

Biodiversity and conservation of rhododendrons in Arunachal Pradesh in the Indo-Burma biodiversity hotspot

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India is one of the 12 mega diversity countries in the world having two hotspots – the Western Ghats and the Eastern Himalayas, based on species rarity and endemism. Arunachal Pradesh in the Eastern Himalaya is among the 200 globally important ecoregions. The state harbours nearly 50% of the total flowering plant species in India. Rhododendrons form the dominating species all along the cool temperate, subalpine and alpine zones in the Arunachal Himalaya. Rhododendron is one of the largest genus of the Ericaceae family, occurring in the higher altitudes having ecological significance and economic importance in addition to its graceful flowers. About 98% of the Indian species is found in the Himalayan region, among which 85% is found in the Arunachal Himalaya. It has aesthetic, sacred, aromatic, medicinal and fuelwood values. Due to human interference the natural populations of rhododendrons in the Arunachal Himalaya are gradually diminishing. Major threats to rhododendrons in western Arunachal Pradesh are deforestation and unsustainable extraction of firewood by the local people. Rhododendrons which are classified as rare, endangered and threatened may be wiped out in near future from the biota, if proper management and conservation initiatives are not taken up. Various in situ as well as ex situ measures like establishment of arboreta, sanctuaries, parks and reserve forests, protected areas through community management, botanical gardens and in vitro research procedures are prescribed to conserve this species for posterity. Moreover, awareness and participation of and by the people is warranted for successful conservation.

Keywords: Anthropogenic threats, Arunachal Pradesh, biodiversity, conservation, rhododendrons.

WHILE conservation biologists warn that 25% of total life forms could become extinct during the next twenty to thirty years, the causes for loss of species are numerous, most importantly, the fragmentation of natural habitats¹. About 1.4 million different species of living organisms exist in this world; 750,000 insects, 41,000 vertebrates² and 270,000 plant species, out of which 33,798 were threatened vascular plant species³. Tropical forests cover only 7% of earth's land surface, yet they are estimated to contain at least 50% of total species². Mexico, Colombia, Ecuador, Peru, Brazil, Zaire, Madagascar, China, India, Malaysia, Indonesia and Australia together hold up to 70% of the world's total species diversity⁴. The process of industrialization and urbanization tends to damage this resource base that could be disastrous to the human race. In view of biological conservation and to minimize degradation of natural ecosystems, protected areas

have been established that cover about 5% of the total land area of the world⁵. Tropical forests have enjoyed special attention due to high floral and faunal diversity, fragility of their structure and function as well as provision of forest products and ecosystem services⁶. Due to this, policy planners and administrators have paid less attention to the temperate ecosystems as a whole, in purview of demarcation of these regions as protected areas. However, recent studies have revealed that the temperate regions too have some characteristic flora and fauna, which need immediate attention from conservation viewpoint. In India, a total of 572 protected areas, including national parks and wildlife sanctuaries (150,809.6 km²) cover 4.8% of the total geographical area (3,287,213 km²) of the country. Arunachal Pradesh, a biodiversity hotspot in the Indian eastern Himalayas, has a total of 13 protected areas, including national parks and wildlife sanctuaries, covering 10,074.59 km² (i.e. 12.03% of the geographical area of the state)⁷. Yet the protected areas of Arunachal Pradesh largely cover the low and mid-elevation forests. This is despite the fact that 23% of the area of the state⁸ is above 3000 m.

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India in biodiversity context

India is a vast country with rich diversity of biotic resources due to varied physiography and climatic regime⁹. It encompasses a wide spectrum of habitats, viz. tropical rainforests to alpine vegetation and coastal wetlands to desert scrubs. India is one of the 12 mega diversity countries in the world having two hotspots – the Western Ghats and the Eastern Himalayas, based on species rarity and endemism¹⁰. India's forests have been exploited for millennia and intensely during the past two centuries¹¹. The present forest cover is 63.7 mha (i.e. 19.4%) of the total land area. India occupies 2.5% of the world's land area and 1.8% of the global forest area¹². The number of plant species in India is estimated to be over 45,000, representing 7% of the world's flora; about 15,000 constitute flowering plants. About 4900 species of flowering plants are endemic to India; 2532 species are found in the Himalayan region and 1782 species in peninsular India. Among these, about 1500 species are facing varying degrees of natural or anthropogenic threats². In India, although the degree of anthropogenic pressure varies in different parts of the country, human disturbances have become a widespread feature in most of the forested areas throughout the Himalayas¹³. The Himalaya, with a total area of nearly 100 mha, dominates the floristic estimate of the entire Indian sub-continent². The eastern Himalayas differ significantly from the western Himalayas, in climate as well as vegetation. For instance, conifers dominate the western Himalayan mountains, while the eastern Himalayan region is dominated by broad-leaved forests. There are more than 20 oak species in the east compared to 5 species in the west. Ferns and orchids in the east far outnumber those in the west¹⁴. The Western Ghats has been studied widely, while more work has to be carried out in order to explore the rich biodiversity of the Eastern Himalayas located in poorly indeterminate mountain terrains, where chances of finding newer species have been predicted¹⁵.

Arunachal Pradesh – a biodiversity hotspot

According to an estimate based on satellite images¹², the northeastern region has 163,799 km² of the forest, which is about 25% of the total forest cover in the country¹⁶. In the northeastern Himalayan (NEH) region, dependence of tribals on forest for fuelwood as a primary source of energy, coupled with shifting cultivation has been causing deforestation¹⁷. Due to an ever-increasing population, fuelwood consumption is also increasing rapidly in the region¹⁸. The average fuelwood consumption is significantly high (5.23 kg day⁻¹ person⁻¹) in the northeastern hill region¹⁹ compared to other parts of India²⁰.

Arunachal Pradesh, by virtue of its geographical position, climate conditions and altitudinal variations, is a biodiversity-rich region in northeast India, with large tracts of tropical wet evergreen, subtropical, temperate and alpine forests. The state (83,743 km²) occupies a major portion of the Indian

Eastern Himalayas and has 82% forest cover¹². It is located in the Eastern Himalaya – global biodiversity hotspot¹⁰ and is also among the 200 globally important ecoregions²¹. The state harbours the world's northernmost tropical rainforests and is estimated to have nearly 50% of the total flowering plant species in India^{15,22}. The forests harbour a variety of medicinal and other commercially useful plants, e.g. *Berberis wallichii*, *Coptis teeta*, *Fritillaria cirrhosa*, *Illicium griffithii*, *Podophylum hexandrum*, *Panax* sp. (ginseng), *Rhododendron* spp., *Taxus baccata*, etc. Arunachal Pradesh is the only state in India to house maximum number of living gymnosperms (12 genera and 21 species). About 8 genera and 12 species are introduced and/or cultivated in the state²³.

The rhododendrons do exhibit significant diversity in habit, inflorescence, flower colour, etc. in Arunachal Pradesh. Of the total 72 species known from India, 61 occur in Arunachal Pradesh²⁴. About 85% of the Indian *Rhododendron* species are found in Arunachal Himalaya. One of Asia's largest orchidarium is also in Arunachal Pradesh at Tipi, West Kameng district; about 300 species can be seen in the flora glasshouse, some of which are rare and endangered. An orchid sanctuary at Sessa spread over an area of 100 km², has 2600 orchids representing 80 species cultivated in natural surroundings and is home to more than 500 varieties of orchids²⁵. Among the 1200 bird species in India, nearly 600 have been recorded from this state²⁶, which is also recognized as an important endemic bird area by ornithologists²⁷. Arunachal is also home to large herbivores such as the takin (*Budorcas taxicolor*), goral (*Nemorhaedus goral*), screw (*Nemorhaedus sumatraensis*), several primates and carnivores such as the common leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*) and tiger (*Panthera tigris*). The Chinese goral, *Nemorhaedus caudatus* has been reported for the first time in the Mago Chu valley, Tawang district, Arunachal Pradesh and represents a new addition to the list of large mammals from the Indian subcontinent⁸. This is perhaps the only region in the world known to harbour all the three extant species of goral (Chinese goral, Himalayan goral and red goral, *N. baileyi*). Both Chinese and red goral have been recognized as vulnerable in the IUCN's Red List of Threatened Species⁸. Culturally, 26 major tribes and over 110 sub-tribes of human societies²⁸ inhabit different parts of the state, with an intricate lifestyle totally dependent on forest resources, making the entire region a cultural landscape.

History of rhododendrons – A global purview

Rhododendron is an important genus occurring in the high altitudes, having ecological significance and economic importance in addition to its graceful flowers. The term 'Rhododendron' comes from the Greek words 'rhodo' meaning rose and 'dendron' meaning 'tree', in combination 'rose-tree'²⁹. In 1753, Linnaeus, who devised binomial system of plant taxonomy, created two genera, *Rhododendron* and *Azalea*, into which the nine hitherto recognized species were placed. Over the next 240 years, many botanists have

furthered the taxonomy of rhododendrons³⁰ that range in size from tiny mat-like plants to trees up to 30 m height. *Rhododendron* is a spectacular genus consisting of evergreen, semi deciduous and deciduous shrubs and trees. They occupy every possible habitat such as the forest floor, stream sides, marshes, ridges, glades, cliffs, rocks and boulders, open meadows and thickets, scree and mountain tops and even trees, where many species grow epiphytically in the moss and debris at all levels from trunks to the topmost branches²⁹. However, rhododendrons grow well in loose, open, well-aerated, acidic soil with plenty of humus to retain moisture³¹.

Rhododendrons are classified into four groups: the scaly Rhododendrons (subgenus *Rhododendron*); true Rhododendrons (subgenus *Hymenanthus*); the azaleas, which comprise the subgenera *Azalea* and *Tsutsia*; and false azaleas (subgenus *Azaleastrum*)²⁹. *Rhododendron*, the largest genus of the Ericaceae family, includes 1200 species distributed throughout Northeast Asia and Eurasia, Western Europe and North America^{32,33}. Rhododendrons cover a vast section of South East Asia, comprising northwestern Himalaya through Nepal, Sikkim, eastern Tibet, Bhutan, Arunachal Pradesh, and upper Myanmar, western and central China. More than 90% of the world's natural population of rhododendrons is from this region³⁴. They are widely distributed at higher elevation in the Sino-Himalayan regions, with maximum concentration in the western China³⁵. Up to 650 species have been reported in China, making it the largest plant genus there³⁶. In fact, rhododendron is the state flower of West Virginia and Washington State, Georgia's official wildflower in USA, and also prefectures in Japan. *Rhododendron arboreum* is Nepal's national flower, locally known as *Lali Guras* or 'rose tree' in English. It is even depicted on the National coat of arms.

Rhododendrons are usually clustered inflorescence (trusses) at the branch tips and occur in all colours except a true bright blue. The flowers may be single or multicoloured, often with a contrasting throat blotch (flare) or spotting and some species have scented flowers (*R. dalhousiae*, *R. edgeworthii*, *R. johnstoneanum*, etc.). Rhododendrons tend to bloom from late winter to early summer under temperate conditions, but the tropical rhododendrons are far less seasonal and bloom throughout the year, usually reaching a peak in early fall (autumn)³¹. They mostly blossom during summer months from March to June and provide an attractive appearance to the hills with different shades like red (*R. arboreum*, *R. fulgens*, *R. thomsonii*), pink (*R. campanulatum*, *R. niveum*), white (*R. griffithianum*, *R. maddenii*, *R. wallichii*), yellow (*R. campylocarpum*, *R. falconeri*, *R. wightii*) and purple (*R. campanulatum*, *R. glaucophyllum*), depending upon the species.

Rhododendrons in India

The history of Himalayan *Rhododendron* commences with the visit of Captain Hardwick of the Siwalik Mountains of

Srinagar, Kashmir in 1796, where he encountered *R. arboreum*. It was described³⁷ by Sir James Smith in *Exotic Botany* in 1805. Sir Joseph Hooker's journey to the Sikkim Himalaya between 1847–51, opened the doors to the rhododendrons of this area. Within a brief span of time that he travelled in Sikkim, Hooker gathered and described 34 new species and provided details of all 45 species from the Indian region in his monograph entitled *The Rhododendrons of the Sikkim-Himalaya*, published in 1849 and considered the standard text for the study of Himalayan *Rhododendron*. The monograph still remains unparalleled in its exhaustive details and elegant paintings^{37,38}.

Reportedly, 98% of the rhododendrons are confined to the Himalayan region³⁴. In a total of 72 species, 20 subspecies and 19 varieties have been listed from India (Table 1). The western Himalayan region has 8 species, whereas eastern Himalayan region harbours 71 species. The rhododendrons are found between 1200 m (e.g. *R. dalhousiae*, *R. dendricola*) and 6000 m (e.g. *R. nivale*, *R. leptocarpum*) altitude, but majority of them occur between 2200 and 4000 m. Among all Indian species, *R. arboreum* is widely distributed, occurring from western to eastern Himalayan region and other neighbouring countries. One subspecies (*R. arboreum* ssp. *nilagiri-cum*) is found in the Nilgiri Hills of Western Ghats, Tamil Nadu²⁴.

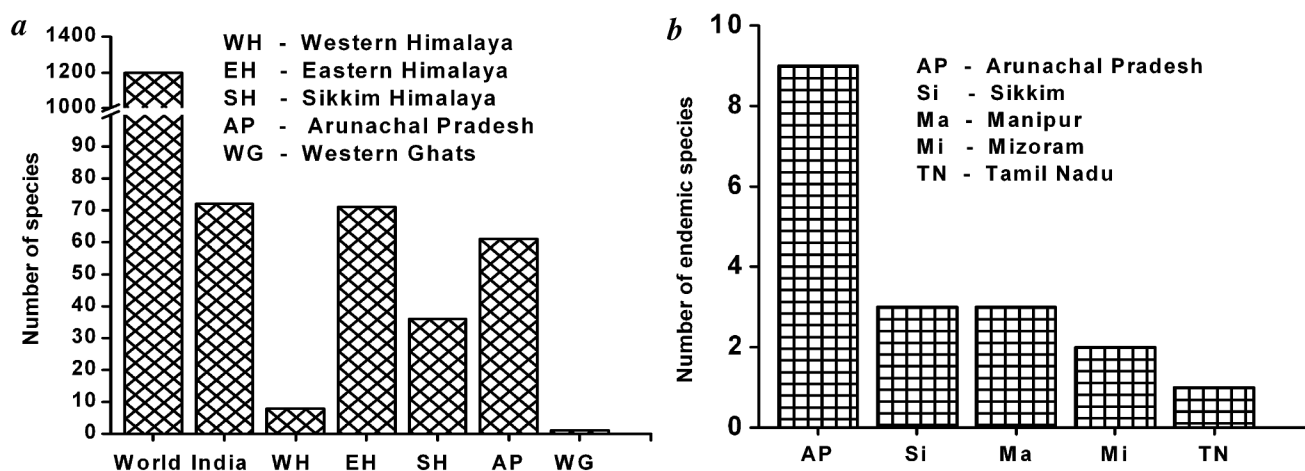
Rhododendrons in India show great diversity in habit within different species ranging from small shrublets (*R. anthopogon* ssp. *anthopogon*, *R. calostrotum* ssp. *riparium*, *R. lepidotum*, *R. megeratum*, *R. nivale*, *R. pemakoense*, *R. setosum*), to shrubs (*R. bailey*, *R. beanianum*, *R. boothii*, *R. bulu*, *R. campylocarpum*, *R. cerasimum*) and trees (*R. arboreum*, *R. barbatum*, *R. cinnabarinum*, *R. falconeri*, *R. grande*, *R. macabeanum*, *R. rex* ssp. *arizelum*, *R. sidereum*). About 15 Indian *Rhododendron* species are either epiphytic (grow on trees) or lithophytic (grow on mossy rocks) (e.g. *R. boothii*, *R. camelliflorum*, *R. dalhousiae*, *R. dendricola*, *R. edgeworthii*, *R. leptocarpum*), while the remaining are terrestrial. Some species (e.g. *R. arboreum*, *R. cinnabarinum*, *R. dalhousiae*, *R. setosum*, *R. thomsonii*) are poisonous. Out of 72 species known from India, Arunachal Pradesh has 61 species²⁴ (Figure 1a). About 36 species of rhododendrons are found in the Sikkim Himalaya between 1500 and 6000 m above msl³⁴. In India, rhododendron is the state flower of Nagaland and state tree of Sikkim³⁹. There are two distinct flowering seasons, viz. March–May and May–July. However, a large number of species flower during April–June, except for a few species like *R. edgeworthii*, *R. griffithianum* and *R. maddenii* that flower during May–July⁴⁰.

Endemism of rhododendrons in India

In terms of biological endemism, rhododendrons contributed 7 species, 2 subspecies and 3 varieties in India⁴⁰. However, a recent estimate shows that 12 species, 2 subspecies and 5 varieties are endemic to India²⁴ (Figure 1b). Among the

Table 1. Species richness of rhododendrons in Indo-Himalayan region and Western Ghats

Himalayan region	State	Species	Subspecies	Variety
Western Himalayas	Himachal Pradesh	1	4	0
	Jammu & Kashmir	3	3	0
	Uttaranchal	3	2	0
Eastern Himalayas	Arunachal Pradesh	61	17	12
	Assam	0	1	1
	Manipur	5	2	3
	Meghalaya	0	2	2
	Mizoram	3	1	0
	Nagaland	2	3	1
	Sikkim	27	11	10
Darjeeling Himalaya	West Bengal	12	7	4
Western Ghats	Tamil Nadu	0	1	0

Source: Mao *et al.*²⁴.**Figure 1.** Species richness (a) and endemism (b) of *Rhododendron* species in northeast and southern India.

northeastern states of India, Arunachal Pradesh has the maximum number of endemic species with 9 species and 1 subspecies, followed by Manipur and Sikkim with 3 species and 1 subspecies, Mizoram with 2 species and the Western Ghats with 1 subspecies (*R. arboreum* ssp. *nilagiricum*). Apart from these endemic taxa, there are about 46 rare, threatened and endangered taxa found within the genus (Figure 2 a–f). Among these, 43 taxa have been recorded as rare, threatened and endangered by Sastry and Hajra⁴⁰ (Table 2), two taxa by Naithani and Bahadur⁴¹ and one taxon by Katak⁴².

Utilization prospects of rhododendrons

Aesthetic and sacred values

The beautiful, magnificent flowers and evergreen foliage of rhododendrons have attracted the attention of botanists and horticultural enthusiasts throughout the world. Today, nearly 50% of the species is under cultivation worldwide and about 5000 to 6000 hybrids of rhododendrons have already

been developed⁴³. These hybrids are sold in the market at high cost. They are mainly grown in gardens, parks and other important places for their showy and attractive flowers. Rhododendron trees can be introduced as avenue trees along road sides and residential areas in the hills between 2000 and 4000 m. In USA and Norway, hybrids of rhododendrons are popular as avenue trees. Rhododendron flowers are also considered sacred and offered in temples and monasteries²⁴.

Medicinal, aromatic and fuelwood values

In India, rhododendrons are mostly utilized by the Bhutias, Lepchas and Nepalis, dominant inhabitants of the Indo-Himalayan region. Apart from aesthetic and sacred values, rhododendrons also have medicinal and economic values. The dried flowers of *R. arboreum* are supposedly highly efficacious in checking diarrhoea and blood dysentery. The fresh and dried corolla that is acid-sweet in nature is given when fishbones get stuck in the gullet³⁷. Leaves of *R. campanulatum* are ground with tobacco and used as

Table 2. Endemic, endangered, rare and threatened species of *Rhododendron* in India

Species	Habit	Habitat	Himalayan region	Altitudinal range (m)	Conservation status
<i>R. arboreum</i> Sm. ssp. <i>delavayi</i> (Franch.) D. F. Chamb. var. <i>peramoenum</i> (Balf. f. and Forrest) D. F. Chamb.	Shrub or small tree	In conifer and mixed forests, open forests, among scrub and thickets and often quite dry areas	Eastern Himalaya (Arunachal Pradesh)	1500–3200	Endemic
<i>R. arboreum</i> Sm. ssp. <i>nilagiricum</i> (Zenker) Tagg	Shrub or small tree	Forest hills	Western Ghats, Nilgiri Hills (Tamil Nadu)	1800–2250	Endemic
<i>R. assamicum</i> Kingdon-Ward	Shrub or small tree	In conifers forest and hilly slopes	Eastern Himalaya (Arunachal Pradesh)	ca. 3000	Endemic
<i>R. baileyi</i> Balf. f.	Straggly to fairly compact shrub	In conifer forests, moist rocks and dry scree of hillsides	Sikkim Himalaya (Sikkim)	3000–4000	Rare
<i>R. beanianum</i> Cowan	Fairly compact shrub or often straggly with age	In bamboo forests, amongst rocks, forest edges and gullies	Eastern Himalaya (Arunachal Pradesh)	3000–3350	Rare
<i>R. boothii</i> Nutt.	Usually an epiphytic shrub, inclined to be straggly	Usually epiphytic, occasionally on rocks and in forests	Eastern Himalaya (Arunachal Pradesh)	1800–2500	Threatened
<i>R. bulu</i> Hutch.	Usually an erect, straggly shrub	In open woodland or scrubby hillsides	Eastern Himalaya (Arunachal Pradesh)	3000–3800	Threatened
<i>R. calostrotum</i> (Balf. f. and Kingdon-Ward) ssp. <i>riparium</i> (Kingdon-Ward) Cullen	Erect, mounded, creeping or prostrate shrub	Alpine meadows and cliffs, rocky slopes, hillsides and damp ground	Eastern Himalaya (Arunachal Pradesh)	3050–4500	Rare
<i>R. campanulatum</i> (D. Don) ssp. <i>aeruginosum</i> (Hook. f.) D. F. Chamb.	Rounded compact shrub	About and above the tree line on rocky moorland, on stony alpine slopes, forest thickets and ridges	Sikkim Himalaya (Sikkim)	4500–5000	Endemic
<i>R. campylogynum</i> Franch.	Prostrate mound-shaped to erect small dwarf shrub	Among other rhododendrons, alpine scrub, rocks and cliffs to open hillsides	Eastern Himalaya (Arunachal Pradesh)	2750–4250	Rare
<i>R. cephalanthum</i> (Franch.) ssp. <i>cephalanthum</i>	Almost prostrate to upright shrub	In moist moorland, rocky slopes, cliffs and open meadows	Eastern Himalaya (Arunachal Pradesh)	3050–4500	Rare
<i>R. chamaethomsonii</i> (Tagg and Forrest) Cowan and Davidian	Dense dwarf shrub, very compact and dense to rather rangy	Mounding habit, steep hillsides and among boulders on rocky slopes	Eastern Himalaya (Arunachal Pradesh)	3665–5000	Endemic
<i>R. cinnabarinum</i> (Hook. f.) ssp. <i>xanthocodon</i> (Hutch.) Cullen	Upright shrub, sometimes spreading with age	In forests and forest margins, common in thickets and on steep hillsides	Eastern Himalaya (Arunachal Pradesh), Sikkim Himalaya (Sikkim) and Darjeeling Himalaya (West Bengal)	3050–3950	Threatened
<i>R. concinnoides</i> Hutch. and Kingdon-Ward	Shrub	In woodlands and thickets	Eastern Himalaya (Arunachal Pradesh)	2462–3385	Endemic and threatened
<i>R. coxianum</i> Davidian	Often epiphytic, usually straggly shrub	In marshy ground or epiphytic	Eastern Himalaya (Arunachal Pradesh)	ca. 1700	Endemic
<i>R. dalhousiae</i> (Hook. f.) var. <i>rhabdutum</i> (Balf. f. and R. E. Cooper) Cullen	Usually leggy and untidy, erect sprawling often epiphytic shrub	Epiphytic or terrestrial in forests or trees, cliffs, hillsides, dry rocky areas and boulders	Eastern Himalaya (Arunachal Pradesh)	ca. 2500	Rare

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Table 2. (Contd...)

Species	Habit	Habitat	Himalayan region	Altitudinal range (m)	Conservation status
<i>R. decipiens</i> Pradhan and Lachungpa (A natural hybrid of <i>R. hodgsonii</i> and <i>R. arboreum</i> in the wild)	Erect shrub or small tree	Ridges, valleys and on open hillsides	Sikkim Himalaya (Sikkim) and Darjeeling Himalaya (West Bengal)	2500–3000	Endemic
<i>R. dendricola</i> Hutch.	Usually straggly shrub	Epiphytic or terrestrial, on rocks, cliffs, forest margins, rocky slopes and thickets	Eastern Himalaya (Arunachal Pradesh)	1200–1400	Rare
<i>R. edgeworthii</i> Hook. f.	Leggy to fairly compact epiphytic shrub	Epiphytic on trees, rocks, cliffs and in dense forests	Eastern Himalaya (Arunachal Pradesh), Sikkim Himalaya (Sikkim) and Darjeeling Himalaya (West Bengal)	2100–3300	Rare
<i>R. elliotii</i> Watt.	Upright, often rather straggly shrub or small tree	In forests, hilly slopes	Eastern Himalaya (Manipur and Nagaland)	2400–2700	Endemic and endangered
<i>R. exasperatum</i> Tagg	Compact to open shrub or small tree	On rocks, conifer forests, dense thickets, fir forests, open ridges and on steep slopes	Eastern Himalaya (Arunachal Pradesh)	3000–4000	Rare
<i>R. falconeri</i> (Hook f.) ssp. <i>eximium</i> (Nutt.) D. F. Chamb.	Rounded, rounded-spreading to columnar large shrub or tree	Moist shady mixed forests, conifer forest and ridges	Eastern Himalaya (Arunachal Pradesh)	3000–3500	Endemic and endangered
<i>R. formosum</i> (Wallich) var. <i>formosum</i>	Fairly compact to straggly and open shrub	In open forests, hill slopes or river bank	Eastern Himalaya (Meghalaya)	1500–2000	Endemic and threatened
<i>R. formosum</i> (Wallich) var. <i>inaequale</i> (Hutch.) Cullen	Fairly compact to straggly and open shrub	In shady forests, hill slopes and river or streams bank	Eastern Himalaya (Arunachal Pradesh, Manipur, Meghalaya and Nagaland)	1500–2000	Endemic and threatened
<i>R. hookeri</i> Nutt.	Usually upright shrub or small tree	Abies and Rhododendron forest and on sheltered slopes	Eastern Himalaya (Arunachal Pradesh)	2500–3700	Rare
<i>R. imberbe</i> Hutch. (possibly hybrid of <i>R. barbatum</i> × <i>R. arboreum</i>)	Upright shrub	In open forests, ridges and hilly slopes	Eastern Himalaya (Arunachal Pradesh) and Western Himalaya (Uttaranchal)	ca. 2770	Endemic
<i>R. johnstoneanum</i> (Watt ex) Hutch.	Usually rather untidy shrub	Forest edges, hillsides, open scrub, forest margins or epiphytic	Eastern Himalaya (Arunachal Pradesh, Manipur and Mizoram)	1160–3000	Endemic and endangered
<i>R. kasoense</i> Hutch and Kingdon-Ward	Shrub	In forests, ridges and hilly slopes	Eastern Himalaya (Arunachal Pradesh)	2500–2700	Rare
<i>R. kendrickii</i> Nutt.	Rather erect, open and sparse shrub or small tree	In dense open evergreen and deciduous forest	Eastern Himalaya (Arunachal Pradesh)	2300–2800	Rare
<i>R. keysii</i> Nutt.	Often straggly or leggy vigorous shrub or small tree	In thickets, conifer and mixed forest	Eastern Himalaya (Arunachal Pradesh), Sikkim Himalaya (Sikkim)	2440–3650	Rare
<i>R. macabeanum</i> (Watt ex) Balf. f.	Upright tree	In mixed forest, brich or pure stands, steep and hilly slopes	Eastern Himalaya (Manipur and Nagaland)	2500–3000	Endemic and rare
<i>R. maddenii</i> (Hook. f.) ssp. <i>maddenii</i>	Compact, sprawling or straggly shrub	In conifer, mixed dense forest, open ridges and slopes, cliffs, bamboo, thickets and mixed scrub	Eastern Himalaya (Arunachal Pradesh) and Sikkim Himalaya (Sikkim)	2400–3650	Rare

(contd...)

Table 2. (Contd...)

Species	Habit	Habitat	Himalayan region	Altitudinal range (m)	Conservation status
<i>R. maddenii</i> Hook. f. ssp. <i>crassum</i> (Franch.) Cullen	Compact sprawling or straggly shrub	In dense forest, open ridges and slopes, rocks, cliffs, and scrubby thickets	Eastern Himalaya (Manipur, Meghalaya and Nagaland)	2250–3000	Rare
<i>R. megacalyx</i> Balf. f. and Kingdon-Ward	Rarely epiphytic, loose, floppy shrub to small open tree	On steep cliffs and banks, forests, bamboo, scrub and thickets	Eastern Himalaya (Arunachal Pradesh)	2160–2770	Rare
<i>R. megeratum</i> Balf. f. and Forrest	Bushy often compact, dwarf shrub	On mossy rocks, boulders, mossy cliffs and old stumps or logs	Eastern Himalaya (Arunachal Pradesh)	3050–4150	Rare
<i>R. mekongense</i> Franch. var. <i>rubrolineatum</i> (Balf. f. and Forrest) Cullen	Broadly upright shrub	Rocky slopes, forest margins and open pastures	Eastern Himalaya (Arunachal Pradesh)	3350–4250	Rare
<i>R. micromeres</i> Tagg	Epiphytic shrub	Mossy trunks in forest, epiphytic or terrestrial	Eastern Himalaya (Arunachal Pradesh)	2450–4000	Rare
<i>R. neriiflorum</i> (Franch.) ssp. <i>phaedropum</i> (Balf. f. and Forrest) Tagg	Compact to loose shrub or small tree	In pine forest, scrub, open meadows and hillslopes	Eastern Himalaya (Arunachal Pradesh)	2000–3400	Threatened
<i>R. nuttallii</i> Booth	Large, sometimes epiphytic shrub or small tree	Epiphytic or in thickets, forest margins, rocky slopes and cliffs	Eastern Himalaya (Arunachal Pradesh)	1200–3650	Rare
<i>R. papillatum</i> (Balf. f. and Cooper) D. F. Chamb.	Creeping to mounding dwarf shrub	Conifer forest, often rocky steep slopes, dense thickets, cliffs and among boulders	Eastern Himalaya (Arunachal Pradesh) and Sikkim Himalaya (Sikkim)	1800–3300	Rare
<i>R. pemakoense</i> Kingdon-Ward	Dense, mound-forming, often stoloniferous shrub	Carpeting steep moss-covered rocks, slopes and cliffs	Eastern Himalaya (Arunachal Pradesh)	2400–3050	Rare
<i>R. pendulum</i> Hook. f.	Straggling to fairly compact shrub	Epiphytic or on steep slopes or cliffs, boulders and dense forest	Eastern Himalaya (Arunachal Pradesh) and Sikkim Himalaya (Sikkim)	2270–3650	Rare
<i>R. pocophorum</i> var. <i>pocophorum</i> (Balf. f. ex.) Tagg	Rather erect shrub	Margins of bamboo and conifer forests, in open rocky slopes, crags and meadows	Eastern Himalaya (Arunachal Pradesh)	3650–4600	Rare
<i>R. pruniflorum</i> Hutch	Bushy shrub	In forests, sheltered rhododendron thickets and rocky hill-sides	Eastern Himalaya (Arunachal Pradesh)	3050–3950	Rare
<i>R. rex</i> (Lev.) ssp. <i>arizelum</i> (Balf. f. and Forrest) D.F. Chamb.	Large erect shrub or small tree	In open conifer or rhododendron forests and thickets	Eastern Himalaya (Arunachal Pradesh)	3000–4000	Rare
<i>R. santapauui</i> Sastry, Katak, P. A. and E. P. Cox, P. C. Hutch.	Fairly compact, dwarf shrub	Epiphytic on large trees	Eastern Himalaya (Arunachal Pradesh)	ca. 1600	Endemic and endangered
<i>R. sikkimense</i> Pradhan and Lachungpa (A natural hybrid of <i>R. thomsonii</i> × <i>R. arboreum</i>)	Upright shrub or small tree	In rhododendron scrub and Abies forest	Sikkim Himalaya (Sikkim)	ca. 3700	Endemic

(contd...)

GENERAL ARTICLES

Table 2. (Contd...)

Species	Habit	Habitat	Himalayan region	Altitudinal range (m)	Conservation status
<i>R. subansiriense</i> D. F.Chamb. and Cox	Erect shrub or small tree	Common in mossy forest with other rhododendrons	Eastern Himalaya (Arunachal Pradesh)	2550–2750	Endemic and endangered
<i>R. succothii</i> Davidian	Broadly upright to rounded and compact shrub or small tree	Amongst rhododendrons and other shrubs, mixed forest, forest margins and scrub	Eastern Himalaya (Arunachal Pradesh)	3400–4200	Rare
<i>R. tanastylum</i> Balf. f. and Kingdon-Ward	Loose spindly tree	Amongst scrub, rocks or in forests, often in valley bottoms	Eastern Himalaya (Arunachal Pradesh)	1850–3350	Rare
<i>R. tephropeplum</i> Balf. f. and Farrer	Bushy to upright and sprawly shrub	On rocky slopes, cliffs, scree and meadows	Eastern Himalaya (Arunachal Pradesh)	2450–4300	Rare
<i>R. thomsonii</i> (Hook. f.) var. <i>flocculosa</i>	Upright shrub or small tree	In rhododendron forest, Abies forest, rocky slopes and open hillsides	Sikkim Himalaya (Sikkim)	3600–4300	Endemic
<i>R. triflorum</i> Hook. f. var. <i>bauhiniiflorum</i> (Watt ex Hutch.) Cullen	Upright shrub	On hillsides, forest margins, cliffs and on rocks	Eastern Himalaya (Manipur)	2470–3080	Endemic and rare
<i>R. veitchianum</i> Hook. f.	Compact shrub to small tree	On rocks, cliffs, dry evergreen forests and on disturbed land	Eastern Himalaya (Mizoram)	1230–1700	Rare
<i>R. walongense</i> Kingdon-Ward	Epiphytic shrub	Epiphytic or terrestrial in forest, thin mixed forest, ravines and rocky cliffs	Eastern Himalaya (Arunachal Pradesh)	1500–2100	Rare
<i>R. wattii</i> Cowan	Shrub or small tree	In forest, slopes and rocks	Eastern Himalaya (Arunachal Pradesh, Manipur and Mizoram)	ca. 2700	Endemic and endangered
<i>R. x candelabrum</i> Hook. f. (A natural hybrid of <i>R. thomsonii</i> × <i>R. campylocarpum</i>)	Upright shrub or small tree	In rhododendron scrub and Abies forest	Sikkim Himalaya (Sikkim)	3600–4300	Endemic
<i>R. xanthostephanum</i> Merrill	Loose upright or spreading shrub	In forests and forest margins, scrub, pastures and cliffs	Eastern Himalaya (Arunachal Pradesh) and Sikkim Himalaya (Sikkim)	1500–3000	Rare

snuff, which is said to be useful in cold, hemiparalysis, chronic rheumatism, syphilis and sciatica. The flowers of *R. arboreum* are used for brewing local wine to prevent high-altitude sickness in the Darjeeling hills of eastern Himalayas. The young leaves are said to be poisonous as well as medicinal and applied on the forehead to alleviate headache⁴⁴.

The leaves of *R. anthopogon* are mixed with those of juniper to make incense sticks that are widely used in Buddhist monasteries. Squash is also prepared from the flowers of *R. arboreum*. The grained wood of *R. arboreum* is used for making 'khukri' handles, pack-saddles, gift-boxes, gun-stocks and posts. The corolla of *R. cinnabarinum* is used for making jams by Lamas and Tibetans. In Sikkim, the corolla of the same species is fried and eaten as delicacy.

The rough leaves of *R. falconeri* are used for packing apples by the people of north Sikkim. The dense tomentum on the undersides of the leaves of *R. fulgens* is scraped and used as wick for lighting fire by inhabitants of north Sikkim. The wood of *R. hodgsonii* is used for making cups, spoons, 'khukri' handles and walking sticks, and its thick leaves with glossy surface are used for packing apples, yak butter and cheese for transportation. The leaves of *R. setosum* are distilled for aromatic oils, which are used in perfumery, cosmetics and in soap manufacture. The vegetative parts of *R. thomsonii* are boiled and the highly poisonous extract is used as a natural insecticide in the Lachen and Lachung villages of northeast Sikkim³⁷.

Local communities inhabiting the temperate and high altitude areas use rhododendrons fuelwood because of its

quality to burn even under raw conditions due to the presence of poly-flavonoids and other resinous substances^{24,34,37}. Firewood from the rhododendrons is also being used at the high altitude trekking corridor for tourism^{34,37}.

Threat to rhododendrons with special reference to Arunachal Himalaya

Conservation of biotic resources remains one of the basic needs in terms of the preserving biotic diversity which, in time, translates into richness of biotic wealth. Plant hunting expeditions by the earlier explorers from Europe into interior Asia since the turn of the century, had set the trend for removal of rhododendrons in large scale from the region. In Britain, Pacific Northwest and northeastern United States, rhododendrons found way to many gardens both in natural forms and hybrids. However, little importance was given to the genus in its homeland, which has gradually led to the present conservation threat on many species³⁴.

With the shrinking of green cover almost everywhere, rhododendrons are also experiencing the impact of disturbed ecological system³⁴. In Arunachal Pradesh, Eastern Himalaya, the ecological systems and land physiography tend to be fragile and are found to be easily disturbed. As many as 43 *Rhododendron* species in India have been brought into

rare, threatened and endangered categories⁴⁰. Among 72 *Rhododendron* species in India, 58 are under endemic, endangered, rare and threatened categories, of which 11 are endemic, 6 endemic and endangered, 3 endemic and threatened, 2 endemic and rare, 32 rare and 4 threatened (Figure 3a) maximum being shrubs, shrubs or small trees and epiphytic shrubs (Figure 3b). Rhododendrons growing in high altitude areas are also facing the impact of disturbances due to various natural and anthropogenic factors^{24,34}. Many of the species are threatened due to various anthropogenic pressures associated with developmental activities. Natural threats include landslides and forest fires which affect the rich growth of rhododendrons²⁴. Most of the alpine and subalpine rhododendrons are also facing severe problem from heavy snowfall. Young trees, seedlings and saplings are most inclined to avalanches as they have least resistance to the rushing mass of snow. Heavy rainfall and greater run-off at higher altitudes also wash them away. Considering the natural and anthropogenic factors affecting the degradation of habitat, species richness and regeneration status, there is an urgent need to investigate the habitat distribution and species diversity of *Rhododendron* species in different parts of the eastern and western Himalayas for sustainability of the species. Extensive shifting cultivation and reduced fallow periods affect forest vegetation and tree regeneration, and hence the land is degraded⁴⁵. Fuelwood collection, animal husbandry, logging, clear-felling, small-scale extraction of timber, fodder, and other non-timber forest products by the local people continues to have an impact on the forests. Cattle grazing and forest fire further affect regeneration. During our field survey, it was observed

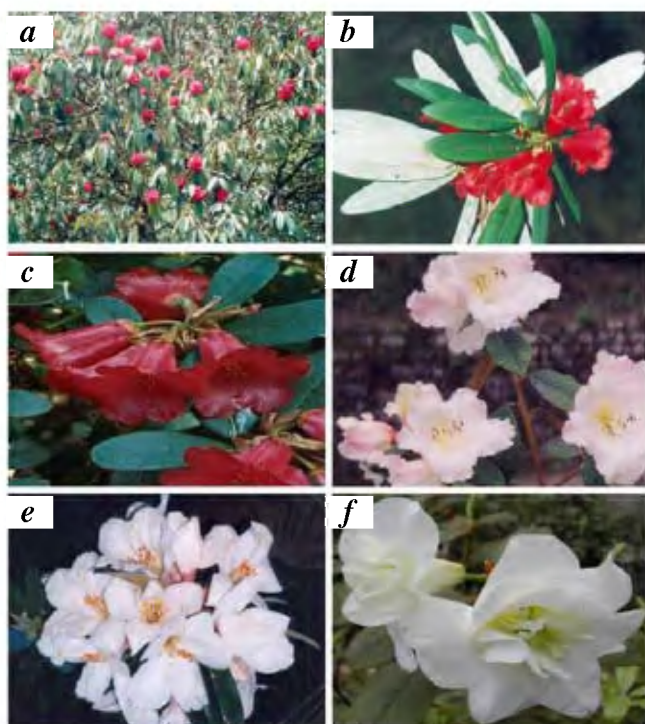


Figure 2. Few species of *Rhododendron* with their life form and conservation status occurring in Arunachal Pradesh. **a**, *R. arboreum* – tree, common; **b**, *R. neriiflorum* – shrub or small tree, threatened; **c**, *R. chamaethomsonii* – dwarf shrub, endemic; **d**, *R. edgeworthii* – epiphytic shrub; rare; **e**, *R. maddenii* – shrub; rare; and **f**, *R. johnstoneanum* – shrub, endemic and endangered.

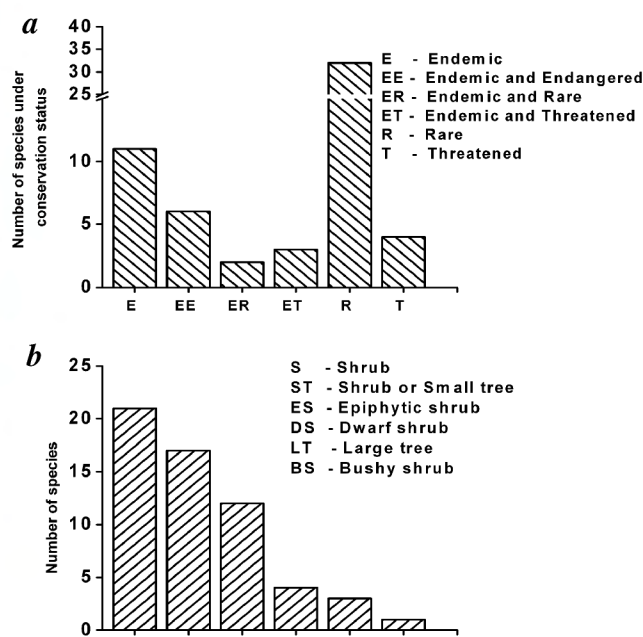


Figure 3. Conservation status (a) and habit (b) of *Rhododendron* species.

that hundreds of rhododendron trees were cut down for fuelwood, used for melting coal tar for road construction in different areas in Arunachal Pradesh. Moreover, increasing human population has also increased the demand of land for local farming and animal husbandry practices, construction of roadways, etc. which has intensified the pressure on the habitat. Eventually, forest lands are being increasingly encroached for human settlements. All these activities intensified pressure on the population of *Rhododendron* species. Nonetheless, the two anthropogenic threats seem to be deforestation and unsustainable extraction of firewood by the local people (Figure 4 a–c).

Rhododendrons: A keystone species at higher altitudes

Presence of keystone species is crucial in maintaining the organization and diversity of their ecological communities⁴⁶.



Figure 4. a. View of *Rhododendron* forest; b. Deforested *Rhododendron* patch and c. Stock pile of *Rhododendron* wood for transportation.

Rhododendrons act as keystone species in the higher altitudinal region in western Arunachal Pradesh. Hence, the subalpine to alpine transition zone that includes timberline is the most fragile ecosystem in the Himalaya. Rhododendron is the only group of plants that has continuum in the aforesaid ecotone, and beyond doubt, maintains the biological sustenance in this fragile zone³⁴. Rhododendrons have a good association with *Daphne papyracea*, an understorey shrub species. Unsustainable extraction of rhododendrons for fuelwood has also affected the growth and regeneration of *D. papyracea*. The local people (Monpa tribe) use the bark of *D. papyracea* for making local paper, which is used for encrypting Buddhist manuscripts, making flag poles and as decoration during festivals. Rhododendrons also help in checking soil erosion in the steep slopes of high altitude areas. They support a whole variety of plants and animals and provide food and shelter to a wide range of wildlife along an altitudinal gradient. Thus clearing of *Rhododendron* patches/forests may not only degrade the habitat and deplete the associated biodiversity (thus altering ecosystem functioning in high altitudes), but would also affect the socio-economic condition of the local tribes (Monpas) residing in the area.

Conservation strategies of rhododendrons in Arunachal Pradesh

Rhododendrons can be conserved *in situ* and *ex situ*. *In situ* conservation can be exercised by establishing sanctuaries, parks, reserve forests, etc. For example, Sikkim government had declared two sanctuaries, namely Shingba and Barsey as ‘rhododendron’ sanctuaries. The G. B. Pant Institute of Himalayan Environment and Development (GBPIHED) Sikkim Unit has been evaluating the status of rhododendrons in nature for the past eight years³⁴. Presently WWF-India is also trying to map rhododendron-rich forest patches in the landscape and categorize forest areas under different degradation regimes using GIS techniques in West Kameng and Twang districts, Arunachal Pradesh⁴⁷. Similar efforts could be made by the Arunachal Pradesh Government as the state harbours more than 50% of the rare and endemic Indian rhododendrons. *Rhododendron*-rich areas in Tawang and West Kameng districts, Arunachal Pradesh should be brought under protected area network to conserve the rare, endangered and endemic species from various anthropogenic factors. This should be done as part of participatory community management, as much of the forests are under community control (e.g. Unclassed State Forests). WWF-India has been trying to implement *Rhododendron* forests conservation through the community management programme with financial support from WWF-Japan and WWF-International⁴⁷.

Ex situ conservation could be practised by cultivating the *Rhododendron* species in gardens, parks under suitable climatic conditions and also by tissue culture techniques. Stock materials can be prepared in forest nurseries. Local

Table 3. Altitudinal distribution of *Rhododendron* species explored from West Kameng and Tawang districts, Arunachal Pradesh during 2003–04

Altitudinal range (m asl)				
1500–2000	2000–2500	2500–3000	3000–3500	3500–4000
<i>R. arboreum</i>	<i>R. arboreum</i>	<i>R. arboreum</i>	<i>R. barbatum</i>	<i>R. barbatum</i>
<i>R. arboreum</i> ssp. <i>delavayi</i>	<i>R. arboreum</i> ssp. <i>delavayi</i>	<i>R. barbatum</i>	<i>R. campylocarpum</i>	<i>R. campylocarpum</i>
<i>R. maddenii</i> ssp. <i>maddenii</i> *	<i>R. dalhousiae</i>	<i>R. dalhousiae</i>	<i>R. cinnabarinum</i>	<i>R. fulgens</i>
	<i>R. edgeworthii</i> *	<i>R. edgeworthii</i> *	<i>R. falconeri</i>	<i>R. hodgsonii</i>
	<i>R. falconeri</i>	<i>R. falconeri</i>	<i>R. hodgsonii</i>	<i>R. thomsonii</i>
	<i>R. grande</i>	<i>R. glaucophyllum</i>	<i>R. keysii</i> *	<i>R. wightii</i>
	<i>R. kendrickii</i> *	<i>R. grande</i>	<i>R. thomsonii</i>	
	<i>R. maddenii</i> ssp. <i>maddenii</i> *	<i>R. griffithianum</i>		
	<i>R. neriiflorum</i> **	<i>R. kendrickii</i> *		
		<i>R. keysii</i> *		
		<i>R. maddenii</i> ssp. <i>maddenii</i> *		
		<i>R. neriiflorum</i> **		
		<i>R. triflorum</i>		

*Rare; **Threatened.

people should be trained in propagation of *Rhododendron* species. An *ex situ* conservation initiative by the GBPIHD has been the establishment of a *Rhododendron* arboretum at Pangthang near Gangtok, Sikkim, where twenty-four species of rhododendrons are housed and some of them have started flowering. India's only *ex situ* conservation is also in progress³⁴. WWF-India also intends to install mist chambers in the forest department nurseries for better upkeep of *Rhododendron* seedlings, which will be used for direct plantation in degraded forest lands⁴⁷. Such efforts could be adopted by the State Forest Department. Efforts should also be made to impart environmental education to the local communities emphasizing on conservation of forest resources, particularly rhododendrons. Local communities maybe provided with alternative sources of fuelwood such as LPG, solar heaters, room heaters, coke, etc. Also species like *Alnus nepalensis*, which is a fast-growing and atmospheric nitrogen-fixing tree species maybe introduced on large-scale for reclamation of degraded lands to reduce excess harvesting of *Rhododendron* as fuelwood. For this, people's participation is of utmost importance. Construction of roads, hydel-power stations and army camps should be located away from the important *Rhododendron* habitats. Forest planners should take into consideration non-timber trees and shrubs like rhododendrons, that are of value to the locality in the aesthetic and economical upliftment of the people. Floricultural development using rhododendron plants would be far more appealing to the inherently nature-loving people. Rare, endangered and threatened species should be taken under *in vitro* research activities. Conservation efforts like a botanical garden or an arboretum where all the species should be under natural cultivation (e.g. Kew Botanical Garden), protected areas, sanctuaries, reserve forest, *in vitro* research procedures, etc. are essential. In the Eastern Himalaya, at North Eastern Regional Institute of Science and Technology (NERIST), we have started exploring rhododendrons and studies on

population level are underway. So far, 30 different *Rhododendron* species have been explored in different areas of West Kameng and Tawang districts, and herbarium specimens have been maintained. Out of these, 20 have been identified at the species level consulting relevant literature and herbaria, of which 4 are rare and 1 threatened (Table 3). The best way to implement the conservation plan is to solicit the cooperation of the local communities. Joint Forest Management, Social Forestry, Village Forest Management Community, Unclassed State Forest, Anchal Forests and Community Forest Management activities should focused on the conservation of rhododendrons in West Kameng and Tawang districts. In addition, economic activities such as squash preparation from *R. arboreum* flowers, incense making from *R. anthopogon*, and forest establishment could demonstrate to be social upliftment strategies towards sustainable development in Arunachal Pradesh.

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