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ORIGINAL RESEARCH ARTICLE

Survival problem in regeneration of high altitude Kharsu oak (*Quercus semecarpifolia* Smith.) forests in central Himalaya, India.

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Abstract: The high altitudinal (2200-2600m) viviparous kharsu oak (*Quercus semecarpifolia* Smith.) is a late successional evergreen tree species. The species is showing failure to regenerate in the Himalayan region. The present study was undertaken to analyze the seed fall density, seedling recruitment and population dynamic of this species on two different aspects over a six-year period (2004-2009). During the study period from 2004 to 2009 only one good seed crop occurred in 2005. In this year at northern aspect, the average seed fall density was 22.8 ±1.24 seeds m^{-2} and at southern aspect it was 26.02 ± 0.90 seed m^{-2}. In 2008 the seed fall density on the northern aspect was 8.5±0.73 seeds m^{-2} and on the southern aspect it was 8.2 ±0.73 seed m^{-2}. In the years 2004, 2007 and 2009 a negligible seed crop was produced and did not play a significant role in seedling recruitment. In year 2005, new recruitment of seedling from fallen seeds occurred in August and it ranged from 60-75% at both the aspects. Maximum seedling mortality was in the 1st year of recruitment thereafter, rate of mortality declined. At the end of observation after six years the total mean seedling density at northern aspects was 1.41 seedling $m^{-2}$and at southern aspect; it was only 0.67 seedling $m^{-2.}$ The seedling survival between the two aspects did not vary significantly.

Key Words: *Quercus semecarpifolia*; Climatic irregularities; Seed fall density; seedling recruitment

INTRODUCTION

Forest plays a dynamic role in protecting the fragile mountain ecosystem. Himalaya has a long altitudinal spreading gradient from sub-montane to alpine with diversified vegetation which ranges from forests to alpine meadows. In the Himalayan region a 2°C rise in temperature has been projected because of carbon dioxide rise in the atmosphere (Ravindranath *et al.,* 2006). The impact of this global climatic change can have a major impact on regeneration of certain viviparous species and species with short seed viability (Joshi & Tewari, 2009). Population dynamics of trees are helpful in predicting the future contribution of constituent species in forest communities. The germination percent and the rate of seedling survival constitute biological and ecological advantages for the population dynamics of species, which is a character of effective regeneration strategies. Although, seedling and sapling data are regularly collected as an aid in predicting the future contribution of different constituent species in forest communities, little is known about the seed production, germination and population dynamics of dominant tree species in natural environment (Verma, 2012). Regeneration is a crucial phase of forest management, because it maintains the desired species composition and stocking. The success of tree regeneration in a forest is determined by successful completion of several events in the tree life cycle such as seed production and dispersal to safe sites, germination and seedling emergence, establishment and onward growth (Barik *et al.,* 1996). Due to several biotic and abiotic factors when any event in the life cycle of a tree is broken down the tree fails to regenerate. The possible causes of regeneration failure include poor seed production of trees (may be limited by various factors such as resource availability, pollination failure, predation on flowers, fruits and leaves), unfavorable micro-sites and anthropogenic pressure and climatic irregularities.

The high altitudinal (2200-2600m) viviparous kharsu oak (*Quercus semecarpifolia* Smith.) is a late successional evergreen tree species which forms a gregarious patch in the Central Himalayan region, with one year leaf life span and concentrated leaf drop in the spring season. The brown oak not only makes an important biome, it is also of considerable human use as fuel wood, fodder for livestock, leaves for tasar culture and seeds are now recognized as having commercial importance. In Nainital district of Kumaun, Kharsu oak forms forest tracts of several miles in gregarious patches on gentle slopes of the hills. This oak produces a good seed crop every 2-3 years interval (Troup, 1921).

Climatic irregularities like rising temperature and irregular pattern of rainfall may impact synchronization between timing of seed fall and monsoon rains particularly in *Q. semecarpifolia* which is a viviparous species and coincides its seed maturation with monsoon rains. The main objectives of this study were to analyze the seed fall density, seedling recruitment and population dynamic pattern on two aspects at China peak forest site over six-year period (2004-2009) in *Q. semecarpifolia* dominated forest and its resultant impact on regeneration.

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Materials and Methods

Site description

Two contrasting aspect i.e. northern aspect and southern aspect at China peak forest site dominated by *Q. semecarpifolia* with intermittent trees of *Quercus floribunda* and *Rhododendron arboreum* were selected for the study, China Peak is located between 29° 27' to 29° 29' N latitude and 79° 23' to 79° 25' E longitude with altitude varying between 2500 and 2610 m. General observation was that the seedlings recruited in poor seed years failed to survive the first season drought in summer. The temperatures are similar to those of temperate regions because of high altitude but latitudinal they come within the subtropical belt. The basic climatic patterns are governed by the monsoon rhythms. There are three main season, winter season (December-March) a relatively dry summer (April to mid-June) and a warm, humid rainy season (mid June to September), which accounts for approximately 70% of the annual rainfall. Severe frosts are usual throughout the winter season and snowfall is frequent with snow persistent for months in the northern pockets. The mean annual rainfall varied between 1586-2086mm during the study period. The temperature data was collected using a thermohygrometer kept in the laboratory at 2000m located in the study area. The summer mean maximum temperature was 18.3°C and minimum 10.2°C and winter mean maximum temperature was 10.7°C and minimum 2.5°C. In January on certain days temperature as low as -2°C were common.

Methodology

24 permanent plots of 5.6m radius (12 plots at each site) were marked on both aspect (i.e. northern & southern) in 3ha area at China peak forest site and the vegetational parameters, density and basal area estimated (Ambasht and Ambasht, 2002). For developing population structure circumference at breast height (cbh) 1.37 m from the base of the tree with a meter tape was taken. The data were categorized in eight circumference classes and population structure developed following (A=251-300cm, B=201-250cm, C=151-200cm, D=101-150cm, E=51-100cm, F=31-50cm, G=11-30cm, H= 0-10cm) Verma, *et al.*, 2012. To assess the seed fall density, seedling recruitment and mortality, ten seed traps 1×1 m^2 size were placed randomly in the study sites. Seed size and weight was estimated following Tewari *et al.*, 2011. Seed traps were placed directly on the forest floor with side extending upwards=5cm. Seeds were collected from the traps every week from end of July to end of August. Quadrats (1×1 m^2 size) were set adjacent to each seed trap in August 2005 (good seed year), within which newly recruited seedlings were tagged individually in December 2005, when they were 2-3cm in height and subsequently monitored for survival till July 2009 on seasonally intervals. The seedlings recruitment in poor seed year which were very low in number were neglected within the traps. All data were analyzed by using statistical software SPSS (Statistical package for social Sciences) Version 16.0.

Results

Vegetational Parameters

The total density of trees on northern aspect was 420tree $ha^{-1}$and the total basal area of all the tree species was 31.18m^2ha^{-1}. *Q.semecarpifolia* had maximum density of 410trees ha^{-1} and the total basal area was 31.10m^2ha^{-1}. The total density of tree on southern aspect was 490 trees $ha^{-1}$and the total basal area of all the tree species was 12.23m^2ha^{-1} (Table 1).

Table 1: Vegetational parameters of tree species in *Quercus semecarpifolia* dominated forest of China Peak at northern aspect and southern aspect (MBA= mean basal area, TBA= Total basal area, IVI= Important value index).

Aspects	Species occurs	Density (ind ha^{-1})	TBA (m^2ha^{-1})	IVI
Northern aspect	*Q. semecarpifolia*	410	31.10	289.32
	R. arboretum	10	0.08	10.65
	Total	420	31.18	299.97
Southern aspect	*Q. semecarpifolia*	490	12.23	300
	Total	490	12.23	300

Table 2: The mean annual seed fall density (±SE) on northern aspect and southern aspect at China peak forest site of *Q. semecarpifolia* dominated forest. The values are in seeds m^{-2}.

Year	Northern Aspect (Seeds/m^2)	Southern Aspect (Seeds/m^2)
2004	1.2 ± 0.358	0.66 ± 0.22
2005	22.8 ± 1.24	26.02 ± 0.90
2006	5.1 ± 0.58	8.22 ± 0.77
2007	1.4 ± 0.20	4.5 ± 0.61
2008	8.5 ± 0.74	8.2 ± 0.73
2009	1.6 ± 0.22	5.32 ± 0.78

At southern aspect, the majority of trees (approximately 75%) of *Q. semecarpifolia* were between 251-300cm girth classes (old growth forest) and at the northern aspects the population of relatively younger trees was higher compared to southern aspect with 60% trees between 201-250cm and 15% trees between 251-300cm girth classes with some young regeneration. Absence of saplings and seedling was evident at southern aspect (Fig.1).

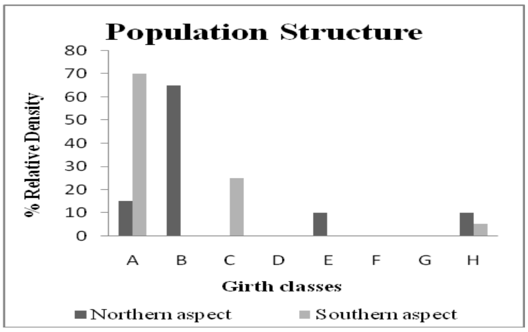

Figure 1: Population structure of *Quercus semecarpifolia* in Northern and Southern aspect at China Peak site. Girth classes have been divided into following (A= 251-300cm, B= 201-250cm, C= 151-200cm, D= 101-150cm, E= 51-100cm, F= 31-50cm, G= 11-30cm, H=0-10cm).

Seed fall density

During the study period from 2004 to 2009 only one good seed crop occurred i.e., in 2005. In this year at northern aspect, the average seed fall density was 22.8 ±1.24 seeds m^{-2} and at southern aspect it was 26.02 ± 0.90 seed m^{-2}. Across the aspects, the seed size ranged between 7.0 and 12.03 cm^2 and seed fresh weight 6.2-8.2g $seed^{-1}$ and the mean dry weight was 4.1g $seed^{-1}$. In 2008 the seed fall density on the northern aspect was 8.5±0.73 seeds m^{-2} and on the southern aspect it was 8.2 ±0.73 seed m^{-2}. The seed fall density was relatively low in other years and did not play an important role in seedling recruitment. In the years 2004, 2007 and 2009 a negligible seed crop was produced (Fig.2).

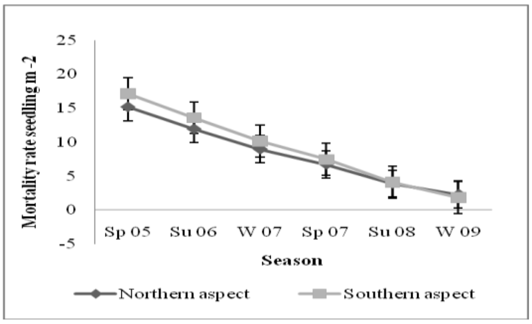

Figure 2: Decline in seedling number per meter² on the two aspects observed over four-year period (2005-09) seasonally (winter=w, spring=sp, summer-su) started from spring 2005.

Seedling recruitment and Survival

In year 2005, new recruitment of seedling from fallen seeds occurred in August and it ranged from 60-75% at both the aspects. Maximum seedling mortality was in the 1st year of recruitment in the winter and summer season, thereafter, rate of mortality declined between 2nd and 5th year of recruitment. In poor seed years only 8-23% recruitment occurred and the seedling did not survive more than one year after recruitment. Across the aspects seedling mortality ranged from 85-95%. At the end of observation after six years the total mean seedling density at northern aspects was 1.41 seedling $m^{-2}$and at southern aspects; it was only 0.67 seedling m^{-2} (Fig.2). The height of existing seedlings ranged from 12cm to19 cm. The seedling survival between the two aspects did not vary significantly. Survival of seedlings in traps was significantly correlated with the season (n=260), r^2= -0.953 ($p<0.001$). Interaction between survival of seedlings in traps and seed fall density varied significantly ($p <0.001$).

Discussion

Q. semecarpifolia, a high-altitude tree species produces seed crops that vary widely in quantity from year to year (mast crop or no crop). The study observed seedling dynamics along with seed fall density of this important Himalayan oak species. Forest degradation is quite common in the Himalaya as a result of chronic disturbance where forest stock declines without perceptible change in area (Singh 2002). Due to of lopping of leafy branches seed set is reduced and grazing by domestic animals restricts seedlings from becoming saplings and saplings rarely into trees. *Q. semecarpifolia* produced seed crops that varied widely in quantity from year to year between 2004 to 2009 with only one good seed year in 2005. This is contrary to the earlier reports (Troup, 1921) that this species produces mast seed crops every 2-3 year intervals). Even though earlier studies suggest (Sork *et al.,* 1993) that acorn production in oaks is not simply a response to weather events, widening of gap in mast seed years in another higher altitude Oak *Quercus floribunda* (2000-2400m) is an indicator that rise in winter temperatures can severely effect seed production and germination (Joshi & Tewari, 2009). No long-term seed bank exists for oaks because acorns do not survive from year to year and this *Quercus* species being viviparous coincides its seed maturity with monsoon rains. Vivipary drastically reduces both natural and artificial store of seeds and the presence of large amount of food makes it a preferred species of domestic and wild animals. Of the total seed fall density only 50% of the seeds in good seed year germinated and developed into seedlings. The contribution of the good seed crops of 2005, in seedling survival at northern aspect was 1.41 seedling m^{-2} and at the southern aspects was 0.67 seedling m^{-2} at the end of study. It is evident that the seedling numbers may decline further and may stabilize after 12-13 years as reported by Joshi & Tewari, 2009 for *Q. floribunda*. Cattle, goat and sheep eat the seedling and leaves of *Q. semecarpifolia* especially during the lean months or during dry season from February to April when other green fodder is not available. Herbivore mammals may eat the whole seedling before it becomes woody. Therefore, exclusion of mammals from the forest significantly reduces seedling mortality rates.

Difficulty in the regeneration of oaks has also been reported by Abrams, 1992; Buckley et al. 1998 from North American Forests. Much of the problem of failure of brown oak to regenerate is related to the way humans use this high-altitude species. However, the effect of climate factor cannot be ruled out, as the area of this oak is indicated to have declined in Himalaya during the warming phase in the past (Singh and Singh, 1992). The species must shift its distributional range toward higher altitudes with rise in climatic temperature. In higher altitudes, the land available for its occupation would decline with increasing elevation. Slow soil formation and high soil in-fertility or steep slopes may further limit migration of these oak to higher ranges. The distributional area of brown oak is likely to be smaller, fragmented and in isolated patches with expected climatic warming. Initial indication based on results of regeneration on two aspects indicates that *Q. semecarpifolia* appears to be one of the first major forests forming tree species that is facing the threat of extinction due to climatic irregularities and anthropogenic pressure. According to Joshi & Tewari (2009) winters have become milder and there has been a perceptible rise in the winter temperature over a fifteen-year period (1990-2005). Similar trends were also observed in the climatic data of present study. On the southern aspect, which had comparatively older forest, the mortality rate after four years of observation (after 2005) was similar to the northern aspect. Grazing and other biotic disturbance may have a bearing but do not appear to be the only reasons for limited survival of the species. Decrease in number of masting years, enhanced evapo-transpiration rates and resultant water stress because of rising winter temperature and unpredictable rainfall pattern coupled with biotic disturbance may be instrumental for low survival of seedlings.

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