboldtia*, and *Symplocos* in the Agasthyamala Biosphere Reserve.

No.	Species/Varieties in ABR	Distribution	Endemic to WG	Stenoendemic to ABR	IUCN Status
I. <i>Garcinia</i> (Clusiaceae)					
1	<i>G. cambogioides</i> (Murray) Headland	WG, NE India			LC
2	<i>G. gamblei</i> Shameer, T.Sabu & N.Mohanani	Western Ghats	+	+	CR
3	<i>G. gumi-gutta</i> (L.) N.Robson	India, Sri Lanka			LC
4	<i>G. imbertii</i> Bourd.	Western Ghats	+	+	CR
5	<i>G. rubro-echinata</i> Kosterm.	Western Ghats	+		EN
6	<i>G. travancorica</i> Bedd.	Western Ghats	+	+	CR
7	<i>G. wightii</i> T.Anderson	Western Ghats	+		EN
II. <i>Humboldtia</i> (Fabaceae)					
1	<i>H. decurrens</i> Bedd.	Western Ghats	+	+	NT
2	<i>H. ponmudiana</i> E.S.S.Kumar, Shareef & RajVikr.	Western Ghats	+	+	NE
3	<i>H. unijuga</i> Bedd. var. <i>unijuga</i>	Western Ghats	+	+	EN
4	<i>H. unijuga</i> var. <i>trijuga</i> Joseph & Chandras.	Western Ghats	+	+	CR
5	<i>H. vahliana</i> Wight	Western Ghats	+		EN
III. <i>Symplocos</i> (Symplocaceae)					
1	<i>S. authilingomii</i> A.N.Henry & Gopalan	Western Ghats	+	+	NE
2	<i>S. cochinchinensis</i> subsp. <i>laurina</i> (Retz.) Noot.	Asia			LC
3	<i>S. foliosa</i> Wight	Western Ghats	+		NE
4	<i>S. gardneriana</i> Wight	Western Ghats	+		NE
5	<i>S. kothayarensis</i> Sundaresan, Jothi, S.Rajkumar & Manickam	Western Ghats	+	+	NE
6	<i>S. macrocarpa</i> Wight ex C.B.Clarke	Western Ghats	+		NE

No.	Species/Varieties in ABR	Distribution	Endemic to WG	Stenoendemic to ABR	IUCN Status
7	<i>S. mohananii</i> J.Stephan, R.Akhil & P.W.Fritsch	Western Ghats	+	+	NE
8	<i>S. nairii</i> A.N.Henry, Gopalan & Swamin.	Western Ghats	+	+	EN
9	<i>S. namboodiriana</i> (Sivad. & N.Mohanan) J.Stephan, P.W.Fritsch & N.Mohanan	Western Ghats	+	+	NE
10	<i>S. oligandra</i> Bedd.	Western Ghats	+	+	EN
11	<i>S. parvibracteata</i> J.Stephan, P.W.Fritsch & N.Mohanan	Western Ghats	+	+	NE
12	<i>S. pulchra</i> subsp. <i>coriacea</i> Gopalan & A.N.Henry	Western Ghats	+	+	EN
13	<i>S. rosea</i> Bedd.	Western Ghats	+		NE
14	<i>S. sessilis</i> C.B.Clarke	Western Ghats	+	+	NE
15	<i>S. wayanadensis</i> (Kuntze) Noot.	Western Ghats	+		NE

Note: WG: Western Ghats; ABR: Agasthyamala Biosphere Reserve; +: Present; CR: Critically Endangered; EN: Endangered; NT: Near Threatened; LC: Least Concerned; NE: Not Evaluated.

are more challenging to discern through traditional taxonomy alone. Consequently, detailed molecular characterization of these genera and their constituent species within the ABR is strongly recommended. Such phylogenetic studies are essential to elucidate the precise evolutionary trajectories and ancestral relationships that govern this unique, island-like flora.

Literature Cited

- AHMEDULLAH M. & M.P. NAYAR 1986. *Endemic Plants of the Indian Region*. Volume 1. Peninsular India. BSI Publications, Calcutta.
- ANOOP P.B., PRADEEP S.V. & P.S. UDAYAN 2016a. Ecology and distribution of the genus *Humboldtia* Vahl (Leguminosae) in India. *International Journal of Plant, Animal and Environmental Sciences* 6(2): 87–94.
- ANOOP P.B., PRADEEP S.V. & P.S. UDAYAN 2016b. A note on the occurrence of *Humboldtia laurifolia* Vahl (Leguminosae-Caesalpinioideae), a vulnerable tree species in India. *International Journal of Current Science* 19(3): 1–5.
- ANTONELLI A., SMITH R.J., PERRIGO A.L., CROTTINI A., HACKEL J., TESTO W., FAROOQ H., JIMÉNEZ M.F.T., ANDELA N. [...] & H. RALIMANANA 2022. Madagascar's extraordinary biodiversity: Evolution, distribution, and use. *Science* 378(6623): eabf0869. <https://doi.org/10.1126/science.abf0869>
- IUCN 2025. *The IUCN Red List of Threatened Species*. Version 2025-2. <https://www.iucnredlist.org/> (Accessed on 12.02.2026).
- KUMAR E.S.S., SHEREEF S.M. & R.R. VIKRAMAN 2022. *Humboldtia ponmudiana* (Fabaceae-Detarioideae), a new species from Kerala, India. *Phytotaxa* 552(1): 115–121. <https://doi.org/10.11646/phytotaxa.552.1.11>
- LIU Y.I., WANG Y., WILLETT S.D., ZIMMERMANN N.E. & L. PELLISSIER 2024. Escarpment evolution drives the diversification of the Madagascar flora. *Science* 383 (6683): 653–658. <https://doi.org/10.1126/science.adi0833>
- MACARTHUR R.H. & E.O. WILSON 1967. *The Theory of Island Biogeography*. Princeton University Press.
- MOEF Government of India 2017. *Agasthyamala Biosphere Reserve*. Available at: https://moef.gov.in/uploads/2017/08/BR_Agasthyamala.pdf (Accessed on 12.02.2026).
- MOHANAN N. 2025. An Inventory of the Stenoendemic Angiosperms of Agasthyamala Biosphere Reserve,

- Western Ghats, India. *ResearchGate preprint* <https://doi.org/10.13140/G.2.2.13159.36008/1>
- MOHANANI N. & M. SIVADASAN 2002. *Flora of Agasthyamala*. Bishen Singh Mahendra Pal Singh, Dehra Dun. p. 889.
- MOHANANI N., SHAMEER P.S. & T. SABU 2023. Taxonomic revision of *Garcinia* (Clusiaceae) in India. *Rheede* 33(3): 101–158. <https://doi.org/10.22244/rheede.2023.33.03.01>
- NAYAR M.P. 1996. *Hot Spots of Endemic Plants of India, Nepal and Bhutan*. TBGRI Publications, Thiruvananthapuram.
- RAJKUMAR G., PANDURANGAN A.G. & R. PRAKASHKUMAR 2022. Agasthyamala Biosphere Reserve: a natural landscape for unique paradise of bioresources with phytogeographical significance. In: MISRA S.K. (ed.), *Biosphere Reserves, Botanic Gardens, Zoological Parks, Museums, Biodiversity of India-Identification, Conservation & Management*. Govt. M. S. Golvalkar College, Rewa. pp. 29–40.
- SANJAPPA M. 1986. A revision of the genus *Humboldtia* Vahl (Leguminosae-Caesalpinioideae). *Blumea* 31: 329–339.
- SHAMEER P.S., RAMESHKUMAR K.B. & N. MOHANANI 2016. Diversity of *Garcinia* species in the Western Ghats. In: RAMESHKUMAR K.B. (ed.), *Diversity of Garcinia species in the Western Ghats: Phytochemical Perspective*. JNTBGRI, Thiruvananthapuram. pp. 1–18.
- SHAMEER P.S., SABU T. & N. MOHANANI 2017. *Garcinia gamblei* (Clusiaceae), a new species from the southern Western Ghats, India. *Phytotaxa* 297(1): 71–76. <https://doi.org/10.11646/phytotaxa.297.1.7>
- STEPHAN J. 2023. *Taxonomic revision of the family Symplocaceae Desf., of India*. Ph.D. Thesis, University of Kerala, Thiruvananthapuram.
- STEPHAN J., FRITSCH P.W. & N. MOHANANI 2017. *Symplocos parvibracteata* sp. nov. (Symplocaceae) from the Western Ghats, Kerala, India. *Nordic Journal of Botany* 35: 426–431. <https://doi.org/10.1111/njb.01212>
- STEPHAN J., FRITSCH P.W. & R. AKHIL 2021a. *Symplocos mohananii* sp. nov. (Symplocaceae) from the Western Ghats of Kerala, India. *Phytotaxa* 480(2): 195–200. <https://doi.org/10.11646/phytotaxa.480.2.8>
- STEPHAN J., FRITSCH P.W., MOHANANI N. & D.K. LIRIINA 2021b. Elevation of *Symplocos macrophylla* subsp. *namboodiriana* (Symplocaceae) to the species rank. *Phytotaxa* 502(1): 101–106. <https://doi.org/10.11646/phytotaxa.502.1.8>
- UNESCO 2016. *Agasthyamala Biosphere Reserve, India*. Available at: <https://www.unesco.org/en/mab/agasthyamala> (Accessed on 12.02.2026).