Population Dynamics of *Quercus floribunda* Lindl. Seedlings Under Denser and Lighter Canopied Microhabitats

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ABSTRACT: Population dynamics of *Quercus floribunda* seedlings in a fenced and protected forest plot were studied over a 14 months period to determine the influence of temperature and drought in seedling mortality in different seasons. The experiment involved two forest microhabitats (denser and lighter canopied microhabitats) located at an altitude of 2100 m in Central Himalaya. Total seedling mortality of 74.6% was observed in lighter microhabitat and 51.6% in denser canopied microhabitat. Seedling mortality in different months correlated negatively with predawn and midday water potential. Significant correlation also existed between seedling mortality, soil temperature and air temperature at both microhabitats. [Nature and Science. 2009;7(1):84-90]. ISSN: (1545-0740).

Keywords: Population dynamics; predawn water potential; midday water potential; microhabitats; seedling density.

INTRODUCTION

In terms of species richness, Mexico, North America and China are the major centres of the genus *Quercus* and Himalaya is relatively unimportant. However, the four oak species that occur in Central Himalaya dominate more forest areas than many species do in any other part of the world. They occupy most of the areas (approximately 20,000 km^2) from 1000 to 3000 m altitude in Central and Western India (Kumaun, Garhwal and Himanchal Pradesh) (Singh et al. 2000).

Q. floribunda (Moru oak) is the largest of the Western Himalayan oaks, occurring between 2100-2700m elevation although found on all aspects, it avoids very dry situations and favours moist, cool localities and northerly aspects. It also stands more shade than the other oaks of this region (Troup, 1921). The Nainital Hills where the study was under taken is one of the major centres of this oak where it occurs on cool moist slopes.

In 1991, *Q. floribunda* produced a mast seed crop which resulted in recruitment of seedlings in large numbers of similar-aged plants during the warm and wet rainy season (July-August) over a range of microhabitats.

Although changes in species composition have been related to environmental variation in grassland communities (Watt, 1981), the role of environmental variation in regulatory forest community dynamics has received less attention. We monitored these seedlings from the time of recruitment till they were one year old to determine the extent to which temperature (soil and air), soil moisture (at 30 cm depth) and water potential of seedlings (as an indicator of stress) are responsible for large scale mortality of newly recruited seedlings of *Q. floribunda* in different seasons in the monsoon climate.

The present study attempts to determine a suitable microhabitat for this important oak species of Central Himalaya where green felling is banned completely.

MATERIAL AND METHODS

Study site

The study site was protected and enclosed by a barbed wire fence (fencing done by Department of Botany Kumaun University, Nainital) as a result human and cattle pressure was negligible. The study site is located in Nainital catchment on eastern aspect at 2150 m elevation, between 29°22’47”-29°23’04” N latitude and 79°26’5”-79°28’36” E longitude in Central Himalaya. The study site was disturbed about 20 years ago, as a consequence of road construction which involved hill cutting in the upper part of the slope. The basic climatic pattern is governed by the monsoon rhythms. Severe frosts are usual throughout the winter season and snow falls frequent, snow persists for months. The annual rainfall was 2086 mm during the study year however, during the winter season just 48 mm of rainfall occurred. Mean minimum and maximum temperatures were -2.0 and 20ºC. However, on certain days in January temperature as low as -6.0 ºC were common. Within the study site two microhabitats of 1 ha were selected, a denser canopied microhabitat with 78% cover and a lighter canopied microhabitat with 48% canopy cover estimated by a densiometer.

The soil was always moister in denser canopied microhabitats than in lighter canopied microhabitats. The lighter canopied microhabitat was covered with gravel and had little soil and the denser canopied microhabitat had good and uniform soil cover (Table 1).

Population dynamics and growth behaviour

Ten seed traps of 50x50 cm size, constructed of a wooden frame attached to a fibre glass screen base, were placed were placed directly on the forest floor with sides extending upwards ≈5 cm at different position(i.e. under canopy, under overlapping canopies and under the canopy gaps) in both microhabitats. The seeds falling within the seed traps (15 July-30 August 1997) were counted fortnightly to calculate the seed fall density (Donna et al. 1989). Next to each seed trap in each plot were placed 1x1 m permanent quadrat to observe seedling recruitment and mortality at monthly interval. The emerging seedlings were located and marked within these permanent quadrats by white paint.

To determine dry weight changes seedling of size and diameter similar to that of seedling within permanent quadrats were marked in both microhabitats. Only three seedlings were harvested at monthly interval from April to October to estimate the biomass allocation to different components (e.g. leaf, stem and root) of seedling. Net primary productivity was calculated by positive increase method (Singh and Yadava, 1974).

Shoot Water potential

For assessing the water stress in seedlings, water potential was measured at two times of the day, first during early morning(predawn) when the seedling water potential is most favourable, and second during mid-day when water stress is most severe (Turner, 1987). The data was collected over 12 months (autumn to rainy).

Data were analyzed by linear regression (Snedecor, and Cochran, 1968). Analyses of variance (ANOVA) were undertaken for seedling mortality and shoot water potential following Snedecor and Cochran (1968) and to test the significance of differences in seedling mortality between microhabitats and seasons.

RESULTS

Seed fall density and seedling recruitment

Seedling recruitment was recorded between August-September. Seed fall was significantly higher ($P<0.01$) in the denser canopied microhabitats (38.0 seeds m^{-2}) than in lighter canopied microhabitats (28.8 seeds m^{-2}), 56.1% of those germinated in denser canopied microhabitat and 52.1% in lighter canopied microhabitats. The greater seed fall in denser microhabitat was possibly due to greater crown cover.

Population dynamics

Initially the mean seedling number was greater in denser canopied microhabitats (21.3 seedlings m^{-2}) than lighter canopied microhabitats (15.0 seedlings m^{-2}).

Seedling numbers started to decline from October-November (autumn) and continued to decline until summer. Total seedling mortality was greater in lighter canopied microhabitats (74.6%) than denser microhabitats (51.6%). The seedling mortality was the maximum during winter (Table 2) and much less in spring and summer. By summer the live seedling density had declined to 10.3m^{-2} in denser microhabitat and 3.8m^{-2} in lighter canopied microhabitat. Therefore, by end of year, the density had decreased by 51.6% in denser microhabitat and 74.7% in lighter canopied microhabitat.

Water potential

Pre-dawn and mid-day water potentials of seedlings under denser and lighter canopies did not vary significantly between seasons. The predawn seedling water potential in denser microhabitats ranged between -0.3 and -1.9 MPa and -0.4 to -2.3 MPa under lighter canopied microhabitat, respectively. Water potential was most negative during the winter months (December- January) and most favourable during monsoon months (Table 3).

Seedling dry mass

Peak seedling mass, 3.92 g $seedling^{-1}$ vs. 5.52 g $seedling^{-1}$, recorded a net increment of 1.04 and 1.58 g from April to October in denser and lighter-canopied microhabitats, respectively. The difference between seedlings of the two microhabitats (3.92 g $seedling^{-1}$ vs. 5.52 g $seedling^{-1}$) was highly significant ($P<0.01$). At both microhabitats proportional contribution of leaves to total seedling mass increased marginally from April to July, rapidly during August-September and declined thereafter (Figure 1). The stem contribution was almost equal to seedling weight throughout the study period. The contribution of root declined from April to August and thereafter increased marginally. A declining root:shoot ratio was recorded throughout the study period with a marginal increase towards October (Figure 2).

Table 1. Comparison of microhabitats for soil characters. Soil texture and soil chemical data are on dry weight basis.

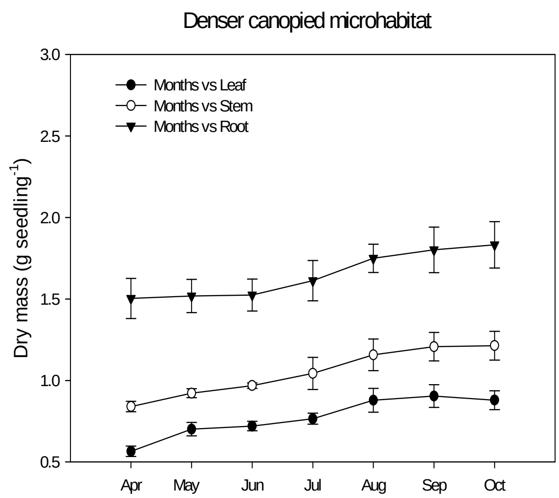
		Denser microhabitat	**Lighter canopied microhabitat**
Soil texture			
Gravel and other Coarse material		80.4±0.013	88.9±0.034
Sand		8.9±0.03	6.2±0.006
Silt		6.4±0.012	3.0±0.005
Clay		4.0±0.004	1.7±0.003
Soil pH		8.14±0.023	8.03±0.004
Soil organic carbon		1.41±0.012	1.02±0.005
Soil nitrogen		0.10±0.023	0.15±0.006
Air temperature			
	Maximum (ºC)	19.5±0.03	20.0±0.132
	Minimum (ºC)	-2.1±0.002	-2.0±0.002
Light intensity (lux)		57.8 x 100±0.387	152.4 x 100±0.768

Table 2. Seed fall density and population dynamics of 1-yr old seedlings of *Quercus floribunda in denser and lighter canopied microhabitat*

Parameters		**Denser microhabitat**	**Lighter canopied microhabitat**
Period of seed fall density		June – Sep.	June –Sep.
Seed fall (seed m^{-2})		38.0±0.45	28.8±0.35
Period of peak seed germination		Late Aug. – Sep.	Late Aug. – Sep.
Percent seed germination		56.1	52.1
Total number of newly recruited seedlings (no. m^{-2})		21.3+0.32	15.0+0.035
Period of seedling mortality			
Total percent annual seedling mortality		Oct. – June	Nov. – June
Seasonal seedling mortality (%)		35.2	55.6
	Summer		
	Rainy	8.7	13.3
	Autumn	0.0	0.0
	Winter	5.5	11.2
	Spring	47.3	56.9
		15.4	3.3

Table 3. Seasonal variation in predawn and midday water potential of *Quercus floribunda* seedlings in denser and lighter canopied microhabitats

	Predawn		Mid-day	
Season	Denser canopied	Lighter canopied	Denser canopied	Lighter canopied
Autumn	-0.7	-0.68	-1.3	--1.26
Winter	-1.47	-1.5	-1.65	-1.76
Spring	-0.83	-1.08	-1.33	-1.36
Summer	-0.67	-0.85	-1.35	-2.35
Rainy	-0.38	-0.58	-1.03	-2.09



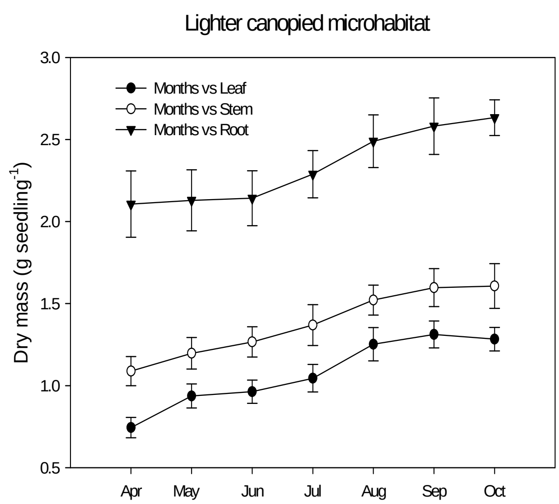


Figure 1 Monthly variation in seedling dry mass (g seedling^{-1}) in denser and lighter canopied microhabitats.

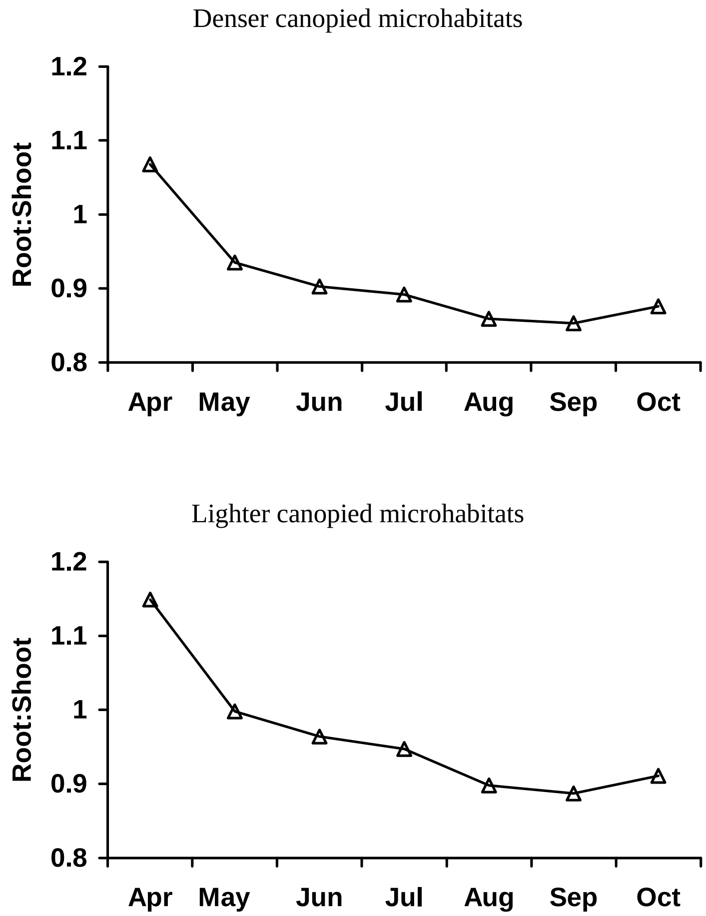


Figure 2 Monthly variation in root:shoot ratio in denser and lighter canopied microhabitats.

DISCUSSION

The study began to monitor the seedlings of *Q. floribunda* when they were 1 to 2 months old. Other studies (Pandey, 1979; Upreti et al., 1985) on vegetational analysis in the same catchment, elevation and aspect have reported that in the non-mast years seedling density ranges between 1.2 seedlings m^{-2} and 1.3 seedlings m^{-2} (Negi et al., 1996). In this study during a year of good seed population at the time of recruitment seedling density was comparable with Negi *et al.* (1996) who reported about four-times greater seedling density in mast years compared to normal years.

The greater number of seedlings in denser canopied microhabitats could be attributed to larger seed production at this site because of a denser canopy and high shade tolerance capacity in *Q. floribunda* seedling (Rao and Singh, 1989). Limited mortality due to frost in this denser canopied microhabitat too cannot be ruled out for higher seedling density compared to the micro habitat with lighter canopy density at the end of the year.

However, winter drought in the first year was the major contributor to the seedling mortality (47.3% and 56.9% in denser and lighter-canopied microhabitats, respectively). The low winter air temperatures and only 19 mm of rainfall may have led to maximum seedling mortality in both these microhabitats. For *Eucalyptus pauciflora,* Osmond *et al.* (1987) found temperatures less than -5 ºC to be most lethal.

Soil temperatures of -2.3 and 2.0ºC during January were experienced by the seedlings of *Q. floribunda*. For the most part, plants experience the highest and the lowest temperatures near the soil surface. Thus, mortality of juveniles during establishment usually determines the ecological impact of temperature tolerance limits. The smallest seedlings suffer the most extreme thermal stress (Nobel, 1984).

It is likely that water stress, like temperature stress, has a major influence on plant distribution during seedling establishment. The most rapid change in water availability take place at the soil surface, and several studies show that seedling mortality during water stress is higher than adult mortality (Wellington, 1984). Tree seedlings experience more severe water potentials than larger individuals on the same site (Crombie, 1997). In a study on *Q. floribunda* saplings on the same site during an unusually severe drought in 1999 when only 26.5 mm of rain was recorded over a period of about 8 months after the monsoon of 1998. Pre-dawn water potentials were found to range between -3.1 MPa to -5.5 MPa resulting in most of saplings having dead withered leaves. This oak population keeps its stomata open and fixes carbon even at a heavy cost in transpirational water loss (Singh et al., 2000). During winters in the present study the values of predawn water potential i.e. -1.9 and -2.3 MPa in denser and in lighter canopied microhabitats suggest severe water stress. Large scale mortality in *Q. floribunda* seedlings may have occurred due to this winter drought, when soil moisture content at 30 cm depth was -26.4% and mean root length of seedling was only 8.7 cm.

A significantly greater annual gain in seedling dry mass in lighter canopied microhabitat than in denser canopied microhabitat indicates that the conditions for healthy growth were better at former microhabitat, where seedlings were fairly widely spaced and competition was low. In this respect the opportunities for the development of healthy seedlings at denser canopied microhabitat were poor, where the seedlings were more in number and may hold chance of self thinning in the future course of growth.

The net gain in seedling dry mass strongly coincided with rainy season, for about 89% of the total gain in dry weight occurred during rainy season. However, seasonal pattern of dry matter build up in aboveground and belowground parts was different. The decreasing root:shoot ratio from March to August suggests that there occurs translocation of minerals and food reserves to the aboveground parts during favourable growing period to maximize photosynthetic gain (Joshi and Rawat, 1996). A substantial increase in root:shoot ratio from September onwards indicates the accumulation of food reserve in belowground parts to ensure the supply in the next growing season. This strategy helps seedlings to survive in conditions of stress and have been fairly documented (Kozlowski 1971).

In conclusion, it can be emphasized that the two microhabitats having different soil characteristics and light conditions have their own advantages with regard to growth and survival of *Q. floribunda* seedlings. While denser canopied microhabitat, possesses potential of supporting a large number of seedlings with more water potential, but hold risks for self shading and thinning in longer run for the demand of nutrients, moisture, sunlight etc. On the other hand lighter canopied microhabitat has a potential to establish few healthy individuals with greater gain in dry weight, likely to grow into healthy individuals. Therefore, in the regeneration programmes of *Q. floribunda* consideration of large seed crop, removal of biotic interference and microhabitat conditions within the disturbed forest sites should be kept in mind.

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