Indian Journal of Ecology (2024) 51(6) (SI): 1424-1431
DOI: https://doi.org/10.55362/IJE/2024/4419

Manuscript Number: 4419
NAAS Rating: 5.38

Rhododendron arboreum Sm. in the Indian Himalayan region: Ecology, Uses Exploitation and Threats

Ravindra Singh, Neha Singh Panwar[1], Pravin Rawat[2*], Gaurav Chand Ramola and Santan Barthwal[1]

Doon Business School Global University, Dehradun-248 011, India
[1]ICFRE-Forest Research Institute, Dehradun-248 195, India
[2]ICFRE-Himalayan Forest Research Institute, Shimla-171 013, India
**E-mail: ravirawat2010@gmail.com*

Abstract**:** *Rhododendron arboreum* is one of the dominant species of the Indian Himalayan region. The species is well known for its beautiful flowers and ecological importance. The flowers of *R. arboreum* is used by the local people to make juice, jam, syrup, chutney, honey, squash, etc. But, increasing demand of its products and uncontrolled collection of flowers by local inhabitants for ethno-botanical purposes and fulfillment of their basic livelihood, the species is facing threat in its natural habitat. Additionally, reduced regeneration capability due to various ecological and anthropogenic factors has led to drastic reduction in natural population of *R. arboreum* in forest. Sustainable harvesting practices and community awareness can help balance human needs with ecological preservation ensuring the survival of this vulnerable species for future generations. Present review focuses on ecological behavior of the species, its socio-economic importance, regeneration, threats and an immediate conservation measure to combat it's over exploitation.

Keywords**:** Indian Himalayan region, Medicinal importance, Distribution, Exploitation and Conservation

The Indian Himalayas are one of the most diverse geo-climatic zones and biodiversity rich area. It is extended for more than 2400 km in length, and shows the tremendous variation in prevalent climatic conditions from subtropical to boreal forest type (Rawal et al 2018, White et al 2019). It covers 12 states of India of India from Jammu & Kashmir, Himachal Pradesh, Uttarakhand, West Bengal, Assam, Tripura, Mizoram, Manipur, Nagaland, Meghalaya and Arunachal Pradesh. Its forest cover is vital to maintain environment and ecological balance (Wani et al 2022) and provide numerous ecological and environmental services. Indian Himalayan Region is mostly dominated with different types of *Rhododendron*s species. The word *Rhododendron* originates from a Greek words 'rhodon' (rose) and 'dendron' (tree), which means rose tree (Iqbal and Negi 2017). *Rhododendron*s are dominant and primitive group of flowering plants belonging to family Ericaceae (Singh et al 2009, Menon et al 2012). Linnaeus was the first to name the genus, *Rhododendron* (Purohit 2014). There are about 1025 species in the world (Chamberlain et al 1996), among which 87 species, 12 subspecies and 8 varieties are recorded in Indian Himalayan Region (Basnett and Ganesan 2022). In Western Himalayas 6 species of *Rhododendron* are recorded as *viz Rododendron arboreum*, *R. anthopogon, R. barbatum, R. campanulatum*, *R. lepidotum* and *R. nivale* (Sekar and Srivastava 2010). *Rhododendron*s are either evergreen or deciduous, shrubs or trees, found mainly in Asia. They are widely distributed throughout the southern high-lands of Appalachian Mountains of North America (Paul et al 2010), extending across Europe, Asia to Japan, from extreme north of the Equator (Rawat et al 2017), southern and north-eastern China, Myanmar, Thailand, Malaysia, Indonesia, Philippines and New Guinea.

Habit and Habitat

R. arboreum is one of the splendid, valuable and impressive species of genus *Rhododendron*. The name arboreum comes from the Latin word arboreum, which is "tree-like" (Orwa et al 2009, Srivastava 2012). It is an evergreen shrub or small tree with beautiful red blossoms that is also known as Burans in India and Gurans in Nepal. The species holds a high socio-cultural veneration and has been entitled as the 'National flower' of Nepal (*de* Milleville 2002, Tewari et al 2018), 'State tree' of Uttarakhand and Sikkim and State flower of Nagaland (Srivastava 2012, Gaira et al 2014, Tewari et al 2018). The species is widely distributed from Western to Eastern Himalayan region and various other neighboring countries (Giriraj et al 2008). *R. arboreum* forests of Milke Danda in the eastern Nepal are possibly the largest *Rhododendron* forest in the world (de Milleville, 2002). It strives under the canopy of oak forests such as *Quercus leucotrichophora* and *Q. floribunda* forests in the low to mid hills and *Q. semecarpifolia* forests in the high hills (Chauhan 1999). *R. arboreum* holds the Guinness World Record for the World's largest *Rhododendron* species and is well-known for its therapeutic and commercial significance.

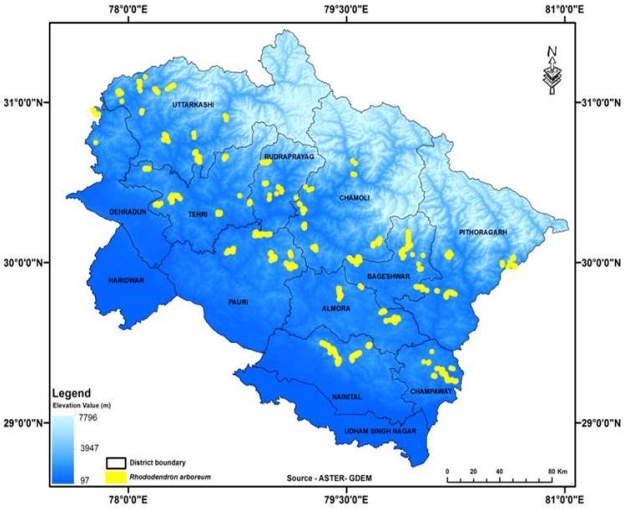
Indian Himalayan region provides an ideal habitat for *R.*

arboreum in India. The origin of discovery of the plant is north India from Kashmir to Bhutan, as well as in the hills of North-eastern states between 800-3000m amsl (Srivastava 2012). Forest type includes from subtropical and temperate to subalpine and alpine ecosystems in the range of 3000-3500m amsl (Bhattacharyya and Sanjappa 2008). The species also dwells in Bhutan, China, Myanmar, Nepal, Sri Lanka, Thailand, Pakistan and Tibet (Sekar and Srivastava 2010). *R. arboreum* has the widest elevation range in comparison to any other species in India (Naithani 1984). In Western Himalayas the species is found as an associated species of *Quercus*, *Myrica nagi*, *Neolitsea pallens*, *Alnus nepalensis*, *Viburnum mullaha*, and *Pinus roxburghii* (Negi et al 2013). This keystone species of Indian Himalayan region flourishes well in fair light, moist and acidic soils (Srivastava 2012). 12-17^{o}C of mean annual temperature and 200-1800m mean annual rainfall is favored by *R. arboreum* with well drained sandy and loamy soil along with light woodland (semi-shade) or no shade conditions (Orwa et al 2009). *R. arboreum* is distributed in 11 different district of Uttarakhand (Bhandari et al 2020, and Chauhan et al 2021) (Table 1 and Fig. 1).

Morphological Characteristics

The trunk of *R. arboreum* is often heavily branched (Fig. 2a), twisted, or gnarled (Orwa et al 2009) (Fig. 2b and c). Exfoliating in thin flakes, the bark is reddish brown, soft, and rough (Chauhan, 1999). The oblong-lanceolate leaves are 10-20 cm long and 3.6 cm broad. When young, the petiole is covered in white scales and crowded towards the ends of branches (Orwa et al 2009). It has shiny green with strongly imprinted veins from above, while the underside is cinnamon or reddish brown. *R. arboreum* has a wide range of flower colours, from deep scarlet to red with white lines, pink to white. When in full bloom, the species can have up to twenty flowers on a single truss, making it a magnificent spectacle. The vivid red variants of this *Rhododendron* are often found at lower elevations. The flowers are bright red and arranged in thick globose cymes (Chauhan 1999) (Fig. 3, 4). Filaments filiform, anthers-ovate, style-capitate, calyx-fine cleft, corolla-tube spotted funnel shaped, stamens-hypogynous decreasing, anthers-ovate (Paxton 1849). Fine lobes form the capsule-curved centre, which can be up to 3.8 cm long and 1.25 cm. Seeds are small, dark brown, compressed, thin, and linear, with an obvolute membrane (Orwa et al 2009).

Floral biology and phenology of *R. arboreum:* The genus *Rhododendron* has two distinct flowering seasons depending upon the altitudinal gradient, ranging from the month of February to April in the lower altitude and May to



Source: Bhandari et al 2020

Fig. 1. Distribution map of *R. arboreum* in Uttarakhand

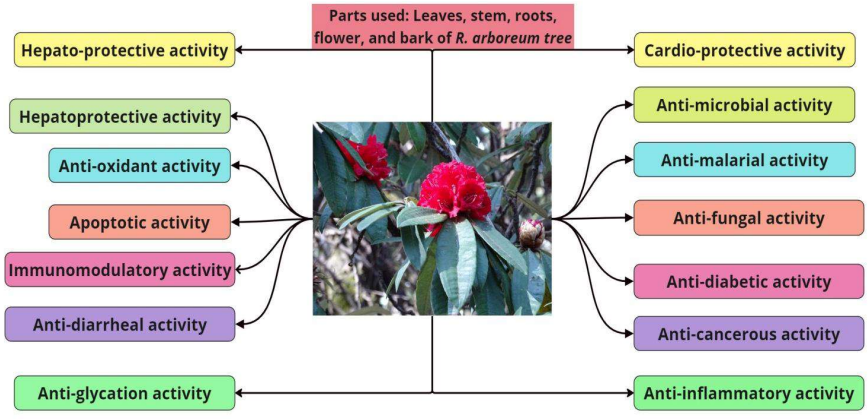
Table 1. Distribution of *Rhododendron arboreum* in Uttarakhand

District	Places of distribution	References
Almora	Ranikhet, Manila, Kosi katarmal, Almora, Dunagiri, Binsar	Bhandari et al (2020)
Bageshwar	Dharamghar, Kaushani (Border), Laubanj, Kapkot	Bhandari et al (2020)
Chamoli	Nandasain, Nauti, Mohankhal, Gairsain, Gwaldam,	Chauhan et al (2021), Bhandari et al (2020)
Champawat	Chirapani, Siutal,	Bhandari et al (2020)
Dehradun	Mussoorie, Chakrata, Deoban, Tiuni, Nagtibba	Bhandari et al (2020)
Nainital	Kalona, Manora/ Takula, Tippen Top, Pangot, Vinayak, Bhanwali, Maheshkhan, Mukteswar	Bhandari et al (2020)
Pauri Garhwal	Phadkhal, Khirsu, Dhdhatoli, Peethsen, Chorikhal, Adwani,	Chauhan et al (2021), Bhandari et al (2020)
Pithoragarh	Munsiyari, Didihat, Pithoragarh, Kunj kharak, Sandev,	Bhandari et al (2020)
Rudraprayag	Khadpatiya, Ghimtoli, Chopta, Badhanital,	Chauhan et al (2021), Bhandari et al (2020)
Tehri Garhwal	Jhadipani, Ranichauri, Dhanauti, Chamba, Chirbatiya, Chandrabadani temple, Narendra nagar,	Chauhan et al (2021), Bhandari et al (2020)
Uttarkashi	Radi top, Dharsu, Bhokki & Sukki top, Jarmola top, Chaurangi khal, Ghes	Bhandari et al (2020)

June at higher altitudes (Ziello et al 2009). *R. arboreum* first flowering occurs in March-May while second time flowering takes place in June-July. Sometime, early flowering may also take place in January and February (Iqbal and Negi 2017) which brings the scientific attention to study the phenology and reproductive behavior of this species. *Rhododendron* inflorescence varies from three to more than twenty blooms (Bhattacharyya 2011). Racemes or corymbs yield few to clusters of flowers reduced to one and in a variety of colors, typically with a contrasting throat blotch or spot (Mao et al 2001, Bhattacharyya 2011). In general *Rhododendron* flowers are bell-shaped, tubular, funnel-shaped, or saucer-shaped. Each flower has spots and blotches on it, and the inflorescence is usually a cluster of 20-25 flowers. Spots and blotches can be observed on the inner surfaces of the petals, and blotches can be seen at the base of the petals (de Milleville 2002). The hermaphrodite flowers are insect-pollinated (Orwa et al 2009). Leaves appear to be small, ranging from 10 to 20 cm on an average (Kondratovics and Kondratovics 2017). Visitors are drawn to the aesthetic splendor of fully developed flowers of *R. arboreum* throughout its blossoming time (Srivastava, 2012). During the summer (March to June), they mostly flower and provide an aesthetic look with a variety of enchanting colours of petals, including red (Mao et al 2001, Bhattacharyya 2011).

Fig. 2. *Rhododendron arboreum* plant parts: a) Tree, b) Flowers on branches, c) Flower

Regeneration status of *R. arboreum:* *Rhododendron* in Himalayan region is already facing serious issues of natural regeneration.Germination is a complicated process influenced by a variety of biological (species, seed viability, seed dormancy, seed size) and environmental factors (moisture availability, temperature, relative humidity, light intensity and duration) (Singh et al 2010). *Rhododendron* can be propagated through seed, stem cuttings, layering, grafting (Wells, 1985), micro-propagation (tissue culture) (Anderson, 1984), and even leaf bud cuttings (Blazich et al 1991, Hartmann et al 2002). Since *R. arboreum* is a naturally regenerating species, the forest floor is where 95% of its regeneration occurs. The forest floor is usually susceptible during the flower-harvesting season, and a great deal of regrowth is lost during this time leading to decline rates of regeneration (Chauhan et al 2021). *R. arboreum* show signs



(Srivastava 2012, Kaur et al 2023)

Fig. 3. Medicinal properties of *R. arboreum*

of J-shaped distribution where density of saplings are found to be very less than that of seedlings and adult trees. Density of the tree is found to be decreased with increasing girth (Paul et al 2019). Additionally, with the growth of seedlings, decrease in resource availability as seedlings get larger, the transition of producing tissues to structural tissues, the self-shedding of leaves, and various other related processes cause the ratio of relative growth of the species to decrease (Iqbal et al 2023). It is therefore clear that *R. arboreum* is vulnerable and is facing poor regeneration issues along with anthropogenic pressure. Thus, study of seed germination is of utmost importance for conservation.

Utilization and socio-economic values of *R. arboreum:* *R. arboreum* is mostly used by local inhabitants in the Indian Himalayan Region for ethno-botanical purposes and fulfillment of their basic livelihood (Menon et al 2012) and also used as a medication to treat diarrhoea, dysentery and dyspepsia. Consumption of dried flowers of *Rhododendron* after frying in ghee can even help in checking dysentery. Young leaves of *Rhododendron*s are very good astringent and poultice. Their fine paste can be applied to forehead to mitigate severe headaches. Coughs, diarrhoea, and dysentery are all treated with the bark's juice. The flower's petals are also consumed to aid in the removal of any animal bone that has lodged in the throat (Srivastava, 2012). The sweet and sour blooms of *R. arboreum* are used in the making of squash, jams, jellies, and local beer in hilly areas. It is a popular and enjoyable drink that is consumed once a day as a refreshing appetiser and also to prevent high altitude sickness. Chutney is made using freshly picked petals (paste). To get rid of bed lice, the leaves' juice is sprayed on cots and beds. Its wood is used in making charcoal and fuel. 'Khukri' (knife) handles, packsaddles, gift-boxes, gunstocks, and posts are all made from the grained wood of *R. arboreum* (Paul et al 2005).

Medicinal properties of *R. arboreum:* *R. arboreum* is a species of the genus *Rhododendron* that is significant for its aesthetic, medicinal, and economic qualities. The tree's bark, leaves, and flowers all have significant therapeutic benefit (Swamidasan et al 2020). Numerous secondary metabolites, including alkaloids, flavonoids, glycosides, saponins, tannins, steroids, and phlobatannins, are present in significant amounts in the plant (Srivastava 2012 and Swamidasan et al 2020). This plant possesses anti-malarial, anti-microbial, anti-oxidant, immunomodulatory, ant-diabetic, anti-inflammatory, anti-diahhreal, and anti-fungal properties in its leaf, flower, and bark extracts (Verma et al 2010, Srivastava 2012, Sonar et al 2013, Swamidasan et al 2020) (Fig. 3). The species is overexploited and is under a lot of anthropogenic strain due to its great medicinal and aesthetic properties.

Threats to *R. arboreum:* Edible flowers that are used for making syrups and beverages, and being an excellent fire wood that burns early under damped conditions due to presence of polyphenols and flavonoids make *R. arboreum* a very vulnerable species (Sekar and Srivastava 2010). This has

Table 2. Medicinal properties of *R. arboreum*

Medicinal properties of *R. arboreum*	Plant parts used	References
Anti-microbial activity	Flower, leaves, bark,	Verma et al 2011, Srivastava 2012, Saklani and Chandra 2015, Chauhan et al, 2016, Iqbal and Negi 2017, Lal et al 2017, Kashyap et al 2017 Kaur et al 2023
Anti-diabetic activity	Flower, stem, root,	Bhandary and Kawabata 2008, Srivastava 2012, Raza et al 2015, Prakssh et al 2016, Gautam and Chaudhary 2020, Kaur et al 2023
Anti-inflammatory activity	Flower, leaves, bark, roots,	Verma et al 2011, Srivastava 2012, Nisar 2016, Swamidasan et al 2020, Kaur et al 2023
Anti-malarial activity	Flower	Verma et al 2011, Srivastava 2012, Kaur et al 2023
Anti-diarrheal activity	Flower	Srivastava 2012, Prakssh et al 2016, Kaur et al 2023
Anti- fungal activity	Flower, leaves,	Nisar 2013, Srivastava 2012, Kaur et al 2023
Hepato-protective activity	Flower, leaves,	Prakash 2007, Verma et al 2011, Srivastava 2012, Kaur et al 2023
Anti-oxidant activity	Flower, leaves, bark,	Anpin et al 2010, Prakssh et al 2016, Kashyap et al 2017, Gautam et al 2020, Kaur et al 2023
Apoptogenic activity	Flower, leaves,	Kashyap et al 2017, Gautam et al 2020, Kaur et al 2023
Immunomodulatory activity	Flower, leaves,	Srivastava 2012, Rawat et al 2018, Kaur et al 2023
Anticancer activity	Flower, leaves, roots, bark, stem	Srivastava 2012,Gautam et al 2018, Gautam and Chaudhary 2020, Kaur et al 2023
Cardio-protective activity	Leaves, stem, roots	Manjunatha et al 2011, Nisar et al 2011, Srivastava 2012, Cheng et al 2017, Parcha et al 2017, Kaur et al 2023
Anti-glycation	Flower	Verma et al 2011, Raza et al 2015, Prakssh et al 2016

already led to scarcity of few species and few are at the verge of extinction. Therefore, conservation of *Rhododendron*s by means of *in situ* and *ex situ* conservation strategies is the need of hour. *R. arboreum* is a wild plant species with considerable ecological importance and its flowers have a unique therapeutic and nutritional value. The flowers are edible and are used to make a pleasant drink in the Central Himalayan mountain region. Despite its high medicinal value and enormous bioprospecting potential, the species has received little attention in the western Himalayas for conservation and management (Negi et al 2013). The Central Himalaya, notably Uttarakhand, is a major religious and tourist destination, with millions of pilgrims and visitors passing through each year (Maikhuri et al 2004), resulting in a significant market demand for the commodity. However, unemployment is a major issue in Uttarakhand right now. There are very little opportunities available for young people, both educated and uneducated in the public sector. The fear of unemployment somehow reduced significantly when few unemployed of the region immersed themselves in the preparation of high-quality wild food items (Negi et al 2011). As *R. arboreum* grows abundantly in the wild and requires no further inputs other than gathering the flowers, the total output and net return for its products are extremely high. Many businesses have linked this venture to eco-tourism and have reaped significant financial rewards by marketing their products during the peak tourist season. Collecting such wild edibles and related value added goods which have high long-term prospects as a source of income for the locals increases the risk of exploitation of the species leading to its extinction. The climate change is also showing adverse effect on *Rhododendron*s. Gaira et al (2014) investigated the effects of climate change on *R. arboreum* flowering in India's Central Himalayas. Studies from all across the world have produced evidence of the effects of climate change on phenology and species persistence. However, for the vast majority of locations and species, including the climate-sensitive Himalayan biodiversity hotspot, datasets or evidence is unavailable.

Deforestation and unsustainable extraction for firewood and incense by local people are the two biggest risks to *Rhododendron*s. If suitable conservation efforts are not taken, time is not so far for a group of rare/endangered *Rhododendron*s to be wiped out from the biota in near future (Singh et al 2003, 2009, Bhandari et al 2020). Climate change has a major impact in occurrence of *R. arboreum* position. Its habitat has been directly suffered with change in altitudes, elevations of 11m as per the evidence. Additionally, rise in temperature has also lead to early blooming of flowers and foliar damage (Ranjitkar et al 2014, Joshi et al 2024, Veera et al 2019, 2023). This shift in temperature and altitude is a major threat to survival and distribution of *R. arboreum*. Veera et al (2023) has thrown light on this elevation shift which is an issue to be highlighted as even if the elevation has rose, the species survival is in danger beyond 3500m amsl.

Aforesaid description and review elaborated the use of *Rhododendron* as one of the primitive and widely distributed plant genera in the mountains. Inspite of such multifarious uses of *Rhododendron*, the genus remained one of the most ignored groups of plants when comes to scientific enquiry. Among *Rhododendron, R. arboreum* and its varied subspecies are majorly concentrated from Western to Eastern Himalayas within the Indian Himalayan Region (IHR). About 90 per cent population of the species is found in this region. This wide distribution is possible only because of the species' endurance to tolerate extreme temperature range and to grow in diverse habitats. Combination of light and small seeds of *R. arboreum* privileges the species to strongly get disseminated by wind and animals, perhaps leading to long dispersal and wider degree of adaptation and distribution. Such pollen dispersal capability of the species shapes its spatial genetic structure and hence estimates the extent of gene flow between individuals and populations (Hahn et al 2016). The degree of gene flow can be influenced by deciding whether an individual is either out crossing or self crossing, often called as mating system patterns of the population (Whitehead et al 2018). Although distribution patterns and regeneration status of *R. arboreum* has been studied by various researchers in the past, but seed germination and survivability of the seedlings has not been studied in much detail. Moreover, mating system analysis and gene flow of the species remained untouched which will greatly help in its conservation and related breeding programme.

It is reported that natural populations of *R. arboreum* in the Himalayas are steadily dwindling due to human influences and anthropogenic disturbances associated with deforestation, unsustainable extraction, over-exploitation and agricultural practices. All these activities have collectively put pressure on *Rhododendron* forests and many of its species have now become endangered, rare, or threatened (Singh et al 2003). Due to high economic, medicinal value and high ecological significance *R. arboreum* species is overexploited by local inhabitant in the Himalayas. Therefore, urgent needs of conservation strategies are in demand to restore *Rhododendron* populations in the wild. Time is not so far when human land use patterns and climate change will put negative pressure on *R. arboreum* diversity and distribution (Sala et al 2000). Singh et al (2009) surveyed the problem of deforestation and unsustainable firewood and incense extraction by local

people and focused on incorporating biotechnological and traditional ways to combat the threat to the existence of these plants. Major approach was to identify ways to conserve *Rhododendron* populations in the wild by mass propagating them *in vitro* and *ex situ* and restoring them in the wild. It was therefore concluded that thorough understanding of the protocols is required to conserve and monitor natural populations of *Rhododendron*s including *R. arboreum*. Furthermore, government has initiated strategies to conserve floral diversity of *R. arboreum* by only using 60% of the flowers from a tree which will help in sustainable management of the species for regeneration naturally as the remaining bloom will mature into seeds. However, lack of this knowledge to local communities, NTFP collectors and distributors has created an issue of over-exploitation (Negi et al 2013). Therefore, more awareness programs and capacity building involving Van Panchayats, gram sabhas and NGOs is a major necessity to educate locals.

CONCLUSION

The review highlights *Rhododendron* as a vital yet scientifically neglected genus in the mountains, particularly *R. arboreum*, which thrives in the Indian Himalayan Region (IHR). Despite its wide distribution due to adaptability and effective seed dispersal, studies on its seed germination and mating system remain limited. Human activities and climate change threaten its populations, necessitating urgent conservation strategies. Efforts should include *in vitro* and *ex situ* propagation, sustainable management, and education for local communities to prevent over-exploitation. Government initiatives and awareness programs are crucial for conserving the ecological and economic value of the species.

REFERENCES

Anderson WC 1984. A revised tissue culture medium for shoot multiplication of *Rhododendron*. *Journal of the American Society for Horticultural Science* **109**(3): 343-347.

Anpin, Raja RD, Prakash JW and Jeeva S 2010. *Antibacterial activity of some medicinal plants used by Kani tribe, Southern Western Ghats, Tamilnadu, India*. In: Trivedi, P.C. (Ed.), Ethnic Tribes and Medicinal Plants. Jaipur: *Pointer Publishers:* 28-45.

Bertiller MB, Irrisarri, MP and Ares JO 1990. Phenology of *Festuca pallescens* in relation to topography in north-western Patagonia. *Journal of Vegetation Science* **1**(5): 579-584

Bhandari MS, Meena RK, Shankhwar R, Shekhar C, Saxena J, Kant R, Pandey VV, Barthwal S, Pandey S, Chandra G and Ginwal HS 2020. Prediction mapping through maxent modeling paves the way for the conservation of *Rhododendron arboreum* in Uttarakhand Himalayas. *Journal of the Indian Society of Remote Sensing* **48**(3): 411-422.

Bhattacharyya D 2011. *Rhododendron* species and their uses with special reference to Himalayas: A review. *Assam University Journal of Science and Technology* **7**(1): 161-167.

Bhattacharyya D and Sanjappa M 2008. *Rhododendron* habitats in India. *Journal of American Rhododendron* Society **62**: 14-8.

Blazich FA, Warren SL, Acedo JR and Reece WM 1991. Seed germination of *Rhododendron catawbiense* and *Rhododendron maximum*: Influence of light and temperature. *Journal of Environmental Horticulture* **9**(1): 5-8.

Chamberlain DF, Hyam R, Argent G, Fairweather,G and Walter KS 1996. *The genus Rhododendron: Its classification and synonymy*. *Royal Botanic Garden*, Edinburgh, p. 181.

Chauhan NS 1999. *Medicinal and aromatic plants of Himachal Pradesh*. *Indus Publishing Company*, New Delhi. p 353.

Chauhan P, Singh J, Sharma RK and Easwari TS 2016. Anti-bacterial activity of Rhododendron arboreum plant against *Staphylococcus aureus. Annals of Horticulture* **9**(1): 92-96.

Chauhan DS, Lal P and Shrama AK 2021. Extraction of *Rhododendron arboreum* Smith flowers from the forest for the livelihood and rural income in Garhwal Himalaya, India. *Science Report* **11:** 20844.

Cheng X, Zhang J and Chen Z 2017. Effects of total flavones from *Rhododendron simsi* plant flower on postischemic-cardiac dysfunction and cardiac remodeling in rats. Evidence-Based Comp. and Alter. Med., doi: 10.1155/2017/5389272. Epub 2017 Jun 8. PMID: 28684968; PMCID: PMC5480058.

de Milleville R 2002. *The Rhododendron of Nepal.* Himal Books, Katmandu, Nepal. p 136.

Gaira KS, Rawal RS, Rawat B and Bhatt ID 2014. Impact of climate change on the flowering of *Rhododendron arboreum* in central Himalaya, India. *Current Science* **106**(12): 1735-1738.

Gautam S and Chaudhary K 2020. Evaluation of anti-diabetic and antihyperlipidemic activity of *Rhododendron arboreum* bark extract against streptozocin induced diabetes in rats. *Journal of Medicinal Herbs and Ethnomedicine* **6:** 11-16.

Gautam V, Kohli S, Arora S, Bhardwaj R, Kazi M, Ahmad A and Ahmad P 2018. Antioxidant and antimutagenic activities of different fractions from the leaves of *Rhododendron arboreum* Sm. and their GC-MS profiling. *Molecules* **23**(9): 2239.

Giriraj A, Irfan-Ullah M, Ramesh BR, Karunakaran PV, Jentsch A and Murthy MSR 2008. Mapping the potential distribution of *Rhododendron arboreum* Sm. ssp. *Nilagiricum (*Zenker) Tagg (Ericaceae), an endemic plant using ecological niche modelling. *Current Science* **94**(12): 1605-1612.

Hahn CZ, Michalski SG and Durka W 2016. Gene flow, and mating system of, *Rhododendron* simsii in a nature reserve in subtropical China. *Nordic Journal of Botany* **35**(1): 1-7.

Hartmann HT Kester DE, Davies FT and Geneve RL 2002. *Hartmann and Kester's Plant Propagation: Principles and Practice*, 7th edn. Prentice Hall, Upper Saddle River, New Jersey.

Hora B 1981. *The Oxford Encyclopedia of Trees of the World*. Oxford University Press. Conscent Books, New York, USA: p. 288.

Iqbal K and Negi AK 2017. *Rhododendron* in Uttarakhand: Diversity and conservation. *International Journal of Environment* **6**(1): 31-45.

Iqbal K, Negi AK, Pala NA and Todaria NP 2023. Seedling Recruitment of Rhododendron arboreum: An important NTFP species of North-Western Himalaya, *India*. *Ecological Questions* **34**(3): 1-19.

Joshi RK, Gupta R, Mishra A and Garkoti SC 2024. Seasonal variations of leaf ecophysiological traits and strategies of co-occurring evergreen and deciduous trees in white oak forest in the central Himalaya. *Environmental Monitoring and Assessment* **196**(7): 634.

Kashyap P, Anand S and Thakur A 2017. Evaluation of antioxidant and antimicrobial activity of *Rhododendron arboreum* flowers extract. International Journal of Food Fermentation Technology **7**(1): 123-128.

Kondratovičs R and Kondratovičs U 2017. Introduction and breeding of *Rhododendron* in Latvia. In *Proceedings of the Latvian Academy of Sciences* **71**(3): 248.

Lal, K Ahuja, V and Rajeshwer AKB 2017. In vitro study of antimicrobial activity of *Rhododendron arboreum* plant extract on selected pathogenic bacterial isolates. *Life Science International Research Journal* **4**(1): 64-67.

Maikhuri RK, Rao KS and Saxena KG 2004. Bioprospecting of wild edibles for rural development in the central Himalayan mountain of India. *Mountain Research and Development* **24**(2): 110-113.

Manjunatha P, Mudagal, Karia S and Goli D 2011. Preventive effect of *Rhododendron arboreum* on cardiac markers, lipid peroxides and antioxidants in normal and isoproterenol-induced myocardial necrosis in rats. *African Journal of Pharmacy and Phramacology* **5**(6): 755-763.

Mao AA, Singh KP and Hajra PK 2001. In Floristic Diversity and Conservation Strategies in India (Eds. N P Singh and D K Singh), *Botanical Survey of India, Kolkata,* IV: p 2167-2202.

Menon S, Khan ML, Paul A and Peterson AT 2012. *Rhododendron* species in the Indian Eastern Himalayas: New approaches to understanding rare plant species distributions. *Journal American Rhododendron Society*: 78-84.

Naithani BD 1984. *Flora of Chamoli*. Botanical Survey of India, Dehradun. 800.

Negi VS, Maikhuri KR, Rawat LS and Chandra A 2013 Bio respecting of *Rhododendron arboreum* for livelihood Enhancement in Central Himalaya, India. Environment and We *International Journal of Science and Technology* **8:** 61-70.

Negi VS, Maikhuri RK and Rawat LS 2011. Non-timber forest products (NTFPs): A viable option for biodiversity conservation and livelihood enhancement in central Himalaya. *Biodiversity Conservation* **20**(3): 545-559.

Nisar M, Ali S and Qaisar M 2011. Preliminary phytochemical screening of flowers, leaves, barks, stem and roots of *Rhododendron arboreum*. *Middle East Journal of Science Research* **10**: 472-476.

Nisar M, Ali S, Muhammad N, Gillani SN, Shah MR, Khan H and Maione F 2016. Antinociceptive and anti-inflammatory potential of *Rhododendron arboreum* bark. *Toxicology and Industrial Health* **32**(7): 1254-1259.

Nisar M, Ali S, Qaisar M, Gilani S N, Shah MR, Khan I and Ali G 2013. Antifungal activity of bioactive constituents and bark extracts of *Rhododendron arboreum*. *Bangla Journal of Pharma* **8**(2): 218-222.

Orwa C, Mutua A, Kindt R, Jamnadass R and Simons A 2009. Agroforest tree Database: A tree reference and selection guide version 4.0 available at (http://www.worldagroforestry. org/af/treedb/)

Parcha V, Yadav N, Sati A, Dobhal Y and Sethi N 2017. Cardioprotective effect of various extract of *Rhododendron arboreum* Sm. flower on Albino rats. Journal of Phargnosy. and Phytochemistry **6**(4): 703-1707.

Paul A, Das AK and Khan LM 2010. Utilisation of *Rhododendron* by Monpas in western Arunachal Pradesh, India. Journal American *Rhododendron* Society: 81-84.

Paul A, Khan ML and Das AK 2019. Population structure and regeneration status of *rhododendrons* in temperate mixed broad-leaved forests of western Arunachal Pradesh, *India. Geology, Ecology, and Landscapes* **3**(3): 168-186.

Paul A, Khan ML, Arunachalam A and Arunachalam K 2005. Biodiversity and Conservation of *Rhododendron* in Arunachal Pradesh in the Indo-Burma Biodiversity Hotspot. *Current Science* **89**(4): 623-634.

Paxton J (Ed.) 1849. *Paxton's Magazine of Botany, and Register of Flowering Plants*. Beadbury and Evans, London (16): 376.

Purohit CS 2014. *Rhododendron arboreum* Sm. – *An economically important tree of Sikkim*. Popular Kheti 2: 193-198.

Rai T and Rai L 1994. Trees of the Sikkim Himalaya. Indus publishing, New Delhi.

Ranjitkar S, Kindt R, Sujakhu NM, Hart R, Guo, W, Yang X, Shrestha KK, Xu J and Luedeling E 2014. Separation of the bioclimatic spaces of Himalayan tree *Rhododendron* species predicted by ensemble suitability models. *Global Ecology and Conservation*, 1: p.2-12.

Raza R, Ilyas Z, Ali S, Nisar M, Khokhar YM and Iqbal J 2015. Identification of highly potent and selective beta-glucosidase inhibitors with antiglycation potential isolated from *Rhododendron arboreum*. *Records of National Products* **9**(2): 262-266.

Rawat P, Rai N, Kumar N and Bachheti RK 2018. Review on *R. arboreum*- a magical tree. *Oriental Pharmacy and Experimental Medicine* **17**: 297-308.

Rawat P, Bachheti RK, Kumar N and Rai N 2018. Phytochemical analysis and evaluation of in vitro immunomodulatory activity of *Rhododendron arboreum* leaves. *Asian Journal of Pharmaceutical and Clinical Research* **11**(8): 123-128.

Saklani S and Chandra S 2015. Evaluation of in-vitro antimicrobial activity, nutritional profile and phytochemical screening of *Rhododendron arboreum*. *World Journal Pharm Pharma. Science* 962- 971.

Sala OE, Stuart Chapin FIII, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M and Wall DH 2000. Global biodiversity scenarios for the year 2100. *Science* **287**(5459): 1770-1774.

Sansevero JBB and Garbin ML 2015. *Restoration success of tropical forests: the search for indicators. In Sustainability indicators in practice*, Warsaw: De Gruyter Open: p 146-159

Sekar KC and Srivastava SK 2010. *Rhododendron* in Indian Himalayan regions: diversity and conservation. *American Journal of Plant Sciences* **1**(02): 131- 137.

Singh KK, Rai LK and Gurung B 2009. Conservation of *Rhododendron* in Sikkim Himalaya: an overview. *World Journal of Agricultural Sciences* **5**(3): 284-296.

Singh KK, Gurung B, Rai LK and Nepal LH 2010. The influence of temperature light and pre-treatment on the seed germination of critically endangered Sikkim Himalayan *Rhododendron* (R. *niveum* Hook F.). *Journal of American Science* **6**(8): 172- 177.

Singh KK, Kumar S, Rai LK and Krishna AP 2003. *Rhododendron* conservation in Sikkim Himalaya. *Current Science* **85**(5): 602-606.

Singh KK, Rai LK and Gurung B 2009. Conservation of *Rhododendron* in Sikkim Himalaya: an overview. *World Journal of Agricultural Sciences* **5**(3): 284-296.

Sonar PK, Singh R, Verma A and Saraf 2013. *Rhododendron arboreum* (Ericaceae): Immunomodulatory and related toxicity studies, *Oriental Pharmacy and Experimental Medicine* **13**(2).

Srivastava P 2012. *Rhododendron* arboreum: An overview. *Journal of Applied Pharmaceutical Science* **2**(1): 158-162.

Swamidasan R, Sanil R and Manasa R. 2020. Medicinal values of *Rhododendron arboreum*: A comprehensive review. *International Journal of Science Research* **9**: 1768-1771.

Tewari D, Sah AN and Bawari S 2018. Pharmacognostical evaluation of *Rhododendron arboreum* Sm. from Uttarakhand. *Pharmacognosy Journal* **10**(3): 527-532.

Veera SN, Panda RM, Behera MD, Goel S, Roy PS and Barik SK 2019. Prediction of upslope movement of Rhododendron *arboreum* in Western Himalaya. *Tropical Ecology:* p.1-7.

Verma N, Amresh G, Sahu PK and Mishra N 2011. Protective effect of ethyl acetate fraction of *Rhododendron arboreum* flowers against carbon tetrachloride-induced hepatotoxicity in experimental *models. Indian Journal Pharmacol* **43:** 291-299.

Verma N, Singh AP, Amresh G, Sahu PK and Rao Ch V 2010. Anti-inflammatory and antinociceptive activity of *Rhododendron arboreum. Journal of Pharmacy Research*, **3**(6): 1376-1380

Wani SA, Ahmad R, Gulzar R, Rashid I, Malik AH and Khuroo AA

2022. Diversity distribution and drivers of alien flora in the Indian Himalayan region. *Global Ecology and Conservation* **38:** e02246

Wells JS 1985. *Plant propagation practices*. American Nurseryman Publishing, Chicago, p 367.

White JC, Saarinen N, Wulder MA, Kankare V, Hermosilla T, Coops NC and Vastaranta M 2019. Assessing spectral measures of post-harvest forest recovery with field plot data. *International Journal of Applied Earth Observation and Geoinformation* **80:** 102-114

Received 11 August, 2024; Accepted 22 November, 2024

Whitehead MR, Lanfear R, Mitchell RJ and Karron JD 2018. Plant mating systems often vary widely among populations. *Frontiers in Ecology and Evolution* **6:** 38.

Yang X, Yan D and Liu C 2014. Natural regeneration of trees in three types of afforested stands in the Taihang Mountains, China. *PLoS ONE* **9**(9): e108744.

Ziello C, Estrella N, Kostova M, Koch E and Menzel A 2009. Influence of altitude on phenology of selected plant species in the Alpine region (1971–2000). *Climate Research* **39**(3): 227-234.