

Regeneration Status of *Quercus lanata* (Syn. *Q. lanuginosa*) in Central Himalayan Forests

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Abstract

Oaks of the Himalayan region are at risk due to relentless anthropogenic pressure and climate change. This study was undertaken to assess regeneration status of *Quercus lanata* (*Q. lanuginosa*) dominated forests in the Kumaun region of Indian Himalaya. *Q. lanata* has restricted distribution and forms small patches of a few hectares between 1800 and 2400 m elevation. The study was conducted across two forest sites, located in Nainital and Pithoragarh districts, between the elevation ranging 1950 and 2200 m. Present research attempts to evaluate regeneration status of *Q. lanata* at selected sites in Kumaun Himalaya. Across both sites, total tree density varied between 665 and 1115 ind ha⁻¹, and density of *Q. lanata* ranged between 525 and 560 ind ha⁻¹, and total basal area was between 36.96 and 40.52 m² ha⁻¹. Seedling density of *Q. lanata* varied between 80 and 455 ind ha⁻¹ across both sites. Across the study sites, the sapling density was low. The results indicate that *Q. lanata* showed fair recruitment of seedling however the conversion of seedling into saplings is poor. This study emphasizes the requirement for targeted conservation efforts to sustain the biodiversity and ecological balance of the *Q. lanata* Forests.



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Introduction

Oak forests are considered as a keystone species and inhabit an area around 20,000km in Central Himalaya.¹ Himalaya is one of the most fragile ecosystems in the world because of its diverse, rough, rugged and undulating topographical features.^{2,3} In the Himalayan Forest, there have been numerous documented alterations in composition, density,

structure, and regeneration patterns attributable to various biotic pressures. The area exhibits a range of climates, from subtropical to alpine, sustaining a broad range of plant and animal life. This climatic diversity, coupled with the varying elevations in the region, results in a unique and rich ecological environment.

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Genus *Quercus* is native to northern hemisphere and encompasses deciduous and evergreen species, exhibiting range of latitudes from cool temperate to tropical. Majority of oak species are found on continents of Asia, Europe, America, and North Africa. Oaks in the Himalayan region significantly contribute to soil and water conservation, biodiversity maintenance, sustainability, and other ecosystem services.⁴ Oaks perform vital part in Indian Himalayas, serving as key sources of agricultural tools, fuelwood, fodder, charcoal, and materials for making beehive boxes. During dry or lean seasons, oak leaves are commonly used as livestock fodder and also as bedding material for animals.⁵ Additionally, oaks facilitate the replenishment of mountain springs.⁶

In Indian Himalayan region, moist temperate forests are dominated by oaks (*Quercus spp.*), which are climax tree species. Around 35 species of *Quercus* are widely distributed between 1000 to 3500m elevations.⁷ In Uttarakhand, there are five species of oaks, with the exception of *Q. glauca* and *Q. lanata*, all other oak species have widespread distribution and collectively constitute extensive regions in Himalaya.⁸ The anthropogenic pressure on oak forest are high as people depend on their daily needs of fuelwood and fodder on these oaks or the region. *Q. lanata* (rianj) is a large evergreen tree and is usually low branched. It is an oak native to Northern Thailand, China, and Vietnam, where it grows at altitudes between 800 & 2600m In the hills of India, it is found at elevations ranging from 1800 to 2400m.⁹ It occurs in small patches in the Garhwal and Kumaun Himalaya. It has been associated with *Rhododendron arboreum* and *Q. leucotrichophora* at its lower limit and with *Q. floribunda* towards upper limit respectively.⁷ Very few studies on regeneration and seed ecology for *Q. lanata*.

The phytosociological information of a particular tree species helps to better understand their ecology, habit, habitat, vegetational structure, and how they are inter-connected.^{10,11} The basic goal of the forest ecologist is to understand the dynamics of landscape ecosystems, their structure and functions.¹²

The composition and dynamics of forest communities are intricately shaped by the ecological attributes of their surroundings, encompassing factors such as the features of the environment, the variety and abundance of species, the overall diversity, the

spatial distribution of organisms, and regeneration status of species.^{13,14} Community structure is directly influenced by population structure, fundamental component of community. Consequently, development trend of community is clearly evident.

Regeneration is an essential component of forest management, as it is predictable by the structure of the population and ensures the desired species composition and replenishment. Successful regeneration of forest species is indicated by the population structure, which is defined by presence of adequate populations of saplings, seedlings, and young trees.¹⁵ The regeneration profile of a plant species' seedlings, saplings, and trees might be utilised to ascertain its possibilities for regeneration via the patterns of population dynamics.¹⁶

Himalayan forests are experiencing a variety of changes in their structure, density, composition, regeneration as a result of progressive biotic pressures that have been induced by uncontrolled lopping and harvesting of trees for fodder, fuel, and grazing.^{17,18}

Dynamics of forest communities are significantly influenced by these biotic pressures, which also regulate¹⁹ regenerative capacity of a species. Vigour and rate of seed production of trees are reduced as a result of biotic interference, particularly the lopping of trees, which ultimately affects their regeneration status. A comprehensive understanding of forest dynamics is essential for conserving plant diversity.²⁰ Earlier studies have indicated that *Quercus lanata* is found in scattered patches, often forming populations with individuals of varying sizes and ages, reflecting an uneven-aged structure with some large-sized trees. However, there is a need for updated and detailed information on its diversity status and population structure. Understanding the natural variation within populations is essential, as it supports species' ability to adapt, survive, and evolve over time. This becomes especially important for a species with significant ecological and economic value. If the current rate of decline continues, the species may face serious threats in the future. Key environmental factors encompassing soil characteristics, altitude, and seasonal rainfall—particularly during warmest, driest, and coldest quarters—as well as slope, have a strong influence on distribution of *Q. lanata* in Kumaun region.

Present research focuses on evaluating forest composition, regeneration patterns, and population structure of *Q. lanata*. As *Q. lanata* is restricted to small patches, the study is significant to assess the future species composition in these forests.

Materials and Methods

Study area

The Indian Himalayan Region encompasses two mega-floristic zones: Garhwal and Kumaon. Uttarakhand Himalaya is one of them. The study area is situated in Nainital and Pithoragarh district of Kumaun Himalaya Uttarakhand. The study area is located between 29° 25'30" N latitude and 79°25'60" E longitude between 2050 –2200m

elevations in Nainital district and 29° 30'54" N latitude and 80°14'31" E longitude between 1950 –2200m elevations in Pithoragarh district of Kumaun Himalaya. This region is characterized by temperate forests dominated by tree species such as oaks (*Quercus spp.*), *R. arboreum*, and *Lyonia ovalifolia*. Winter (November to February), summer (April to mid-June), and rainy (mid-June to September) are three primary seasons of temperate monsoon climate found at research locations. In addition to typical annual rainfall of 130.92mm and mean monthly rainfall of 3.7 to 451.38mm, mean lowest temperature ranged 5 - 21°C, and mean maximum temperature ranged from 17 - 28°C.²¹

Table 1: Description of study sites

Sites	Elevation (m)	Latitude	Longitude	Major species
Nainital (Kilbury)	2050-2200	29° 25'30"	79°25'60"	<i>Quercus lanata</i> , <i>Rhododendron arboreum</i> , <i>Quercus leucotrichophora</i> .
Pithoragarh (Thalkedar)	1950-2200	29° 30'54"	80°14'31"	<i>Quercus lanata</i> , <i>Lyonia ovalifolia</i> , <i>Rhododendron arboreum</i> .

Sampling Procedure

At each forest site, vegetation was analysed using the quadrat technique. 20 quadrats of 10 × 10m were laid randomly in each forest site for trees, 5 × 5m for saplings and 1 × 1m for seedlings. Sampling size and the number of quadrats were determined, and parameters such as density, total basal area (TBA), and Importance Value Index (IVI) were estimated following the methods described by Misra and Curtis and McIntosh.^{24,25}

For developing population structure circumference at breast height (cbh), 1.37 m from the base of the tree with a meter tape was used. The data were categorized into eight circumference classes and population structure developed following i.e., seedlings (<10cm), saplings (10-30), 31–60 cm, 61–90 cm, 91–120 cm, 121–150 cm, and >150 cm, following the method of Good and Good.²⁶ Shannon-Wiener information index was employed to determine species diversity (H') of each vegetation layer.²⁷

$$H = -\sum (Ni/N) 3.322 \log_{10} (Ni/N)$$

Here, Ni implies the number of individuals of a species, and N indicates total number of individuals of all species in that stand.

Concentration of dominance (Cd) was computed by Simpson's Index²⁸

$$C D = \sum (Ni / N)^2$$

Here, Ni implies the number of individuals of a species, and N represents total number of individuals of all species.

Results

A total of 7 trees species were recorded across both sites. At site -1 the total tree density was 665 ind ha⁻¹. With *Q. lanata* having the maximum density of 525 ind ha⁻¹. Total basal area at this site was 36.96m² ha⁻¹. *Q. lanata* was dominant species followed by *R. arboretum*, *C. torulosa*, *Q. floribunda* and *L. ovalifolia* at site -1. At site -2 total density was 1115 ind ha⁻¹. with *Q. lanata* having a density of 560 ind ha⁻¹ Total basal area at this site was

21.28m 2ha⁻¹. The density of *Q. lanata* was more or less the same across both sites. The Importance Value Index (IVI) of *Q. lanata* was 139.05 at site - 1 and 222.40 at site -2 (Table.2).

Table 2: Tree vegetation analysis of *Quercus lanata* dominated forest in Kumaun Region

Species	Site-1			Site-2		
	D (indha ⁻¹)	TBA (m ² ha ⁻¹)	IVI	D (ind ha ⁻¹)	TBA (m ² ha ⁻¹)	IVI
<i>Quercus lanata</i>	525	36.23	222.40	560	21.28	139.05
<i>Q. floribunda</i>	20	1.64	17.87	10	0.26	3.16
<i>M.esculenta</i>	-	-	-	25	0.7	7.26
<i>Cupressus torulosa</i>	50	1.24	29.50	-	-	-
<i>Lyonia ovalifolia</i>	15	0.32	5.74	100	2.3	33.94
<i>Rhododendron arboreum</i>	55	1.10	24.50	180	5.22	49.02
<i>Q. leucotrichophora</i>	-	-	-	240	7.2	67.57
Total	665	40.52		1115	36.96	

D- Density, TBA-Total basal area, IVI- Importance value index

Table 3: Seedling, Sapling Density and Total Basal Area of *Quercus lanata* dominated forests in the Kumaun Region

Species	Site-1			Site-2		
	Seedlings	Saplings		Seedlings	Saplings	
	D (ind ha ⁻¹)	D (ind ha ⁻¹)	TBA (m ² ha ⁻¹)	D (ind ha ⁻¹)	D (ind ha ⁻¹)	TBA (m ² ha ⁻¹)
<i>Q. lanata</i>	80	20	0.080	455	10	0.058
<i>Q. floribunda</i>	10	10	0.028	10	-	-
<i>C. torulosa</i>	10	5	0.033	-	-	-
<i>R.arboreum</i>	15	65	0.023	55	5	0.025
<i>Q.leucotrichophora</i>	15	5	0.260	130	50	0.224
<i>M.esculanta</i>	-	5	0.023	190	20	0.098
<i>L.ambrosa</i>	-	5	0.014	-	-	-
<i>L.ovalifolia</i>	-	5	0.010	325	10	0.04
Total	130	120	0.470	1165	95	0.444

D- Density, TBA-Total basal area

The total seedling density was 130 ind ha⁻¹. at site-1 whereas site-2 it was 1165 ind ha⁻¹ and the total sapling density was 120 ind ha⁻¹ at site-1 and 95 ind ha⁻¹ for site-2. Seedling density of *Q. lanata* ranged from 80 - 455ind ha⁻¹, while sapling density ranged 10 - 20 ind ha⁻¹ across both sites. Total basal area

of *Q. lanata* saplings varied between 0.058 - 0.080 m² ha⁻¹ (Table.3) across the sites. At site-1 the maximum sapling density was of *R. arboreum* and in site-2 of *Q. leucotrichophora*. *Q. lanata*, seedling density was higher at site-2, but sapling density was greater at site-1.

Tree Diversity index of study sites

The species diversity (H) for the tree layer across both sites ranged from 0.861 to 1.897. The diversity for saplings and seedlings varied between 1.868 and

2.164, and 1.719 and 2.09, respectively. Cd for tree layer ranged from 0.333 to 0.637, while for saplings it varied between 0.337 and 0.346, and for seedlings, it ranged from 0.272 to 0.417 (Table.4).

Table 4: Tree Diversity index of study sites

Site-1	Tree	Sapling	Seedling
H	0.861	2.164	1.719
Cd	0.637	0.337	0.417
Site-2	Tree	Sapling	Seedling
H	1.897	1.868	2.09
Cd	0.333	0.346	0.272

H- Diversity, Cd- Concentration of dominance

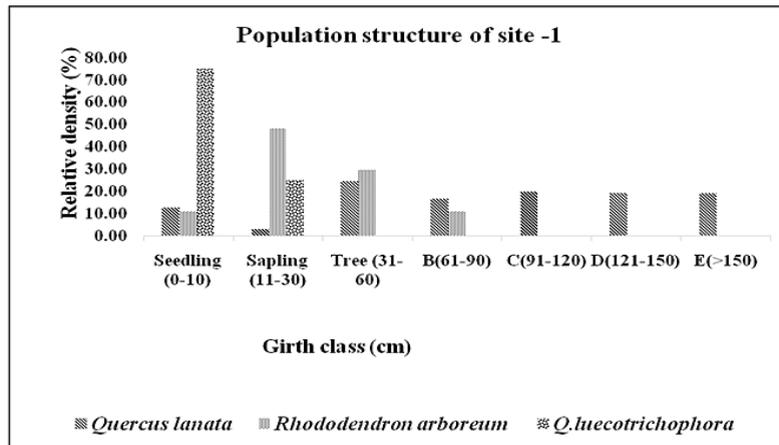


Fig. 1: Population dynamics of major species in the Rianj oakdominated forest

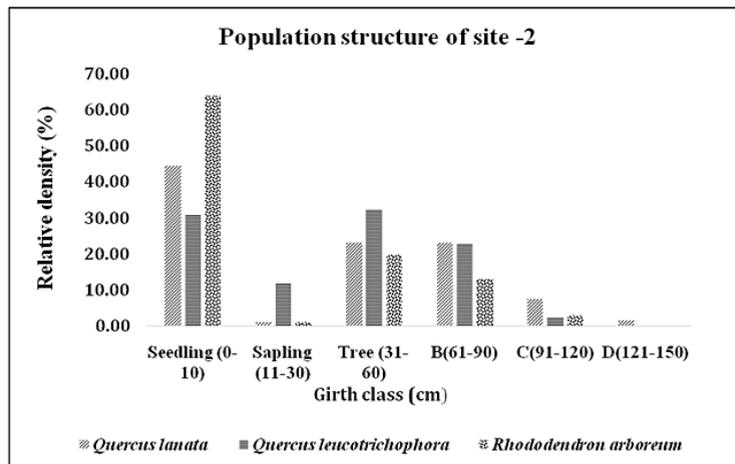


Fig. 2: Population dynamics of major species in the Rianj oakdominated forest

Population Structure

At site -1 *Q. lanata* shows all girth classes from seedling (0–10 cm) to the highest girth class (>150 cm). *Q. leucotrichophora* is only represented in the seedling (0–10 cm) and sapling (11–30 cm) classes, with no individuals observed in higher girth classes, indicating poor recruitment into mature stages. *R. arboreum* is present in various girth classes, mainly in the sapling (11–30 cm) and small tree (31–60 cm), but is absent in the larger girth classes (>90 cm), indicating limited transition to mature stages (Fig. 1). Several ecological and anthropogenic disturbances such as logging, fuelwood collection that selectively removed mature trees, leading to a gap in older age classes. At site-1 tree density pattern generally decreases with increasing girth, which highlights the absence of older and larger trees.

At site-2 as the girth class increases (B 61 - 90cm, C 91-120cm, D 121-150cm), the relative density decreases, with a limited number of species represented in the larger girth classes. *Q. lanata* shows fair regeneration status, as indicated by presence of considerable proportion of seedlings, mature trees. However, comparatively low density of saplings indicates their generation is limited during the sapling stage conversion rate from seedling to sapling was poor. The absence of trees in the highest girth class (D) indicates a lack of very old or mature trees in the site (Fig. 2). The absence of higher girth class trees may be due to low recruitment rates, high mortality, other disturbances such as logging or grazing, or environmental stress. The restricted conversion of seedlings of *Q. lanata* to sapling stage shows that the species is facing regeneration problem.

Discussion

Density of saplings and seedlings is a criterion implemented for assessing regeneration status of tree species in any forest. A population's reproductive status and future outcome are determined by the ratio of various age groups.²⁹ Regeneration maintains forest vitality by ensuring a continuous replacement of aging trees with saplings and seedlings.³⁰ In space and time, forest's wealth is contingent upon potential regenerative status of species that comprise the forest stand.³¹

In the present study across both the sites the tree density of *Q. lanata* ranged between 525 and 560

ind ha⁻¹. which was lower than the density reported by Singh *et al.*,³² for the species Dhar *et al.*,³³ The structural diversity and representativeness of forest vegetation in the Kumaun Himalaya were studied, and the density of *Q. lanata* was reported at 832 ind ha⁻¹.

Sapling density of *Q. lanata* across both the sites was 10 and 20 ind ha⁻¹. In oak-dominated forests of Nainital, sapling density ranges from 500 to 950 ind ha⁻¹ as reported by Singh *et al.*,³⁴ while in the Binsar Wildlife Sanctuary, Almora, total sapling density ranged from 20 to 380 ind ha⁻¹ as reported by Khan and Arya.³⁵ These values indicate that the sapling density observed in this study is lower than that reported previously (Table 3).

Seedling density of *Q. lanata* at site 1 has been 80 ind/ha and at site 2 density was 455 ind ha⁻¹. Seedling density at site 1 has been lower than that at site 2. The low seedling density at site 1 could be due to low seed production, failure of germination, dense canopy cover, herbivory, and anthropogenic disturbances. Drywood collection is common in the area in which the study is located.

In the present study, total seedling density varied between 130 and 1165 ind ha⁻¹ across both sites of Kumaun Himalaya. Similarly, a previous study reported by Khan and Arya.³⁵ the seedling density ranges from 640 to 1880 ind ha⁻¹ in the central Himalaya, which was higher than the value of present study in oak-dominated forests.

Total basal area of *Q. lanata* in the current study ranges between 21.28 and 36.23 m²ha⁻¹ across both the sites. Which was lower than the total basal area reported by Singh SP, Singh JS.⁹ Total basal area of *Q. lanata* in Kumaun Himalaya 67.7 m²ha⁻¹³³ for the species. In current investigation, total basal area of *Q. lanata* dominated forest ranged from 36.96 to 40.52 m²/ha in Kumaun Himalaya.

Q. lanata, ecologically and economically essential oak species in Kumaun Himalaya, exhibits a highly restricted distribution, typically forming small, fragmented forests. *Q. lanata* distribution in Kumaun region is strongly influenced by several environmental factors, including altitude, soil characteristics, slope, and seasonal precipitation. While altitude plays a key role, rainfall emerges as a critical factor for the

species regeneration, as acorn germination typically occurs under moist conditions during and shortly after the monsoon season. However, once the monsoon ends, field conditions often become dry, which can threaten the survival of the germinated seedlings. Therefore, an extended dry period following the pre monsoon drought season may significantly reduce the survival rate of *Q. lanata* seedlings. Uncontrolled grazing by domestic livestock has a detrimental impact on regeneration of forests, as it removes juvenile seedlings and saplings, leading to soil loss because of trampling.³⁶ The seedling regeneration status of studied species was low. The seedling density of all the other associated species was high but conversion of seedling into sapling was relatively poor. Poor regeneration of species in Himalayan mountain forests has been reported by other workers from time to time.³⁷ Earlier studies by Bisht S, *et al.*³⁸ have show fair regeneration of *Q.lanata* in protected Sanctuary. The seedling density in the study was 245 ind ha⁻¹. It is evident that the species is regenerating in protected area where anthropogenic pressure is low.

The diversity of the *Q. lanata*-dominated forest at Site 1 was recorded as 0.861, which is lower than the value of 1.88 reported by Dhar *et.al.*³³. In current research, the diversity (H) for tree species was 0.861 - 1.89, while for saplings and seedlings, the values ranged from 0.337 - 2.164 and 0.272 - 2.09 (Table.4) respectively, across both the sites.³⁴ reported diversity values ranging from 1.31 - 2.69 for trees, 1.78 - 1.84 for saplings, and 0.87 - 1.50 for seedlings in an oak-dominated forest in Kumaun Himalaya. Diversity indices for saplings and seedlings were comparatively higher than those presented in the earlier study.

Q. lanata is capable of regenerating even under closed canopy conditions, and it occasionally coexists with other species, sharing the forest canopy. Since it is widely used for fuelwood, fodder, and leaf litter, local communities often engage in selective extraction or lopping of these trees. This practice leads to canopy openings, which opens up the canopy and facilitates regeneration.³⁹

Table 5: Comparison of tree, sapling, seedling density and regeneration status of *Q. lanata* with earlier studies in oaks of central Himalayas

Sl. no	Species	Tree density (ind/ha)	Sapling density (ind/ha)	Seedling density (ind/ha)	Regeneration status	Sources
1	<i>Q. lanata</i>	672	Absent	Absent	Poor	Singh and Singh, 1986 ⁹
2	<i>Q. lanata</i>	993	Absent	Absent	Poor	Singh <i>et al.</i> , 1994 ³²
3	<i>Q. floribunda</i>	760	Absent	Absent	Poor	Singh <i>et al.</i> , 2014 ³⁴
4	<i>Q. lanata</i>	570	900	933	Fair	Saxena and Singh 1984 ²³
5	<i>Q. leucotrichophora</i>	210	60	40	Poor	Khan and Arya 2017 ³⁵
6	<i>Q. floribunda</i>	583	50	189	Poor	Giri <i>et al.</i> , 2008
7	<i>Q. semecarpifolia</i>	142.25	232.7	52.65	Poor	Singh and Rawat 2012 ⁷
8	<i>Q. floribunda</i>	740	260	70	Fair	Lodhiyal <i>et al.</i> , 2015
9	<i>Q. lanata</i>	1000	480	1840	Fair	Bisht <i>et al.</i> , 2021 ³⁸
10	<i>Q. lanata</i>	525	20	80	Poor	Present study site1
11	<i>Q. lanata</i>	560	10	455	Poor	Present study site2

Tree size class distribution is the primary indicator of forest population structure.^{23,15} The population structure of site 1 and site 2 shows notable contrasts in girth class distribution among various species. In site-1, the relative density of *Q. lanata* is higher in the seedling (0-10 cm) and sapling (11-30cm) classes. Therefore, density decreases in larger girth classes,

suggesting fewer mature individuals. Site 2 show highest relative density is observed in the seedling class (0–10 cm), indicating active recruitment but the conversion of seedling into sapling was poor. The limited representation of higher girth class trees at both sites may be due to factors such as low recruitment rates, high mortality, or disturbances

like grazing, logging, or environmental stress. The absence of older trees also indicates that the forests might be in an earlier successional stage, where mature individuals are not yet established. Site 2 shows a more sustainable population structure with consistent presence across various girth classes, whereas site 1 appears to depend largely on younger individuals, which might result in challenges in maintaining a stable number of mature individuals. The lack of mature trees in the larger girth classes observed in this study likely reflects the effects of past selective logging or elevated mortality rates caused by anthropogenic disturbances. In addition, climate variability such as irregular rainfall and rising temperature these problems by disrupting the processes of seed development and germination.⁴⁰

Conclusion

The current study strongly indicate that some degree of protection is required for proper regeneration of *Q. lanata* in the Himalayan region where it exists in very small pockets. More studies in the Himalayan region are required for a clear assessment of its regeneration potential and survival. In the Himalayan region poor to fair regeneration with excessively lower conversion of seedling into sapling is a matter of huge concern regarding survival of the species in the coming future. More conservation efforts are required.

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Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Permission to Reproduce Material from other sources

Not applicable

Author Contributions

- **Geeta Sharma:** Conceptualization, Methodology, Field Investigation, Data Collection, Data Analysis, Writing original Draft.
- **Ashish Tewari:** Data Analysis, Writing – Review & Editing.
- **Shruti Shah:** Writing – Review & Editing, Proofreading, Quality Check.

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