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*Research Article*

# Regeneration of Natural Forests in the Hindu Kush Range: A Case Study of Quercus baloot Plants in Sheshikoh Oak Forests, District Chitral, Pakistan

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Regeneration of oak (*Quercus baloot Griff.*) forests is an issue of concern in Khyber Pakhtunkhwa province in general and Sheshikoh Valley of District Chitral in particular. The oak forests cover has been continuously deteriorated and depleted due to uncontrolled grazing, low moisture content of soil, and overusage of the plant as fuelwood and are hence the major contributors toward the failure of oak regeneration. The present study was aimed to asses' different treatments and their impacts on the growth and regeneration of oak forests. This study was conducted in oak forests of Sheshikoh Valley, Chitral, where four plots of 2-acres each were established. Each plot was treated with separate treatment, that is, fencing, mixed treatment (fencing and fertile soil), fencing and trench treatment, and control plot and their regeneration capacity was studied and compared with each other. The data was collected in March and September between 2011 and 2015. The result showed that the number of plants in the first plot (fencing) were 23, with an average height of 43 inches and a diameter of 11.7 mm. In the second plot (fencing and fertile soil), 40 plants grew with an average height of 42 inches and a diameter of 10 mm, whereas in the third plot (fencing and trench), 45 plants developed with an average height of 48 inches and a diameter of 13 mm. However, the fourth plot (nontreated plants) showed poor germination with 8 plants, with an average height of 8.5 inches, and the diameter of plants was 3.7 mm. Therefore, the survival rate of plants in the first, second, and fourth plots remained unsatisfactory at the end of the research. In conclusion, the third treatment (fencing and trench) was the best suitable practice to stabilize oak forests in their natural zones.

## 1. Introduction

Forests play an important role in the stabilization of the whole ecosystems of vast geographical areas. Forests conserve soil, provide fresh air, contribute to precipitation, regulate temperature for the surrounding localities, and support wildlife and other forms of biodiversity [1]. Pakistan is blessed with different types of forests ranging from high-altitude alpine scrub to mangrove forests of the sea coast. Among these forest types, the oak forests are of prime importance because these forests are directly linked with watersheds of upland areas of the country including fragile ecosystems of the Himalayas, Hindu Kush, and northern mountain ranges of Gilgit-Baltistan [1, 2].

In Khyber Pakhtunkhwa, oak forests exist in Dir, Swat, Chitral, Buner, Kohistan, Kaghan, Naran, and in newly merged districts of Khyber Pakhtunkhwa province. Oak belongs to the family Fagaceae. Five species of oak exist in Pakistan, among which, *Quercus ilex* and *Quercus incana* are typically the dry temperate species [3–6].

The regeneration of oak forests is not only linked with the natural factors but also with the anthropogenic factors and is limited by environmental stress. The mitigation of environmental impacts on oak regeneration is always ignored [2, 7, 8]. Among the environmental factors, water availability is considered more crucial for the regeneration of oak, especially in their early stages. Water plays an important role in the germination and establishment of new seedlings of oak forests. Besides water, other environmental factors like humidity, sunlight, and optimum temperature also play important roles in the development of oak seedlings [9, 10].

The dry temperate zone of Chitral supports extensive oak forests which are distributed between 1200 meter and 2000 meter elevation. The oak forests in Chitral exist between the upper limit of agriculture field and lower limit of coniferous forest. These forests are found in pure patches in lower zones and mixed with the chilghoza pine (*Pinus gerardiana*) in upper limits [1]. The estimated oak forest area in District Chitral is approximately 167, 00 hectors [11]. Oak trees are mainly used as fodder, fuel wood, for making agriculture tools, fencing around the agriculture crop, and also as roof thatching material [1]. Moreover, these forests are beneficial for stabilization of watersheds and provide important habitat for various wild life species including birds and mammals. The markhor (*Capra falconeri*) especially depends on oak leaves in winter when other fodder sources vanish due to extreme weather conditions. The foliage and litter fall of oak trees are important to terrestrial ecosystem as they support the productivity of soil and enhance the infiltration and percolation capacity of forest soil [12].

There is always great desire of an educated human society to sustain these highly valued oak forests that in turn demands proper planning and management. Although failure to regenerate oak forest is a common problem throughout the world, a decline in the area of oak forests exerts a negative impact on the biodiversity of the region [12, 13]. Conservation of such threatened and vulnerable tree species is also included in the top priority list of the comprehensive programme of (SDG) of UN Agenda 21. Therefore, scientific planning is needed for long-term conservation and sustainable development of oak forest in the dry zones of the country.

The oak forests were under severe threat in the study area. The factors responsible for this phenomenon were overgrazing, low moisture in soil, and cutting of oak tree for fuel wood purpose. The depletion of oak forest is also directly proportional to the decrease of soil moisture and increase in soil erosion, flash floods, degradation of wildlife habitat, rise in temperature, and loss of biodiversity [14–16]. Therefore, this study focused on the main factors responsible for the degradation and depletion of the oak forests in the study area. The identification of factors helped in designing a plan for the conservation as well as regeneration of these valuable forests in various ecological zones of District Chitral, and, elsewhere in the same ecological zones of the country.

## 2. Material and Methods

The Sheshikoh valley is located at 75-km in the south of Chitral city and connected by a link road with Drosh at Azurdam. Sheshikoh Valley falls in a dry temperate zone with xeric conditions having an average annual temperature of 34°C in summer and −8°C in winter. Data for the present study were collected between 2011 and 2015. The rough topography and dry climatic condition of the valley encourage dwarf and scary ground herbaceous vegetation and pure patches of oak forests.

For the collection of primary data, a research plot was established in Sheshikoh Valley to apply various treatments for enabling the regeneration of the oak forests in the study area. Preferable site for the research plot was southern aspect with a ground slope of 65% to 85%. The total area of the plot was (8) acres. The plot was further divided into four (4) equal plots (2 acres each). Each plot contains at least 5 to 10 mother trees of *Quercus ilex*. Geographical coordinates of the research plot were taken by using GPS. All the 4 plots were treated with separate treatment (i.e., one treatment in each plot), as outlined below:

### 2.1. Treatments

*2.1.1. Treatment through Fencing.* The plot was fenced with barbet wire. The pole-to-pole distance was 10 feet, and the height of the pole was 5 feet. Development/growth of seedlings inside the plot was measured through the following variables:

(i) Number of mother trees using manual counting technique.
(ii) Number of seedlings using manual counting technique.
(iii) Height of seedlings using tape.
(iv) Time of data collection.
(v) Slope of the plot using clinometer apparatus.
(vi) Aspect of the plot from direction of the sun.
(vii) Moisture percentage of soil using the following formula: soil moisture (%) = weight of dry soil (g) × 100 wet weight of soil (g).
(viii) Alternatively, the apparatus "Soil Moisture Meter" was used to get direct readings of soil moisture.
(ix) Humidity. The data were recorded four times in a year by using an hygrometer.

*2.1.2. Mixed Treatment (Fence and Fertile Soil).* In the second plot, clay loam soil of 6 inches thickness was spread in the whole plot area. Good quality viable seeds of *Quercus ilex* were sown in rows in the soil at an equal interval of one foot.

Data collection procedure was the same as in the first plot. However, the following additional parameters were measured for deriving useful findings:

(i) Number of seeds sown using manual counting technique.
(ii) Viability of seeds by viability test using fresh water treatment.
(iii) Nature of the soil was recorded by soil analysis.

*2.1.3. Trench Treatment.* In the third plot, trenches of 4 ft length × 1.5 ft width × 6 inches depth were prepared. Ripen seeds falling from the mother trees were captured in these trenches. Weeding, cleaning, and soil work inside the

TABLE 1: Soil pH and moisture of plots of oak forests in Sheshikoh Valley, Chitral.

| Plot | Treatment | pH | Soil moisture (%) |
|---|---|---|---|
| First | Fencing | $6.5 \pm 0.15$ | $45 \pm 0.25$ |
| Second | Mixed treatment (fencing and fertile soil) | $6.5 \pm 0.14$ | $45 \pm 0.32$ |
| Third | Trench | $6.6 \pm 0.25$ | $55 \pm 0.40$ |
| Fourth | Control/closed plot | $6.6 \pm 0.27$ | $40 \pm 0.35$ |

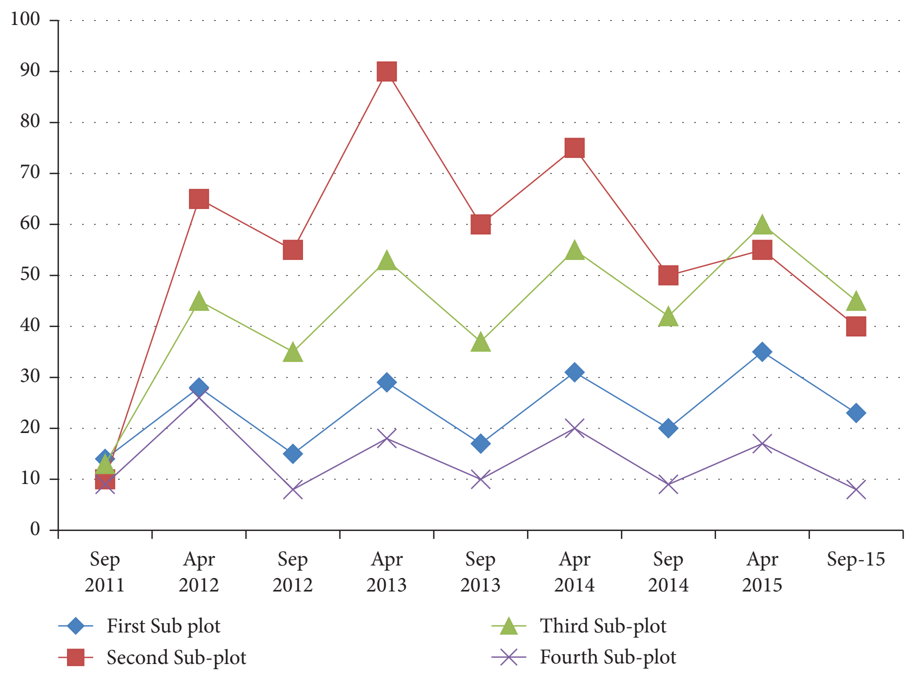


FIGURE 1: Number of plants in the first, second, third, and fourth plots treated through different treatments (*source: field data 2011 to 2015*).

trenches were made after every four months (3 times in a year).

*2.1.4. Control Plot Treatment.* The fourth plot was only a control plot. No fence and no other treatment were applied. All the data regarding the plots were precisely recorded.

The numbers of mother trees of *Quercus baloot* in all the four plots were 23, 25, 26, and 27, respectively. On average, about 25 oak trees were present in each plot. Therefore, the number of falling seeds in each plot was also the same, and the probability of seed germination was equal in all experimental plots. As it is obvious that southern aspects get more sun shine than the northern sites, the soil moisture percentage of southern sites was less than the northern sites. In order to find out the moisture percentage of soil, soil samples were collected from each plot. The soil was dug out from 0 to 10 inches randomly from each plot. One kilogram of soil sample was taken and placed in air tied bags. The soil was analyzed in a forest laboratory to find out its physiochemical characteristics. The pH of the soil was measured by using digital pH meter. Similarly, soil moisture of each plot was calculated by the difference between wet weight and oven dry weight of soil sample, and moisture percentage was found out by using a moisture meter. The accumulative soil moisture for the four plots ranged $45 \pm 0.27\%$, from September 2011 to September 2015. Because of lower slope angle, the third and fourth lots showed higher pH and moisture percentage. The soil pH and moisture of the four plots are given in Table 1 that was recorded using a pH meter at 25.4 cm/10 inches depth.

## 3. Result and Discussion

Figure 1 shows the number of plants in all the four subplots. In the first plot, the number of plants was 14 at the time of first data collection in September 2011 that increased to 28 in April 2012. A significant increase has been observed in the number of plants towards spring season. The number of plants in the second plot was 16 at the time of first data collection (September 2011) that later rose to 65 in April 2012. In first two years, due to additional nutrients inside the $2^{nd}$ plot, the number, height, and width increased, and the height and diameter of plants were comparatively higher as than the other three plots due to the fertile soil. These qualities of the plants reduced with time as the fertile soil that was provided could not adhere itself to the bed of the soil and eroded with time by rain and snowfall. This ultimately affected the essential nutrients in the soil resulting in the downfall of the size and number of plants in the $2^{nd}$ subplot. In $3^{rd}$ plot, soil moisture percentage became high as compared to other three plots. Therefore, the number of plants has increased gradually throughout the experimental period from the first data collection in September 2011 to September 2015. Similarly, due to high moisture content, the plants showed good progress during the research period as compared to the other three plots. Young plants remained healthy inside these trenches. The height and diameter of these plants also showed a progressive development throughout the research period. The fourth plot was treated as closed/control plot. It was only a demarcated plot on ground with no fencing or other treatment and was open for grazing and other human activities. In this plot, no change was observed in the number of plants during the research period. There was an overall increasing trend in plants during spring and a successive decrease in autumn. In autumn season fallen seed germinated in spring however, the number of plants again decreased in autumn season due to continuous grazing and unfavourable climatic conditions. During overall research period, negative change occurred in the "closed plot treatment/control". The number of plants as well as number of mother trees has decreased at the end of research period. Two basic reasons are identified for the failure of oak regeneration in the fourth subplot: low moisture percentage in the soil and continuous grazing by the livestock. Both conditions affected the height and diameter of oak (*Quercus ilex*) plants inside the fourth control plot.

During the study, three basic reasons were identified for this abrupt change in the number of plants between the two seasons. Firstly, slope of the ground was very steep which was >85%. In winter when snowfall occurs, it drifts away the seeds to lower valley site and the slopes remain seedless. Secondly, it was observed that the moisture percentage increases in spring season due to the snowfall in winter. The area falls in a dry temperate zone; therefore, monsoon rainfall does not enter the area, as the result, the soil moisture goes below wilting point in summer season from May to mid of August. Thirdly, sheet erosion occurs due to high intensity of rainfall, after mid of August that ultimately destroys the plants. Furthermore, the remaining new plants are usually grazed by the livestock in summer. Because of the fencing around first plot, the number of plants has increased as shown by the graph which is a clear indication of the negative impact of livestock disturbance on plants. Fencing not only showed a positive impact on the number of plants but also on the height and diameter of plants inside the plot (Figure 1). The height of plants ranged from 6 inches in September 2011 to 40 inches in September 2015. The diameter of plants ranged from 3 mm in September 2011 to 11.4 mm in September 2015.

Similar study was conducted by Raf Aerts and his colleagues to find out the effects of livestock exclusion on the regeneration of church forests of Ethiopia [17]. They investigated the effect of grazing and trampling on seed germination seedling survival and seedling growth. Livestock grazing had a strong negative effect on germination, seedling growth, and mortality. In fenced plot, more seeds germinated, seedling survival was high, and seedlings grew faster than the unfenced area because of the high grazing pressure. In unfenced plots, no seedlings survived. The study concludes that for successful regeneration, grazing should be controlled. The livestock grazing has a paramount impact on the long-term sustainability of church forest and their role in restoring the degraded surrounding. Another similar study was conducted by Jean M., Dufor D to find out the effect of cattle grazing on the density of seedlings and saplings in Tobar oak forest of Israel [15]. The impact of grazing on the densities of seedlings and young saplings was quantified in 46 large sampling plots of 333 square meters each distributed in two experimental sites. The first plot was used as rangeland for decades while the second plot was in forest patch which was totally free from grazing. The density and height of Tobar oak individuals in each sampling plot were recorded. Density of seedlings and young saplings in the grazed forest were lower than the ungrazed treatments.

Another similar problem was studied by Marcelo Sternberg and Maxim Shoshany on the influence of slope aspect on Mediterranean woody formation [18]. The studies investigate the effect of slope on plant community characteristics such as plant cover, species composition, and above ground biomass production. The result of this study showed that slope and aspect had a significant effect on the composition, structure, and density of plant communities. Similar study was conducted by Atta ur Rehman and his group on the effect of environmental and spatial gradient on Quercus-dominated mountain forest communities in the Hindu Kush range of Pakistan and the aim of the study was to provide basic data for the development of a regional oak forest ecosystem framework for ecological restoration and development of management plan to maintain livelihoods of the locals [19]. Hence, they analyzed distribution patterns and environmental factors that affect regional oak forest species composition, and diversity canonical correspondence analysis CCA indicated that community structure was affected by environmental factors including slope, precipitation, elevation, soil structure, and relative humidity. Soil water availability effects on seed germination were studied by Esther Bochet et al. The result of the study concludes that soil water availability after rainfalls occurring during the germination period plays a vital role in the germination of seed and they predicted that soil water is a determinant factor in the colonization process of road slopes in a semiarid environment [20]. They suggested that the ability of species to germinate under water stress could be an indication of a species potential for success under semiarid conditions.

Tailor Wilson studied principal abiotic factors influencing the structure and function of mature pine forest in Israel [21]. The purpose of the project was to assess how biotic factors such as precipitation, elevation, and aspect affect the structure and function of forest. For that purpose, the tree growth factors such as height, stem diameter, basal area, and stem density were analyzed. Understory development in forest was positively related to precipitation, while over story canopy coverage had minimal effects. The conclusion of this study highlights that the growth and survival of Mediterranean forest are strongly influenced by water availability; therefore, there is a need to consider site-specific water-based management regimes for the forest of this region.

## 4. Conclusion

The current study was aimed to find out the possible methods for increasing regeneration potential of oak forests in Sheshikoh Valley, District Chitral. The local community is unaware to conserve the natural resources and about the possible rehabilitation. The Forest Department itself lacks efficiency in managing its resources although forest policies and ordinance provide proper frameworks for its actions. Overall, the regeneration potential of oak forests is decreasing day by day and cannot be halted at the present level or bring improvement in future without remedies to the causes. It was concluded that fencing either social or in material to some extent stabilizes the new plants of oak in natural forests in localized areas but cannot be practiced for longer periods. Fencing can be beneficial in terms of practicing rotational grazing in localized areas. Contrary to fencing, combined treatment approach is the most suitable technique for enhancing the capacity of the habitats for oak regeneration through the provision of required medium for the development of oak plants. Likewise, trench method is a successful treatment for the retention of moisture and minerals. It was observed that certain approaches towards the management of the oak forests would be helpful for their protection, conservation, and rehabilitation. These approaches include efficient land planning mechanism, strengthening of the Forest Department through infrastructure development, capacity building, and legal reforms. The management plans for forests of Chitral should be revised in support of legal reforms in policies and management scenarios.

## Data Availability

We are submitting a data file as supplementary data and even the whole protocol is present with Mr. Zahid Ahmad about the study.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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