Impact of Edaphic Parameters on the Natural Regeneration of *Terminalia chebula* Retz. Across Garhwal Himalaya

ABSTRACT

The study aims to identify the impacts of edaphic parameters on the natural regeneration of *Terminalia chebula* Retz. in the Garhwal Himalaya region. The study is designed as an analytical study based on observation of the edaphic and ecological parameters. It is a backward-direction study to observe the impact of the selected parameters on natural regeneration. The study has been done in the Department of Forestry & Natural Sciences, HNB Garhwal University (A Central University), Tehri, Garhwal, Uttarakhand, between February to April 2022. The study was performed by using simple random sampling for data collection and standard published methods for testing the edaphic parameters. After that statistical inference and impact of the edaphic parameters on natural regeneration of *Terminalia chebula* Retz. has been drawn by using multiple correlation. The study concluded that the selected sites across the Garhwal Himalayas can be considered as 'good natural regeneration spots' for *Terminalia chebula* Retz. An intricate harmony observed between the prevailing soil conditions and the growth characteristics of this particular plant species.

Keywords: Correlation, Edaphic, Habitat, Regeneration status, Seedling

1. INTRODUCTION

The Himalayan region of India is a part of the Himalayan Biodiversity Hotspot. This region is rich in biodiversity and natural resources. The Uttarakhand Himalayan region is demarcated into two distinct regions, namely Garhwal region consisting of seven districts (i.e., Dehradun, Haridwar, Tehri Garhwal, Pauri Garhwal, Rudraprayag, Uttarkashi, and Chamoli) and Kumaon region consisting of six districts (i.e., Kotdwar, Pittoragarh, Almora, Bhageshwar, Champavat, and Uddham Singh Nagar). Garhwal Himalaya has diverse forms of plants that are of high medicinal value. A total of 33 genera and 39 species of growing medicinal trees have been noticed in the study area [1].

Terminalia chebula Retz. belong to the family Combretaceae, a moderate-sized to large deciduous tree with a rounded crown and usually short trunk. The species is distributed in India over the mixed deciduous forests extending to the drier areas [2]. According to Troup, *Terminalia chebula* Retz. ascends to 5000ft. in the outer Himalayas. In Uttarakhand, the flowering season lasts from April to June, and fruiting is observed from January to March [3]. *Terminalia chebula* Retz. is a common species in sal and dry miscellaneous forests up to an altitude of 1400m. The structure and function of the forest ecosystem are determined by the plant component more than any other living component of the system [4].

Terminalia chebula Retz. is considered the "King of medicine" because it contains a large number of phytochemicals that are used for treating a variety of disorders [5]. Composition and community are the vital forest attributes that influence and get influenced by the regional environment and edaphic and anthropogenic factors [6]. The pH of the soil in the natural environment has an enormous influence on soil biogeochemical processes; hence, soil pH is described as the "*master soil variable*" [7]. Soil pH influences myriads of soil biological, chemical, and physical properties and processes that affect plant growth and biomass yield. The study focuses on the regeneration status of *Terminalia chebula* Retz. With respect to edaphological parameters in the different altitudinal zones of Garhwal Himalayas. *Terminalia chebula* Retz. works as a multipurpose tree species and has utilization for many purposes, including the evident one, which is medicinal. The fruit is the main part utilized for medicinal purposes. Based on the different stages of maturity [8,9] the fruits can be identified in three different forms, such as small myrobalan (i.e., the unripe fruit); yellow myrobalan (i.e., after the development of seed, the adult stage of the fruit); and large myrobalan – (i.e., the fully matured fruit) [10]. Hence, utilization of the species is assumed to have an impact on natural regeneration. So, in natural systems where natural regeneration is taking place, the impact of edaphic parameters, which have direct effects/influences on the regeneration process, has been

assessed. Assessment of different edaphic components has been done by multiple correlations to evaluate in which direction the change in parameters has been influencing the regeneration process.

2. MATERIAL AND METHODS

The present investigation has been carried out to analyze the impacts of edaphic parameters of the plots where the natural regeneration occurred. Requirements for the field assessment consist of a rope of a specific size and measuring tape for the tree data. Augur and zip lock bags were used for soil collection sampling.

2.1 Selection of Sites

The altitudinal ranges considered for the study has been categorized as 'Warm Temperate' climatic zone [11]. The temperature of all the sites vary from minimum 0.1^0C to maximum 30.1^0C. Inaccessible hilly tracts were a major challenge for the study. To overcome this challenge simple random sampling was done and the accessible sites were studied. Parameters related to species' altitudinal range, habitat(s), locality factors (*i.e.,* soil physio-chemical parameters), etc., were gathered. Each location, i.e., habitat, was identified based on the dominance of the vegetation along altitudinal gradient.

Table 1: Details of the sites along altitudinal gradient

Plot	Site	Latitude	Longitude	Aspect	Altitude (m A.S.L)
P–1	LUSI,Tehri Garhwal,Uttarakhand	30°17' 2.6016" N	78°43' 5.1996" E	SE	900
P– 2	Jakhni road, Tehri Garhwal,Uttarakhand	30°17' 2.7488" N	78°43' 9.6924" E	NE	950
P– 3	Pindula, Tehri Garhwal	30°17' 36.7476" N	78°42' 59.6124" E	NE	1000
P– 4	Near Pindula,Tehri Garhwal	30°17' 15.5508" N	78°43' 7.9932" E	NE	1050
P– 5	Jakhni, Tehri Garhwal	30°16' 54.894" N	78°43' 10.7544" E`	SE	1100
P– 6	Kathela,Kotdwar	29°50' 59.4744" N	78°38' 18.8844" E	SW	1150
P– 7	Deosal, Khanda,Pauri Garhwal	30°10' 44.3532" N	78°49' 10.2324" E	NW	>1200

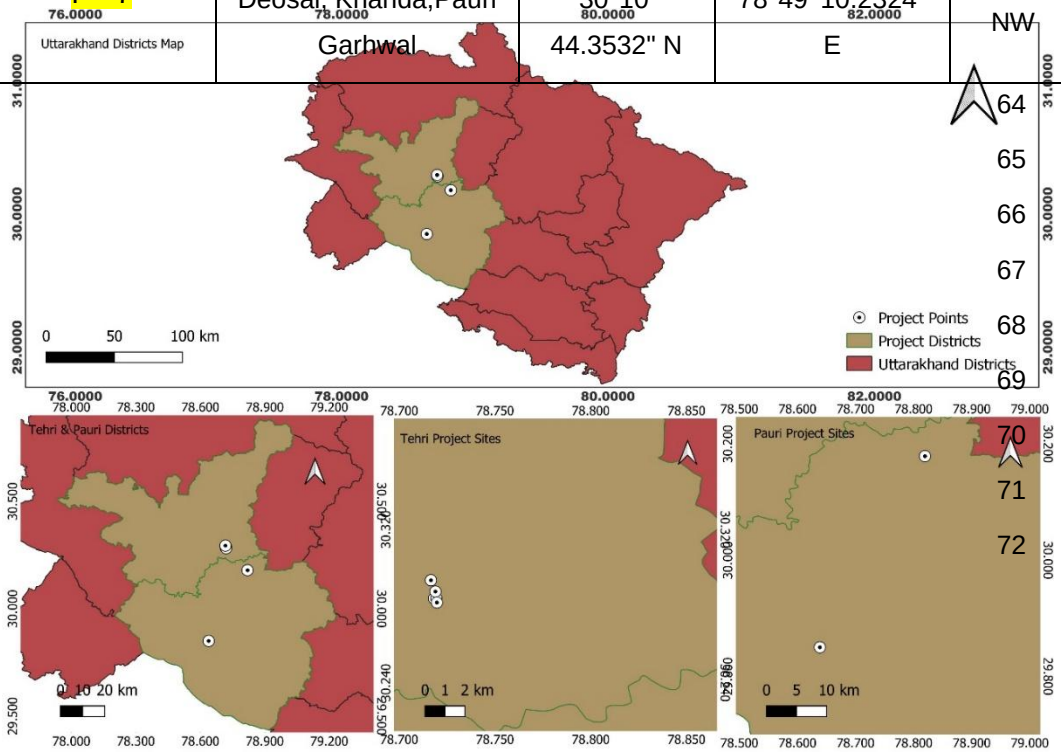

Figure 1: Project Location of Tehri and Pauri Districts

2.2 Sampling of the Natural Vegetation

In each selected site, a plot of 50 m× 50 m (0.25 hectare) was laid. Seedlings, saplings, and trees were sampled sequentially. Quadrats of 10 m×10 m dimensions (a total of 31 numbers) were placed inside seven plots at four corners of the plot and in some cases at the middle point. Standard ecological sampling methods were followed for the data collection from the quadrats [12,13,14].

2.3 Sampling of Soil

Standard three out of four soil testing steps have been obtained as described by Walworth [15]. For the collection of soil samples, all seven different sites of different altitudinal levels were sampled.

Seven plots of 50 m x 50 m were laid in the study area. Plots were then classified into seven altitudinal ranges of 900 – 950m, 950 – 1000m, 1000 – 1050m, 1050 – 1100m, 1100 – 1150m, and 1150 – 1200m, respectively (P–1 to P–7). From each altitude, a composite soil sample (comprised of 4 samples) was collected from each quadrat. Samples were collected from a depth of 20 cm. The samples were placed in clean polythene bags and marked properly. It was imperative to use clean sampling tools.

2.4 Measurement of Plants

Significant considerations have been made during the measurement of plants. Such as, stems measuring over 30 cm in diameter at breast height (DBH), i.e., 1.37m [16] and over 13 m in height, are considered '*Mature trees*.' Individuals over 10 cm to less than 30 cm diameter along with less than 2 m height have been considered as '*Poles*.' Individuals having over 1 cm to less than 10 cm collar diameter have been considered as '*Saplings*,' and with less than 1 cm collar diameter and up to 0.5 m height have been considered as '*Seedlings*') [17].

2.5 Analysis of Soil Parameters

Soil physical and chemical properties were estimated using all standard procedures (**Table 1**) in the Department of Forestry & Natural Sciences, HNBGU laboratory.

Table 1: Methodology used for the analysis of different soil parameters.

S.No	Soil Parameter	Reference
1	Soil pH	Watson and Brown, 1998. [18]
2	Soil Texture	Moreno Marato and Alanso- Azcarate, 2022. [19]
3	Bulk Density	Al Shammary et al., 2018 [20]
4	Soil Nitrogen content	Bremner, 1960 [21]
5.	Soil organic carbon and organic content	Mylavarapu, 2014 [22]

2.6 Coefficient of Multiple Correlation

The coefficient of multiple correlations is a measure of how well the given variable natural regeneration status can be predicted using a linear function of a set of other variables, which are edaphic parameters

(e.g., pH, texture, bulk density, nitrogen content, percentage of soil organic carbon (SOC%) and percentage of soil organic matter (SOM%). The correlation between the variables' values and the best predictions has been computed linearly from the predictive variables. The coefficient multiple correlation has been calculated with the help of MS Office for this study.

3. RESULTS AND DISCUSSION

Total of 239 individuals were present in the seven plots (covering 31 quadrats). The individuals were composed of seedlings, saplings, and mature trees. The density of *Terminalia chebula* Retz. seedlings in the 7 different plots from lower to higher altitudes were 0.02, 0.03, 0.02, 0.03, 0.01, Absent, and 0.04 per sq. meter (**Table 2**). The basal area of the seedlings varied between 15.45 to 65.46 cm^2 in a plot.

Table 2: Table of different Edaphic Parameters

Plot No.	Plant Status	Altitude (meters)	Seedling Density (Numbers/m^2)	pH	Nitrogen(kg/m^2)	SOC (%)	SOM (%)	Bulk Density (%)
P-1	Seedling	900	0.06	5.2	0.04	1.63	2.81	0.81
P-2	Seedling	950	0.07	5.66	0.03	2.36	4.36	0.93
P-3	Seedling	1000	0.04	5.8	0.02	2.07	3.57	1.26
P-4	Seedling	1050	0.07	6.22	0.03	1.32	2.28	1.15
P-5	Seedling	1100	0.03	5.72	0.02	2.01	3.47	1.06
P-6	Seedling	1150	Absent	6.52	0.03	1.42	2.44	0.94
P-7	Seedling	1200	0.11	5.52	0.03	2.46	4.23	1.13

The pH level was acidic, ranging 5.2 to 6.52 in the plots. The standard deviation for different parameters were assessed such as the standard deviations of seedling density, pH, nitrogen (kg/m^2), percentage soil organic carbon (SOC %), percentage soil organic matter (SOM %), and bulk density were 0.04, 0.44, 21.37, 0.45, 0.83, and 0.15 respectively (**Table 2**).

Table 3: Table of Correlation

Parameters	Seedling Density (Numbers/m^2)	pH	Nitrogen (kg/m^2)	SOC (%)	SOM (%)	Altitude (meters)	Bulk Density (%)
Seedling Density (Numbers/m^2)	1.00	-	-	-	-	-	-
pH	-0.56	1.00	-	-	-	-	-
Nitrogen (Kg/m^2)	0.31	-0.28	1.00	-	-	-	-
SOC (%)	0.52	-0.56	-0.30	1.00	-	-	-
SOM (%)	0.51	-0.54	-0.27	0.99	1.00	-	-
Altitude	0.00	0.46	-0.34	0.09	0.03	1.00	-
Bulk Density (%)	0.18	0.24	-0.73	0.21	0.16	0.39	1.00

A multiple correlation (**Table 3**) was performed between the altitude and edaphic parameters and their impact on the seedling density. Altitude has no impact on the natural regeneration of *Terminalia chebula* Retz. As all the altitudinal gradients considered for the study lie within the 'warm temperate' climatic zone, the weather parameters act indifferently. Thus, the meteorological parameters were not incorporated. The study suggests that the altitudinal gradients have a moderately positive impact on the pH, moderately negative impact on the soil nitrogen content, and almost no impact on soil organic carbon percentage (SOC %) and soil organic matter (SOM %). The outcome also concludes that pH characteristics of different altitudinal gradients have a high degree of negative impact on the natural regeneration of the *Terminalia chebula* Retz. seedlings.

When the soil pH in the sites increases, the regeneration gradually declines. It suggests that alkaline soil will reduce the regeneration of the species. The percentage of organic matter and the percentage of organic carbon content are highly correlated because the organic carbon concentration depends on the

organic matter present in the site. The percentage of soil organic carbon has a high degree of positive impact in the natural regeneration process of the *Terminalia chebula* Retz.

Nitrogen content in the sites positively correlates with the natural regeneration of *Terminalia chebula* Retz. Thus, it can be concluded that higher nitrogen content per square meter will result in enhanced regeneration. There has also been an inverse correlation between the bulk density and the nitrogen content. The study incorporates the edaphic drawbacks that suppress regeneration ability. Although there was regeneration in the study sites the status cannot be declared as outstanding as the basal area covered by the seedlings and their number was meager. This can be regarded as unsatisfactory in the altitudinal gradients.

The reasons for poor regeneration of *Terminalia chebula* Retz. in natural regeneration were found to be having hard seed coat, the species being a strong light demander, complete burning of seedlings due to forest fires during summer and intensive removal of fruits for sale in the local markets. The scanty/failure of natural regeneration of *Terminalia chebula* Retz. in Himachal Pradesh has also been reported in the study conducted by Sharma [23]. Instead of the hardships related to *Terminalia chebula* Retz. regeneration, the *Terminalia chebula* Retz. seedlings present in the studied sites showed significant seedling density; thus, regeneration is considerable and is attributed to soil pH, soil organic carbon, and soil nitrogen content.

4. CONCLUSION

The study conducted analyzing the relationship between soil properties and natural regeneration, presents an intriguing perspective on ecosystem dynamics. The designation of the natural regeneration in the selected sites across the Garhwal Himalayas as 'good natural regeneration spots' for *Terminalia chebula* Retz. stems from the intricate harmony observed between the prevailing soil conditions and the growth characteristics of this particular plant species. The findings suggest that a sufficient quantity of soil organic carbon and soil organic matter, coupled with an acidic pH (<7) and increased Nitrogen content, yields a net positive impact on the selected study sites of the Garhwal Himalayas along the altitudinal gradient. This underscores the intricate interplay between soil chemistry and ecosystem health. The prevalence of acidic soil in these sites could be a contributing factor, as certain plant species thrive in such conditions, potentially aiding the natural regeneration process. Additionally, the elevated Nitrogen content might enhance nutrient availability, supporting the growth of vegetation crucial for ecological restoration. However, further investigation is required to ascertain the causal relationships and potential mechanisms driving this phenomenon. This study underscores the importance of understanding local soil characteristics in conservation efforts and highlights the intricate connections between soil properties, pH, nutrient content, and ecosystem dynamics.

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COMPETING INTERESTS

Authors have declared that no competing interest exists.

CONSENT

I on behalf of all authors confirm that all authors have read the copy of this manuscript and approved for submission of this manuscript.

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