Effect of stand structure and aspect on the regeneration of banj oak (*Quercus leucotrichophora* A. Camus) forest along disturbance in Garhwal Himalaya, Uttarakhand, India

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Abstract. A study was conducted in an oak forest, to find out the relationship of stand structure, aspect and regeneration of species. Among all disturbance stands the density of banj oak *Quercus leucotrichophora* A. Camus individuals was peaked at 40–50 cm and 50–60 cm diameter at breast height (DBH) classes and low tree density was observed with the increasing DBH classes. North aspect showed higher density for most of girth classes as compared to south facing aspect. Among all the stands, low seedling density was recorded in undisturbed stand at south facing aspect as compared to the moderately and highly disturbed stands. The tree density of *Q. leucotrichophora* was higher in the undisturbed stand followed by moderately disturbed and highly disturbed stand. But in case of seedling density the higher density were observed at undisturbed and highly disturbed stand in both of the aspects.

Key words: disturbance, north aspect, south aspect, tree density, seedling density.

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Introduction

Lack of sufficient regeneration is a major problem of mountain forests (Krauchi *et al.*, 2000). Most studies on subalpine forest have reported poor recruitment in under stories of undisturbed old-growth forests (Coates, 2002; Mori & Takeda, 2004). Regeneration through seeds depends on production, dispersal and germination of seeds, and establishment and growth of seedlings. Several factors such as resource availability, pollination success, production of flowers, fruits

and leaves, genetic makeup, age and size of plant affect the seed production (Winn & Werener, 1987).

Stand structure is the physical arrangement and characteristics of the forest and is a highly visible and described component (Stone & Porter, 1998). Oliver & Larson (1990) define forest stand structure as the physical and temporal distribution of trees in a stand and include within the distribution of the species, vertical and horizontal spatial patterns, size of trees or tree parts, tree age or combinations. In the context of

Figure 1. Map of study area. a – location of Uttarakhand State in India; b – map of Uttarakhand State; ○ – location of study site.

oak forest some reasons that have been suggested to explain the poor regeneration are erratic seed production, defoliation, acorn herbivory, browsing damage to seedlings, forest fire, extensive lopping, accumulation of thick litter with slow decomposition rate, infestation by stem parasites such as mistletoe and leaf damage by insect pests. Grazing activity by large herbivores influences numerous processes associated with the recruitment of individual to a plant population (Hunt, 2001). These factors continuously interfere with the natural regeneration of oak forest (Shrestha, 2003). Seed size is perhaps the most important factor influencing recruitment success in tree species (Gross, 1984; Foster & Janson, 1985; Turnbull *et al.*, 1999; Dalling & Hubbell, 2002).

Material and Methods

The study was conducted in Chandrabadani oak forest, a moist-temperate forest falling at the jurisdiction of Tehri district of Uttarakhand State, India. It lies at 30° 08' 17.4" N latitude and 78° 50' 47.4" E longitudes (Figure 1). A total of six transects were laid

down along altitudinal gradient (03 each in north-facing and south-facing aspects). Sample plots (each 10 × 10 = 100 m²) for tree inventory and nested plots (each 1 × 1 = 1 m²) in 100 m² for seedling analysis were laid down. Transects were spatially distributed so as to minimize the autocorrelation among the vegetation. Quadrats were laid down along each transect in stratified random manner. The whole study area was divided into three altitudinal ranges: upper altitudinal range (> 1,900 m a.s.l.), middle altitudinal range (1,700 to 1,900 m a.s.l.) and lower altitudinal range (< 1,700 m a.s.l.) in north and south facing aspects.

Degree of disturbance in studied area was measured in terms of percent of canopy cover (%), tree density (h⁻¹), lopping intensity (%) and number of cut stumps (h⁻¹). On the basis of these factors, an Index was set up with the help of minimum and maximum values of above mentioned disturbance parameters and then each altitudinal range at 100 m interval has been classified into following disturbance categories as (i) highly disturbed (ii) moderately disturbed and (iii) undisturbed (Table 1).

Table 1. Disturbance categorization of Chandrabadni oak forest.

Disturbance parameters	Undisturbed	Moderately disturbed	Highly disturbed
Tree Density (h^{-1})	> 1,200	800–1,200	< 800
Canopy cover (%)	> 50	30–49	< 30
Lopping (%)	< 20	21–29	> 30
No. of cut stumps (h^{-1})	< 80	81–149	> 150

Results

Different disturbance classes of the studied area shown in Table 2. In whole study area, middle altitude of north aspect and upper altitude of south aspect was recorded under undisturbed stand. The moderately disturbed stands was observed in the upper and middle altitude of north and south aspect respectively, while the lower altitudes of both the north and south aspects was under highly disturbed stand.

Overall results showed that the girth class distribution among all disturbance stands varied with the disturbance intensity. The density of trees was found greater in middle girth classes as compared to higher girth classes. In the north aspect the highest (600 plants / ha) tree density was found in the undisturbed stand for 30–40 cm diameter at breast height (DBH) followed by 500 plants/ha in the moderately disturbed stand for 30–40 cm DBH class and 420 plants / ha in the undisturbed stand for 40–50 cm DBH class. While lowest (20 plants / ha) tree density was recorded at moderately disturbed stand in 80–90 cm DBH class. In the south aspect comparatively low tree density of banj oak *Quercus leucotrichophora* was found. Banj oak is the most common broadleaf tree in the mid-elevational ranges of central Himalaya in India. This broad-leaved genus of family Fagaceae has many superior characteristics for its wide accep-

tance as fuel, timber and nutritious fodder throughout the Himalaya (Saxena & Singh, 1982). The maximum (420 plants / ha) tree density was recorded at moderately disturbed stand in 40–50 cm DBH class followed by 360 plants / ha for 50–60 cm DBH class in moderately disturbed stand and in undisturbed stand at 40–50 cm of DBH class (Figure 2). Among all disturbance stands the tree density of *Q. leucotrichophora* individuals was peaked at 40–50 cm and 50–60 cm DBH classes and low tree density was observed for the *Q. leucotrichophora* density with the increasing DBH classes up to 50–60 cm DBH class. It may be due to cutting of mature trees (higher girth classes) by the local people for fuel wood in the study area (Figure 2).

The study revealed the highest seedling density in moderately disturbed stands followed by undisturbed and highly disturbed stand between both the aspects. However the tree stand density was highest at undisturbed stand followed by moderately and highly disturbed stand among all stands across the aspects (Figure 3). Poor seedling density was observed in the undisturbed stand at south facing aspect as compared to the moderately and highly disturbed stands. It may be due to long radiation period which cause low soil moisture and inhibited the seedling emergence or establishment. On the other hand, tree and seedling density of *Q. leucotrichophora* varied with the disturbance intensity and in different proportion. In the north facing aspect, the highest tree density (740 plants / ha) was observed at undisturbed stand followed by moderately disturbed stand (560 plants / ha) and highly disturbed stand (310 plants / ha) (Figure 3a). The seedling density was highest (1,060 plants / ha) at undisturbed stand followed by highly disturbed stand (1,000 plants / ha) and moderately disturbed stand (880 plants / ha) (Figure 3a). In the south aspect the higher tree density was recorded at undisturbed stand followed by moderately disturbed stand and highly disturbed stand. How-

Table 2. Disturbance parameters observed in different disturbance gradients.

Parameters	Undisturbed		Moderately disturbed		Highly disturbed	
	North middle	South upper	North upper	South middle	North lower	South lower
	(1,781 m)	(2,103 m)	(2,092 m)	(1,829 m)	(1,597 m)	(1,563 m)
Density / ha	1,330±20	1,220±12	1,060±16	1,010±10	780±8	790±8
Canopy cover (%)	60.9	56.5	34.5	42.5	27.7	28.1
Lopping (%)	15.5	18.3	27.7	24.6	38.9	39.4
Cut stumps / ha	50	50	130	110	210	180

Figure 2. Density and diameter at breast height (DBH) of *Quercus leucotrichophora* among different disturbance gradients. North – north facing aspect, South – south facing aspect, UD – undisturbed, MD – moderately disturbed, HD – highly disturbed.

ever, the seedling density was highest (780 plants / ha) at undisturbed and highly disturbed stand and lowest (760 plants / ha) at moderately disturbed stand (Figure 3a).

The tree density of *Q. leucotrichophora* was higher in the undisturbed stand followed by moderately disturbed and highly disturbed stand (Figure 3b). But in case of seedling density the higher density were observed at undisturbed and highly disturbed stand in both the aspects. It may be due to removal of litter and herbaceous biomass in the highly disturbed stands which create suitable microenvironment for seedling growth and development.

Discussion

In present investigation the highest stand density (1,330 tree ha⁻¹) and (1,220 tree ha⁻¹) was recorded in the undisturbed stand at north middle altitude and south upper altitude respectively. The canopy cover ranged from 27.7% at highly disturbed stand to 60.9% at undisturbed stand. Uniyal *et al.* (2010) recorded that the undisturbed forest stand had canopy cover > 60%, cut stump index < 2 and 2,144 trees ha⁻¹, whereas the highly disturbed stand had canopy cover < 49%, cut stump index > 7 and 804 trees ha⁻¹ in *Q. leucotrichophora* forest. The diameter distribution of trees has often been used to represent the population structure of forests (Saxena *et al.*, 1984; Khan *et al.*, 1987). A bell shaped structure was formed by density-diameter curve under different diameter classes of *Q. leucotrichophora* is found similar to Sagar & Singh (2005), who reported concave appearance for the density – diameter curve of the dry deciduous forest of North-East India. Vetaas (2000) indicated that the size class distributions indicate different population structures, which may be related to differences in environment and disturbance regimes of brown oak *Q. semecarpifolia* Sm. in Central Himalaya. The population structure of *Q. semecarpifolia* in the almost undisturbed stand which tend to

a continuous regeneration. Although a clear bell shaped size-class distribution is absent in disturbed forest. This effect of disturbance has been shown in similar evergreen oak forests in Himalaya (Saxena *et al.*, 1984; Rao *et al.*, 1990).

Parthasarthy (2001) studied the changes in forest composition and structure in undisturbed (UD), selected-felled (SF) and moderately disturbed (MD) stands in tropical evergreen forest of Western Ghats and indicated that higher individual density under the 30–60cm of girth class in all three stands and a continuous downfall as the girth class increased from 60–90 cm to > 210 cm of girth class. Our findings were found similar to Sagar & Singh (2005), who reported concave appearance for the d-d curve (dominance-density curves based on the dominance and density of tree species) of the dry deciduous forest of North-East India.

The seedling density was recorded lower in undisturbed stand at south facing aspect as compared to the moderately and highly disturbed stands. It may be due to high radiation in south aspect, which cause low soil moisture and inhibited the seedling emergence or establishment. Sagar & Singh (2005) reported highest seedling density at low disturbed site followed by high disturbed and moderately disturbed sites. They also concluded that the seedling and adult distributions were not spatially associated and seedling community on a site was distinct from the adult tree community.

Conclusions

The study points out an urgent need for the conservation of *Q. leucotrichophora* forest, thus stronger protection and regulatory measures are required. Unmanaged extraction of trees, collection of fuel-wood and fodder by the villagers and over grazing by domestic animals were the major factors of disturbance in the study area. The regeneration of *Q. leucotrichophora* was found severe-

Figure 3. (a) Stand tree and seedling density; (b) *Quercus* tree and seedling density along anthropogenic disturbance gradients. N – north facing aspect, S – south facing aspect, UD – undisturbed, MD – moderately disturbed, HD – highly disturbed.

ly influenced by insect attack on the fallen seeds, seed predation by birds, overcrowding of herbaceous layer and excess litter fall. The disturbance led to thinning of woody layer and change in the microenvironment which, in turn might have impaired regeneration process of the species on one hand, and colonization and establishment of shade-tolerant shrubs and annuals on the

other hand. These factors should be taken into account, while formulating strategies for conservation and management of these forests.

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