

Distribution pattern of the genus *Rhododendron* in Bhutan Himalayan range

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ABSTRACT: The genus *Rhododendron* is considered one of the relictual plant taxa having circumboreal distribution. However, through vicariance followed by orogeny, the distribution of this plant genus was vastly affected. A total of forty six *Rhododendron* species in Bhutan Himalayan region share most of its species with central Himalayan countries. Additionally, the genus *Rhododendron* is found even to the extend to Far East Asia. However, very little information is available on the comparative study of the phytogeographic distributions of genus *Rhododendron* between Himalayan countries and the extent of East Asia. Various literatures and derived data on the *Rhododendron* species availability were studied. Findings revealed that the *Rhododendron arboreum* is found to be widely distributed across the whole Himalayan range to the neighbouring countries in East Asia. It could be reasoned that *Rhododendron* species of Himalayan range are confined within their geographical boundary and remain isolated from other populations. We proposed that heterogenous environmental condition offered by might have played an important role in sustaining the diversity of *Rhododendron* in Himalayan range. Although Bhutan Himalayan range is not accounted a center of distribution of *Rhododendron* species, it might have helped as an important corridor for the dispersal of plant elements as it connects many floristic region and biogeographic realms.

KEYWORDS: geographic distribution, *Rhododendron*, Bhutan Himalayas, phytogeography

INTRODUCTION

The genus *Rhododendron*, family Ericaceae is considered an old plant genus which presumably might have occurred ca. 50 million years ago during a tertiary period [1], and it is proposed to be one of the tertiary relict genera where once this plant genus was having circumboreal distribution in the northern hemisphere [2]. Later, during late tertiary period (44–55 million years ago), the collision of Indian plate and Eurasian plate gave rise to the Himalayan mountains (region of extreme relief). With the uplift of the Himalayan mountains and change in climatic condition followed by the geological time scale, the distribution of floristic composition of a plant community was vastly affected [3]. The Himalayan mountain range plays an important role in plant biogeography as it connects different biogeographic realms [4] and provides refuge to many plants due to the unique ecological niche for the diversity of the plants [5]. Moreover, the Himalayan range is important in terms of plant biogeography as the range has connected to many important plant biogeographic regions [6] where *Rhododen-*

dron could be found i.e. Eastern Himalaya province (region 2), Irano-Turanian province (region 8), Sudano-zambazian province (region 12), India (region 16) and Indochinese region (region 17) according to Takhtajan's system of plant geography [7].

Bhutan Himalayas, which forms a major part of eastern Himalayas, is mostly characterized by the geographical complexity and climatic variability [8,9]. The vegetation is so diverse that it provides a cradle for vast section of floristic richness, especially *Rhododendron* where it contributes four percent to the global population of the genus *Rhododendron*. Bhutan Himalayas harbours forty-six taxa of *Rhododendron*, mostly belonging to the subgenera *Hymenanthes* and *Rhododendron* growing on different geographical mountains forming a critical component of a montane ecosystem.

Tobgye et al [6] studied the comparative study of the floristic elements on the lower montane forest of Bhutan Himalayan range and proposed the probable floristic dispersal routes. Although, Bhutan Himalayas is one of the hosts for the *Rhododendrons*, the phytogeographic information of this plant genus

is least achieved. Therefore, the present work tries to draw the patterns of distribution throughout the Himalayan range to East Asia in terms of general phytogeography of *Rhododendron*.

MATERIALS AND METHODS

The study was conducted in different geographical ranges from west to east of Bhutan Himalayas covering all the places where a wild population of *Rhododendron* is found (Fig. 1) i.e. Chele-La (27°37.31' N; 89°37.27' E), Dochula (27°48.34' N; 27°48.34' E), Pelela (27°51.70' N; 90°54.89' E), Yotongla (27°52.14' N; 90°60.93' E), Phrumsengla National Park (27°39.84' N; 90°99.41' E); Dagala (27°26.58' N; 89°65.26' E) and Sakteng (27°41.85' N; 91°87.62' E) within an elevation range between 2400–4300 m above sea level. The vegetation in all geographical regions of the study sites is characterized as a mixed coniferous forest except Sakteng where it is an open wetland valley. Plants were collected from March to July 2019 to cover all the flowering seasons. The distribution of selected *Rhododendron* species was studied in initial field survey, and a set of parameters including geographic coordinates and habitats was recorded. All the species were photographed and recorded with the field notes. The collected specimens were identified according to the Flora of Bhutan [10]. The herbarium specimens were prepared and deposited in the Bhutan National Herbarium Center, Serbithang.

The information on the distribution of *Rhododendron* species in Himalayan countries and countries of East Asia where *Rhododendron* could be found was compiled from available scientific published papers, monographs, online database and published taxonomic books on this plant genus like 'A revision of *Rhododendron* II. subgenus *Hymenanthes*' [11], 'The Encyclopedia of *Rhododendron* Species' [12], 'A revision of *Rhododendron* I. subgenus *Hymenanthes*. Notes from the Royal Botanic Garden' [13], 'The *Rhododendron* Species Volume II Elepidotes Species, series *Arboreum-Lacteum*' [14], 'Flora of China' [15], '*Rhododendron* of China' [16], 'The *Rhododendron* species in the Indian Eastern Himalaya' [17], 'The *Rhododendrons* of Nepal' [18] and 'Flora of Thailand' [19]. For the global status of this species, we have referred to 'The red list of *Rhododendrons* 2011' [20].

RESULTS AND DISCUSSION

The genus *Rhododendron* species have wide distribution along Himalayan range of Bhutan (Fig. 2).

Based on the distribution of *Rhododendron* species from different taxonomic literature, two groups of the taxa could be summarized according to their presence in the given areas. *Rhododendron arboreum* is found throughout the Himalayas, and it is also found in neighbouring countries from East Asia i.e. Myanmar, Vietnam and Thailand (Table 1) while the other selected taxa are confined to Himalaya region of Bhutan, south-west of China, north-west of India and Nepal Himalayan range.

R. arboreum is taxonomically placed under the subgenera *Hymenanthes* and section *Pontica* subsection *Arborea* Sleumer that comprises ca. 300 *Rhododendron* species [13]. In Bhutan Himalayan range, *R. arboreum* species is widely distributed within the altitudinal range from 2500–3600 m above sea level, growing on a different ranges of habitats like a rocky cliff, marshland and temperate forest. This taxon occurs as seven different morphological forms, viz., *R. arboreum* var. *album* Wall, *R. arboreum* subsp. *nilagiricum* (Zenker) Tagg, *R. arboreum* subsp. *arboreum* Smith, *R. arboreum* subsp. *cinnamomeum* (Wallich ex G. Don) Lindley, *R. arboreum* subsp. *delavayi* (Franchet) Chamberlain, *R. arboreum* subsp. *Cinnamomeum* var. *roseum* Lindley and *R. arboreum* subsp. *zeylanicum* (Booth) Tagg [13]. Therefore, it could be plausibly reasoned that its high levels of genetic variability and withstanding high and low thermal regime might have attributed to their dominance distribution [21]. However, these paleoendemic taxa hold a subject of much ongoing taxonomic debate especially regarding the center of diversity and a gradual migration of *Rhododendron* taxa [20].

Another plausible explanation for the wide distribution of *R. arboreum* could be related to ecological niche theory [22]. *R. arboreum* species is the only species that holds a wide range of altitudinal distribution (Table 2) and habitats. Chandra et al [23] also spotted *R. arboreum* below 1000 m in Indian Himalayan region. Kutapety et al [24] reported that annual mean temperature was found to be an ecological factor that defined the survival of *R. arboreum* var. *cinnamomeum* and *R. arboreum* var. *arboreum* in a different geographical locations of Indian Himalayan range. *R. arboreum* has high degree of adaptability and grows in a different habitat. Due to its broad realized niche and high recolonization ability, it competes with other plants and grows with already established vegetation [21]. Further, some species like *R. arboerum* subsp. *Nilagiricum* is found in the south Western Ghats of India and even in the moun-

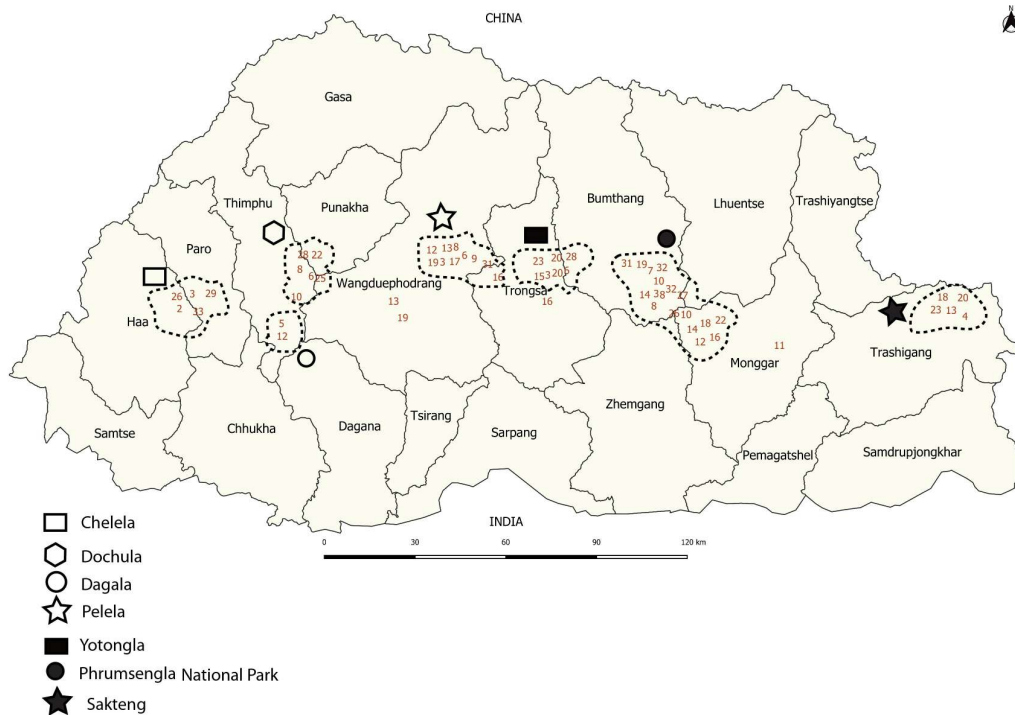


Fig. 1 Map showing the distribution of genus *Rhododendron* on different geographical mountain ranges of Bhutan Himalayas. *Rhododendron* species: 1, *R. aeruginosum* Hook. f.; 2, *R. anthopogon* Wall; 3, *R. arboreum* Smith; 4, *R. argipeplum* Balfour & Cooper; 5, *R. baileyi* Balfour & Cooper; 6, *R. barbatum* G. Don; 7, *R. campanulatum* D. Don; 8, *R. campylocarpum* Hook. f.; 9, *R. Ciliatum* Hook. f.; 10, *R. cinnabarinum* Hook. f.; 11, *R. dalhousiae* var. *rhabdotum* Balfour & Cooper; 12, *R. edgeworthii* Hook. f.; 13, *R. falconeri* Hook. f.; 14, *R. fulgens* Hook. f.; 15, *R. grande* Wight; 16, *R. graffithianum* Wight; 17, *R. hodgsonii* Hook. f.; 18, *R. Kendrickii* Nuttall; 19, *R. kesangiae* Long & Rushforth; 20, *R. keysii* Nuttall; 21, *R. lanatum* Hook. f.; 22, *R. lindleyi* Moore; 23, *R. maddenii* Hook. f.; 24, *R. neriiflorum* Franchet; 25, *R. niveum* Hook. f.; 26, *R. setosum* D. Don; 27, *R. succothii* Davidian; 28, *R. thomsonii* Hook. f.; 29, *R. triflorum* Hook. f.; 30, *R. tsariense* Cowan; 31, *R. virgatum* Hook. f.; 32, *R. wallichii* Hook. f. and 33, *R. wightii* Hook. f.

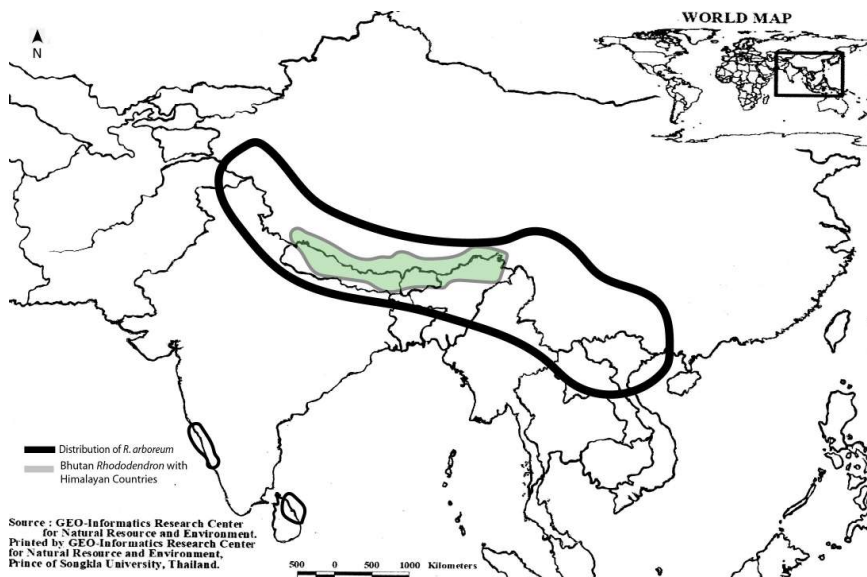


Fig. 2 Map showing the distribution of *Rhododendron* species in the Himalayan range and East Asia.

Table 1 List of *Rhododendron* species in Bhutan Himalayas in comparison with their occurrence in Himalayan and East Asian countries.

Rhododendron species	Bhu	Chi	Ind	Nep	Pak	Mym	Viet	Thai	Habit	Status
<i>R. aeruginosum</i> Hook. f.	×	×							1	2
<i>R. anthopogon</i> D. Don	×	×	×	×		×			2	2
<i>R. arboreum</i> Smith	×	×	×	×	×	×	×	×	3	2
<i>R. argioplum</i> Balfour & Copper	×	×	×	×					4	2
<i>R. baileyi</i> Balfour f.	×	×	×						4	2
<i>R. barbatum</i> G. Don	×	×	×	×					4	1
<i>R. bhutanense</i> Long & Bowes Lyon*	×								4	1
<i>R. camelliflorum</i> Hook. f.	×	×	×	×					4	2
<i>R. campanulatum</i> D. Don	×	×	×	×					4	2
<i>R. campylocarpum</i> Hook. f.	×	×	×	×					4	2
<i>R. ciliatum</i> Hook. f.	×	×	×	×		×			4	2
<i>R. cinnabarinum</i> Hook. f.	×	×	×	×					4	2
<i>R. dalhousiae</i> var. <i>rhabdotum</i> Balfour & Cooper	×	×	×	×		×			4	2
<i>R. edgeworthii</i> Hook. f.	×	×	×			×			4	2
<i>R. falconeri</i> Hook. f.	×		×						3	2
<i>R. fragariiflorum</i> Kingdon Ward	×	×		×					4	2
<i>R. flinckii</i> Davidian	×			×					4	1
<i>R. fulgens</i> Hook. f.*	×	×	×			×			4	2
<i>R. glaucophyllum</i> Rehder	×	×	×	×					4	2
<i>R. grande</i> Wight	×	×	×	×					3	2
<i>R. griffithianum</i> Wight	×	×	×	×					3	2
<i>R. hodgsonii</i> Hook. f.	×	×	×	×		×			3	2
<i>R. kendrickii</i> Nuttall	×	×		×					4	2
<i>R. kesangiae</i> Long & Rushforth	×								3	2
<i>R. keysii</i> Nuttall*	×	×	×						4	2
<i>R. lanatum</i> Hook. f.	×	×	×						4	1
<i>R. lepidotum</i> G. Don	×	×	×			×			4	2
<i>R. leptocarpum</i> Nuttall	×	×	×	×		×			4	2
<i>R. lindleyi</i> Moore	×	×	×			×			4	2
<i>R. maddenii</i> Hook. f.	×	×	×	×		×			3	2
<i>R. neriflorum</i> Franchet	×	×		×		×	×	×	4	2
<i>R. nivale</i> Hook. f.	×	×	×						4	2
<i>R. niveum</i> Hook. f.	×	×	×	×					3	1
<i>R. papillatum</i> Hook. f.	×	×	×						4	1
<i>R. pendulum</i> Hook. f.	×	×	×	×					2	2
<i>R. pogonophyllum</i> Cowan	×								4	1
<i>R. pumilum</i> Hook. f.*	×	×	×	×		×			4	2
<i>R. setosum</i> D. Don	×	×	×	×					2	2
<i>R. succothii</i> Davidian	×		×						4	2
<i>R. thomsonii</i> Hook. f.	×	×	×	×					4	2
<i>R. triflorum</i> Hook. f.	×	×	×	×		×			4	2
<i>R. tsariense</i> Cowan	×	×	×	×					4	1
<i>R. vacciniodes</i> Hook. f.	×	×	×	×		×			4	2
<i>R. virgatum</i> Hook. f.	×	×	×	×					4	2
<i>R. wallichii</i> Hook. f.	×	×	×	×					4	2
<i>R. wightii</i> Hook. f.	×	×	×	×					4	2

* Endemic to Bhutan. Countries: Bhu, Bhutan; Chi, China; Ind, India; Nep, Nepal; Pak, Pakistan; Mym, Myanmar; Viet, Vietnam and Thai, Thailand. Habit: 1, krummholz; 2, prostrate shrub; 3, tree and 4, shrubby tree. Status: 1, globally threatened *Rhododendron*; 2, least concern.

tain forest of Sri Lanka [21]. Therefore, these taxa stimulate an intriguing questions about the course of evolution.

When floral morphology of *R. arboreum* is taken into account, it is assumed that this species could be pollinated both by bees and birds which might have helped in rapid seed developmental allometries due to high visitation rate by the different pollinators [25]. The *R. arboreum* tree which extended up to 15–20 m in height coupled with superior capacity to disperse by wind and animals owing to small and light seeds [26] might have triggered long dispersal and adaptation. Through dispersal

means, it might have therefore used as an evolutionary measure for a wide distribution of such plant taxa, especially *R. arboreum* where it has a diverse distribution over the Himalayan range to East Asia. However, further in-depth study of the phytogeography, molecular phylogenetic analysis as well as the pollination ecology and seed dispersal of this plant taxa is suggested to encourage future research on a topic that deserves further consideration.

Bhutan Himalayan kingdom retains four endemic *Rhododendron* species out of forty-six [10] i.e. *R. bhutanense* Long & Bowes Lyon, *R. flinckii* Davidian, *R. kesangiae* Long & Rushforth and

Table 2 Environmental variables and *Rhododendron* species that are grown in different study sites in Bhutan Himalayan range.

Species	Altitude (m)	Flowering	Habitat [†]	Height (m)	Site [‡]
<i>R. aeruginosum</i> Hook. f.	3700–4000	May–Jun	1	2±1	2
<i>R. anthopogon</i> D. Don	3900–4200	Jun–Jul	1	0.3±0.2	1 2 4
<i>R. arboreum</i> Smith	2500–3600	Mar–Apr	1 2 3	20±5	1 2 3 4 5 6
<i>R. argipeplum</i> Balfour & Copper	2700–3400	Apr–May	2	3±2	4 5
<i>R. baileyi</i> Balfour f.	3000–4000	May–Jul	1	1.5±0.5	2
<i>R. barbatum</i> G. Don	3000–3600	Mar–Apr	2	6±2	1 3 4
<i>R. campanulatum</i> D. Don	3100–3700	May–Jun	2	4.0±1.5	6
<i>R. campylocarpum</i> Hook. f.	3000–3600	Apr–May	2	6±2	1 4 6
<i>R. ciliatum</i> Hook. f.	2700–3200	Apr–Jun	4	1.5±1.0	4
<i>R. cinnabarinum</i> Hook. f.	3100–3700	May–Jul	2	6±2	1 4 6
<i>R. dalhousiae</i> var. <i>rhabdotum</i> Balfour & Cooper	2100–2600	May–Jun	3	7±3	6
<i>R. edgeworthii</i> Hook. f.	2500–3000	Apr–May	3	5±2	3 4 6
<i>R. falconeri</i> Hook. f.	2500–3100	Apr–May	2	20±7	3 4 5 6
<i>R. fulgens</i> Hook. f.	2900–3500	May–Jun	2	5±2	6
<i>R. grande</i> Wight	2100–2900	Feb–Mar	2	10±5	4 5 6
<i>R. griffithianum</i> Wight	2000–2600	Mar–May	2	7±4	3 4
<i>R. hodgsonii</i> Hook. f.	3000–3600	Apr–May	2	15±5	1 4 6
<i>R. kendrickii</i> Nuttall	2400–3200	Mar–Apr	2	6±2	6
<i>R. kesangiae</i> Long & Rushforth	2600–3400	Apr–May	2	25±6	3 4 5 6
<i>R. keysii</i> Nuttall	2600–3500	May–Jul	2	3.0±1.5	3 4 6
<i>R. lanatum</i> Hook. f.	3500–3900	May–Jun	2	4±1	6
<i>R. lindleyi</i> Moore	2000–2800	Apr–May	3	5±2	6
<i>R. maddenii</i> Hook. f.	2100–2900	Apr–Jun	3	3.5±1.0	5
<i>R. neriflorum</i> Franchet	2500–3100	Mar–May	2	4±2	4
<i>R. niveum</i> Hook. f.	2900–3700	Apr–May	2	8±5	3
<i>R. setosum</i> D. Don	3000–4000	Jun–Aug	1	0.3±0.2	1 2
<i>R. succothii</i> Davidian	3100–3900	Apr–May	2	3±2	6
<i>R. thomsonii</i> Hook. f.	2900–3600	May–Jun	4	6±3	3 5 6
<i>R. triflorum</i> Hook. f.	2300–3600	Apr–Jun	2	4±2	1 3 4
<i>R. tsariense</i> Cowan	3300–3900	May–Jun	2	5±2	6
<i>R. virgatum</i> Hook. f.	2400–2700	Apr–May	2	3±1	6
<i>R. wallichii</i> Hook. f.	2800–3900	Apr–Jun	2	6±1	1 6
<i>R. wightii</i> Hook. f.	3600–4300	May–Jun	2	6±2	1 6

[†] Habitats: 1, alpine shrub; 2, forest; 3, rocky cliff; 4, marsh land.

[‡] Sites: 1, Chelela; 2, Dagala; 3, Dochula; 4, Pelela; 5, Sakteng; 6, Phrumsengla National park.

Table 3 Total number of *Rhododendron* species and number of endemic species in different countries.

Country	Bhutan	China	India	Nepal	Myanmar	Thailand	Vietnam
Total Number of <i>Rhododendron</i> species	46	571	87	30	205	12	90
Number of endemic species	4	423	20	1	*	0	12

* Not assessed.

R. pogonophyllum Cowan (Table 1). Although Grierson et al [10] have proposed the *Rhododendron* species of Bhutan, the enumeration study was confined only in the western and the central part of Bhutan. The extensive survey might have been limited due to rigid and rugged mountain terrains where it remains inaccessible. There are chances that many more species or new record of *Rhododendron* species from other geographical locations of Bhutan could be later found since Bhutan Himalayan region seems likely to offer the refuge of *Rhododendron* species owing to the country’s geographic complexities fueled by varying environmental clines.

Bhutan Himalayas shares most of the *Rhododendron* species with Nepal, India and Southwest China

Himalayan range e.g. *R. anthopogon* (Fig. 3B), *R. arboreum* (Fig. 3C), *R. argipeplum* (Fig. 3D), *R. barbatum* (Fig. 3F), *R. campylocarpum* (Fig. 3G), *R. ciliatum* (Fig. 3H), *R. cinnabarinum* (Fig. 3I), *R. grande* (Fig. 3M), *R. griffithianum* (Fig. 3N), *R. hodgsonii* (Fig. 3O), *R. maddenii* (Fig. 4E), *R. niveum* (Fig. 4G), *R. setosum* (Fig. 4H), *R. thomsonii* (Fig. 4J), *R. triflorum* (Fig. 4K), *R. virgatum* (Fig. 4M), *R. wallichii* (Fig. 4N) and *R. wightii* (Fig. 4O). It could be hypothesized that the formation of Himalayan mountain range particularly Bhutan, Nepal, south west of China and north east of India by the collision between Indian Plate and Eurasian Plate which began ca. 50 million years ago [1] might have created a heterogeneous topography. This topographic complexity may have



Fig. 3 Flowers of: A, *R. aeruginosum*; B, *R. anthopogon*; C, *R. arboreum*; D, *R. argipeplum*; E, *R. baileyi*; F, *R. barbatum*; G, *R. campylocarpum*; H, *R. ciliatum*; I, *R. cinnabarinum*; J, *R. dalhousiae* var. *rhabdotum*; K, *R. edgeworthii*; L, *R. falconeri*; M, *R. grande*; N, *R. griffithianum* and O, *R. hodgsonii*.

helped to create the array of climatic niches and to increase the opportunities for the geographical barrier which gradually accentuates in forming a reproductive isolation where species diversity occurs [27]. Similarly, with the development of complex topography, it might have promoted in forming a unique environmental niche. Thus, the geographic reproductive isolation fueled by the heterogeneous habitat might have promoted the diversification of *Rhododendron* species through allopatric speciation and adaptation to the varying environmental clines [27]. Therefore, the countries of East Asia might not share a common *Rhododendron* species with the Himalayan countries due to its varying nature of habitats and environmental conditions.

Through the study of endemic species of *Rhododendron* in different countries (Table 3), it is supposed that Bhutan Himalayan region might not be a center of diversity of *Rhododendron* species due to its minimum genetic diversity as proposed by Ranjitkar et al [21]. However, it could be suggested that it might have acted as an important corridor for



Fig. 4 Flowers of: A, *R. kesangiae*; B, *R. keysii*; C, *R. lanatum*; D, *R. lindleyi*; E, *R. maddenii*; F, *R. neriiflorum*; G, *R. niveum*; H, *R. setosum*; I, *R. succothii*; J, *R. thomsonii*; K, *R. triflorum*; L, *R. tsariense*; M, *R. virgatum*; N, *R. wallichii* and O, *R. wightii*.

the distribution for many plant elements of different plant genera, especially the plant genus *Rhododendron*.

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REFERENCES

1. Irving E, Hebda R (1993) Concerning the origin and distribution of Rhododendrons. *J Amer Rhododendron Soc* 47, ID 139.
2. Chamberlain DE, Hyam R, Argent G, Fairweather G, Walters KS (1996) *The Genus Rhododendron: Its Clas-*

- sification and Synonymy, Royal Botanical Garden, Edinburgh.
3. Milne RI (2006) Northern hemisphere plant disjunctions: a window on tertiary land bridges and climate change? *Ann Bot* **98**, 465–472.
 4. Jantscho K, Sridith K (2015) Exploring the patterns of alpine vegetation of eastern Bhutan: A case study from the Merak Himalaya. *Springplus* **4**, ID 304.
 5. Chaudhary S, Tshering D, Phuntsho T, Uddin K, Shakya B, Chettri N (2017) Impact of land cover change on a mountain ecosystem and its services: Case study from Phobjikha valley, Bhutan. *Ecosyst Health Sustain* **3**, ID 1393314 .
 6. Tobgye T, Sridith K (2018) Preliminary notes on distribution of Himalayan plants elements: A case study from Eastern Bhutan. *Songklanakarin J Sci Technol* **40**, 370–378.
 7. Takhtajan A (1986) *Floristic Region of the World*, University of California Press, Berkeley, CA.
 8. Oshawa M (1987) *Life Zone Ecology of the Bhutan Himalaya*, Chiba University, Japan.
 9. National Biodiversity Centre (2009) *Biodiversity Action Plan*, MoAF, Royal Government of Bhutan.
 10. Grierson AJC, Long DG (1991) *Flora of Bhutan*, vol 2(I), Royal Botanical Garden, Edinburgh.
 11. Chamberlain DF (1982) A Revision of *Rhododendron* II. subgenus *Hymenanthus*. *Note Roy Bot Gard Edinburgh* **39**, mbox209–486.
 12. Cox PA, Cox KNE (1997) *The Encyclopedia of Rhododendron Species*, Glendoick Publishing, Perth, Scotland.
 13. Cullen J (1980) A revision of *Rhododendron* I. subgenus *Hymenanthus*. *Note Roy Bot Gard Edinburgh* **39**, 1–207.
 14. Davidian HH (1989) *The Rhododendron Species Volume II Elepidotes Species, Series Arboreum-Lacteam*, Timber Press Inc, Batsford, London.
 15. Fang MY, Fang RC, He MY, Hu LZ, Yang HB, Chamberlain DF (2005) Ericaceae. In: Wu ZY, Raven PH, Hong DY (eds) *Flora of China*, Vol. 14, Science Press, Beijing, pp 260–455.
 16. Feng G (1988) *Rhododendrons of China*, Vol. I, Science Press, Beijing.
 17. Menon S, Latif Khan M, Paul A, Peterson AT (2012) *Rhododendron* species in the Indian Eastern Himalaya: New approaches to understanding rare plant species distribution. *J Amer Rhododendron Soc* **66**, 78–84.
 18. De Milleville R (2002) *The Rhododendrons of Nepal*, Himal Books, Katmandu, Nepal.
 19. Santisuk T, Balslev H, Newman M, Barfod A (2015) *Flora of Thailand*, Vol. 13(I), The Forest Herbarium, Department of National Parks, Wildlife & Plant Conservation, Bangkok.
 20. Gibbs D, Chamberlain D, Argent G (2011) *The Red List of Rhododendrons*, Botanic Gardens Conservation International, Richmond, UK.
 21. Ranjitkar S, Kindt R, Sujakhu NM, Hart R, Guo W, Yang X, Shrestha KK, Xu J, et al (2014) Separation of the bioclimatic spaces of Himalayan tree *Rhododendron* species predicted by ensemble suitability models. *Glob Ecol Conserv* **1**, 2–12.
 22. Vetaas OR (2002) Realized and potential climate niches: A comparison of four *Rhododendron* tree species. *J Biogeogr* **29**, 545–554.
 23. Sekar KC, Srivastava KS (2010) Rhododendrons in Indian Himalayan region: Diversity and Conservation. *Am J Plant Sci* **1**, 131–137.
 24. Kuttapetty M, Pillai PP, Varghese JR, Seeni S (2014) Genetic diversity analysis in disjunct populations of *Rhododendron arboreum* from the temperate and tropical forests of Indian subcontinent corroborate satpura hypothesis of species migration. *Biologia* **69**, 311–322.
 25. Howell V, Jesson LK (2013) The effect of bird and bee visitation on pollination and reproductive success in *Phormium tenax*. *N Z J Bot* **51**, 194–205.
 26. Wang Y, Wang J, Lai L, Jiang L, Zhuang L, Zhang L, Zheng Y, Baskin JM, et al (2014) Geographic variation in seed traits within and among forty-two species of *Rhododendron* (Ericaceae) on the Tibetan plateau: Relationships with altitude, habitat, plant height, and phylogeny. *Ecol Evol* **4**, 1913–1923.
 27. Shrestha N, Wang Z, Su X, Xu X, Lyu L, Liu Y, Drimittrov D, Kennedy JD, et al (2018) Global patterns of *Rhododendron* diversity: The role of evolutionary time and diversification rates. *Global Ecol Biogeogr* **27**, 913–924.