Spatial distribution and regeneration of *Quercus semecarpifolia* and *Quercus floribunda* in a subalpine forest of western Himalaya, India

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Abstract Studies were conducted on population status and regeneration of *Quercus semecarpifolia* and *Quercus floribunda* in a subalpine forest of western Himalaya. Saplings of *Q. semecarpifolia* belonging to the 51–100 cm size class and those of *Q. floribunda* belonging to the 101–150 cm size class were well represented in studied subalpine forests. Comparable seedling emergence and establishment of both species, either in the habitat dominated by same or different species seems to be an adaptational strategy of these species in subalpine forests. Seedling to tree ratio for *Q. semecarpifolia* was higher in the stand dominated by *Q. floribunda*, while comparable pattern was observed for *Q. floribunda* in the stand dominated by *Q. semecarpifolia*. Establishment of higher percent of seedlings of one species in the habitats dominated by another species of *Quercus* appears to indicate an oligarchic nature of oaks in subalpine forests. This study describes regeneration strategies, and spatial distribution of these species in a subalpine forest of Uttarakhand.

Keywords Adaptation strategy · Oaks · Oligoarchic · Subalpine forests · Survivorship

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Introduction

Along an altitudinal gradient in western Himalaya the distribution of Oaks (*Quercus* sp.; Family Fagaceae) is specific. *Q. leucotrichophora* occurs in between 1,000 to 2,500 m asl and subsequent to that, *Q. lanata*, *Q. floribunda* and *Q. semecarpifolia* grows up to subalpine forests (SAFs). Almost 35 species of oaks are important sources of fodder, fuel wood, charcoal, agricultural tools and bee boxes in Indian Himalaya (Negi and Naithani 1995). Oaks forests are also considered as established and climax communities (Singh and Singh 1992), however, these species are also vulnerable to climate change (Bisht and Kuniyal 2013). Seeds wastage due to frugivory, inadequate regeneration, low establishment of seedlings and trampling driven damages to seedlings caused by browsing animals are attributed as key reasons for degradation of oaks forest (Thadani and Ashton 1995). *Q. semecarpifolia* (brown oak, vern. Kharsu) and *Q. floribunda* (green oak, vern. Moru) with *Abies spectabilis*, *Betula alnoides* and *Acer caesium* are some of canopy dominant trees in SAFs of western Himalaya (Singh and Singh 1992). Strategies adopted by oaks for maintaining stands structure in harsh climatic conditions of SAFs needs to be studied for determining effective management plans. This communication reports habitat preferences, distribution pattern, regeneration strategies and phenology of *Q. semecarpifolia* and *Q. floribunda* in relation to ambient variables in a SAF area of Uttarakhand.

Materials and methods

Study area

Thorough reconnaissance of a SAF area namely Panar (along ~3,100 to 3,400 m asl; southeast to southern aspects with moderate to sharp slopes) in district

Chamoli, Uttarakhand, was undertaken for studying spatial distribution and regeneration of *Quercus semecarpifolia* and *Q. floribunda*. On the basis of species of *Quercus* dominating habitat, two stands namely; *Q. semecarpifolia* stand and *Q. floribunda* stand were selected at approximately 1.5 km apart. Average air temperatures in this area were recorded 14.6 ± 0.04 °C to 14.8 ± 0.02 °C (max.) during June and 1.2 ± 0.01 °C to 1.3 ± 0.02 °C (min.) during October (Table 1).

Analysis and characteristics of soils

Randomly collected composite soil samples from the depth of 0–30 cm were oven dried at 55 ± 2 °C. Munsell's soil colour chart (Munsell colour division, Baltimore, Maryland, USA) was followed for determining soils colour. Soils texture was determined with the help of textural triangle method. Soil pH was estimated with electronic pH meter (1012 E, ESIC). Total nitrogen content (N %) was estimated using *Microkjeldhal* apparatus (Allens 1974) and phosphorus content (P, Kg·ha⁻¹) was estimated through spectrophotometry (DU-640 series spectrophotometer, Beckman, USA) method (Jones et al. 1991). Potassium contents (K, Kg·ha⁻¹) and organic carbon contents (C; %) were estimated as per the methods suggested by Okalebo et al. (1993).

Soils characteristics of *Q. semecarpifolia* and *Q. floribunda* habitats also varied (Table 1).

Population analysis

Selected stands were sub-divided in 03 vertical transects (at an approximate distance of 250 ± 50 m). Quadrat method was adopted for counting seedlings, saplings and mature trees (Kershaw 1973). Randomly a total 15 quadrat (10×10 m; 100 m^2) in each transects were laid (thus, a total 45 quadrat were laid in each stand). Obtained data were used for calculating frequency, density, abundance, abundance/frequency (A/F) ratio and total basal cover (TBC) as per the methods suggested by Tiwari (2005). Recorded individuals of both species were categorised as seedling (height <20 cm), sapling (diameter at breast height; DBH <10 cm and height >20 cm) and mature tree (DBH >10 cm) as per Deb and Sundriyal (2008). Based on circumference at breast height (CBH), growth stages of the individuals were divided in five size classes, viz. 10–50 cm, 51–100 cm, 101–150 cm, 151–200 cm and 201–250 cm. Dominance of particular life class was determined through percent density of seedlings, saplings and mature individuals. Importance value index (IVI) was calculated by following the method of Curtis and McIntosh (1950).

Table 1 Characteristics of *Quercus semecarpifolia* and *Q. floribunda* stands in selected subalpine forests

Sites and soils characteristics	Stands	
	<i>Q. semecarpifolia</i>	<i>Q. floribunda</i>
Altitude (m asl)	3245–3363	3223–3363
Geographical location	30°28'05"–30°28'08" N 79°21'30"–79°21'39" E	30°28'29"–30°28'32" N 79°21'10"–79°21'20" E
Average temperature		
Maximum (° C)	14.8±0.02 (June)	14.6±0.04 (June)
Minimum (° C)	1.2±0.01 (Oct)	1.3±0.02 (Oct)
Aspect	South-East	South
Forest type	Moist temperate evergreen	Moist temperate evergreen
Slope angle	Moderate	Sharp
Dominant species	<i>Quercus semecarpifolia</i>	<i>Quercus floribunda</i>
Sub-dominant species	<i>Quercus floribunda</i>	<i>Quercus semecarpifolia</i>
Associated species	<i>Abies spectabilis</i> , <i>Taxus baccata</i>	–
Soil characteristic ^a		
Texture	Loam	Sandy loam
Colour	Brown	Dark brown
Moisture content (%) ^b	48.78±7.38	49.67±6.16
pH ^b	6.66±0.22	6.45±0.43
N (%) ^b	0.58±0.15	0.59±0.23
P (Kg ha ⁻¹) ^b	13.47±3.29	10.87±2.86
K (Kg ha ⁻¹) ^b	233.00±28.59	249.81±25.64
OC (%) ^b	2.3 ±0.32	2.26±0.44

^a±SD, n=8

^bAverage of values obtained from monthly estimations during April to October

Regeneration status, survivorship, analysis of static life classes

Regeneration status was determined on the basis of density as per Deb and Sundriyal (2008). Regeneration status was categorised as, good: if seedlings >saplings >mature trees, fair: if seedlings >saplings ≤mature trees, poor: seedlings and mature trees only (saplings are absent) and none: if only mature trees are present (seedlings and saplings are absent). Total regeneration was determined by totalling the density of seedlings and saplings of particular species. Seedlings-trees ratio and saplings-tree ratio was also calculated. Static life classes such as survivorship, mortality, life expectancy etc. for each size class of *Q. semecarpifolia* and *Q. floribunda* in both stands were also calculated as per Begon et al. (1996).

Phenology

A total 90 mature-healthy trees of each species in selected stands (30 trees/transect with 3 transects per stands) were marked for noting observations on phenology (vegetative phenophases: leaf and shoot bud initiation/elongation or growth, leaf fall and reproductive phenophases: flowering, fruiting, seeds maturation and dehiscence and germination) during snow free months (April to October) at an interval of approximately 10 days. Particular vegetative or reproductive phenophases commencing in >5 % marked trees was considered as initiation and remaining in <5 % was considered as cessation of phenophases as per Nautiyal et al. (2001).

Results

Population survey and distribution pattern

The frequency of mature trees of *Q. semecarpifolia* and *Q. floribunda* was 100 %. Whereas, abundance of *Q. semecarpifolia* was 3.40 in the stand dominated by this species and 6.20 for *Q. floribunda* in the stand dominated by *Q. floribunda*. Distribution pattern (A/F ratio) of *Q. semecarpifolia* and *Q. floribunda* in *Q. semecarpifolia* and *Q. floribunda* stands was 0.034 and 0.062 respectively. Total basal cover (TBC: m²·ha⁻¹) for *Q. semecarpifolia* was 48.51±6.82 in *Q. semecarpifolia* stand and 3.10±0.26 in *Q. floribunda* stand. TBC for *Q. floribunda* was 103.98±5.63 and 0.023±0.001 in *Q. floribunda* and *Q. semecarpifolia* stands. Importance value index (IVI) was 137.66 and 284.88 for *Q. semecarpifolia* and *Q. floribunda* respectively in *Q. semecarpifolia* and *Q. floribunda* stand. Tree density (individual's ha⁻¹) for *Q. semecarpifolia* was 340 in the stand dominated by this species, and 20 in the *Q. floribunda* dominated stand. Tree density of *Q. floribunda* was 620 in the stand dominated by this species, and 20 in *Q. semecarpifolia* dominated stand.

Seedlings density (individual's ha⁻¹) was 18 for *Q. semecarpifolia* and 06 for *Q. floribunda* in the *Q. semecarpifolia* stand. In *Q. floribunda* stand, the seedlings density was 02 for *Q. semecarpifolia* and 24 for *Q. floribunda*. Saplings density (individual's ha⁻¹) was 07 and 02 respectively for *Q. semecarpifolia* and *Q. floribunda* in *Q.*

Table 2 Distribution of *Quercus semecarpifolia* and *Q. floribunda* in selected stands

Parameters	<i>Quercus semecarpifolia</i>		<i>Quercus floribunda</i>	
	<i>Q. semecarpifolia</i>	<i>Q. floribunda</i>	<i>Q. floribunda</i>	<i>Q. semecarpifolia</i>
Seedling density ^a	18 (4.93±1.44) ^d	06 (21.43±2.81)	24 (3.70±0.59)	02 (8.33±0.70)
Sapling density ^a	07 (1.92±0.15)	02 (7.14±0.32)	05 (0.77±0.04)	02 (8.33±0.61)
Tree density ^a	340 (93.15±8.21)	20 (71.43±15.53)	620 (95.53±6.69)	20 (83.34±18.21)
Seedlings-trees ratio (ha ⁻¹)	0.05	0.30	0.04	0.10
Saplings-trees ratio (ha ⁻¹)	0.02	0.10	0.01	0.10
Total Regeneration (ha ⁻¹) ^b	25	08	29	04
Regeneration status	Fair	Fair	Fair	Fair
Frequency (trees)	100	20	100	10
Abundance (trees)	3.40	1.00	6.20	2.00
Distribution pattern (trees) ^c	0.034	0.050	0.062	0.200
TBC (trees m ² ha ⁻¹)	48.51±6.82	0.023±0.01	103.98±5.63	3.10±0.26
Importance value index (IVI)	137.66	12.01	284.88	15.11

^a Individuals ha⁻¹

^b Seedlings + saplings density

^c Abundance frequency ratio

^d Values in parenthesis are percent of total individual, ±-S.E.

semecarpifolia stand. Saplings density of *Q. semecarpifolia* and *Q. floribunda* was 02 and 05 respectively in *Q. floribunda* stand. Seedlings-trees ratio for *Q. semecarpifolia* was 0.05 in *Q. semecarpifolia* stand and 0.10 in *Q. floribunda* stand while, seedlings-trees ratio for *Q. floribunda* was 0.04 in *Q. floribunda* stand and 0.30 in *Q. semecarpifolia* stand. Saplings-trees ratio for *Q. semecarpifolia* and *Q. floribunda* was 0.02 and 0.01 respectively in *Q. semecarpifolia* and *Q. floribunda* stand (Table 2).

Regeneration status and survivorship

Total regeneration of *Q. semecarpifolia* and *Q. floribunda* was 25 and 29 in the stands dominated by these species. The regeneration of both species was fair (Table 2). In *Q. semecarpifolia* stand, the density of *Q. semecarpifolia* was decreasing from seedlings to saplings. Mature individuals of *Q. semecarpifolia* in 51–100 cm size class were represented well (130 ± 21.63) in *Q. semecarpifolia* stand, while mature

Table 3 Static life classes of *Quercus semecarpifolia* and *Q. floribunda* in the selected stands

<i>Quercus semecarpifolia</i> dominated							
Size Class ^a (Based on CBH)	<i>Quercus semecarpifolia</i>						
	a_x	l_x	d_x	q_x	L_x	T_x	e_x
Seedlings	18±6.00	1.00±0.00	0.63±0.11	0.63±0.11	0.68±0.05	20.06±4.20	20.06±4.20
Saplings	07±6.00	0.37±0.11	-0.66±0.11	-1.89±0.49	1.01±0.09	19.38±3.95	60.89±32.11
10–50 cm	30±10.15	1.66±0.11	-6.78±2.28	-4.13±1.60	4.55±0.84	18.37±4.35	11.16±3.14
51–100 cm	130±21.63	7.45±1.78	-6.01±1.62	-0.81±0.15	7.23±1.61	13.82±3.63	1.87±0.33
101–150 cm	120±8.54	7.01±1.62	-1.45±1.05	-0.19±0.11	4.73±1.06	6.58±2.18	0.93±0.13
151–200 cm	40±7.55	2.45±1.05	0.58±0.73	0.24±0.32	1.86±0.89	1.86±0.89	0.74±0.45
201–250 cm	20±6.08	1.27±0.73	–	–	–	–	–
<i>Quercus floribunda</i>							
	a_x	l_x	d_x	q_x	L_x	T_x	e_x
Seedlings	06±2.64	01±0.00	2.70±1.33	2.70±3.51	0.65±0.06	4.28±0.55	4.28±0.55
Saplings	02±1.73	0.30±0.13	-0.03±0.16	-0.05±0.18	0.31±0.06	3.63±0.62	14.21±7.01
10–50 cm	02±1.00	0.33±0.07	-1.20±0.35	-3.68±0.56	0.93±0.24	3.32±0.67	10.57±3.50
51–100 cm	09±3.60	1.53±0.41	-0.35±0.96	-0.17±0.66	1.58±0.45	2.40±0.60	1.63±0.57
101–150 cm	07±1.73	1.30±0.61	0.95±0.49	2.89±1.17	0.82±0.37	0.82±0.37	0.63±0.04
151–200 cm	02±1.00	0.34±0.15	–	–	–	–	–
201–250 cm	–	–	–	–	–	–	–
<i>Quercus floribunda</i> dominated							
Size Class (Based on CBH)	<i>Quercus floribunda</i>						
	a_x	l_x	d_x	q_x	L_x	T_x	e_x
Seedlings	24±3.00	1.00±0.00	0.78±0.11	0.78±0.11	0.60±0.05	26.55±3.16	26.55±3.16
Saplings	05±2.00	0.22±0.11	-1.08±0.32	-6.36±4.96	1.15±0.16	25.94±3.10	140.49±65.23
10–50 cm	50±11.53	2.08±0.32	-7.36±0.48	-3.59±0.48	5.21±0.36	24.79±3.04	12.14±2.29
51–100 cm	200±19.16	8.36±0.48	-10.05±2.63	-1.19±0.25	9.68±1.48	19.58±2.84	2.33±0.24
101–150 cm	260±29.21	11.05±2.63	-3.16±0.02	-0.30±0.07	7.61±1.31	9.90±1.36	1.02±0.13
151–200 cm	100±13.00	4.16±0.02	0.57±0.14	0.14±0.04	2.29±0.06	2.29±0.06	0.55±0.02
201–250 cm	10±2.64	0.43±0.14	–	–	–	–	–
<i>Quercus semecarpifolia</i>							
	a_x	l_x	d_x	q_x	L_x	T_x	e_x
Seedlings	02±1.73	0.67±0.58	0.22±0.19	0.22±0.19	0.55±0.48	5.22±4.57	5.22±4.57
Saplings	02±1.15	0.45±0.39	-0.11±0.19	-0.16±0.28	0.50±0.44	4.99±4.48	7.46±6.69
10–50 cm	02±1.00	0.56±0.51	1.45±1.35	-1.72±1.49	1.28±1.18	4.50±4.04	5.43±4.71
51–100 cm	10±2.64	2.00±1.85	0.67±1.15	0.18±0.31	1.67±1.45	3.22±2.87	1.09±0.96
101–150 cm	05±2.00	1.33±1.20	0.22±0.69	0.08±0.31	1.22±1.06	1.22±1.06	0.76±0.69
151–200 cm	03±2.00	1.11±1.02	–	–	–	–	–
201–250 cm	–	–	–	–	–	–	–

^a a_x : the age class or size class; a_x : the survival individual; l_x : proportion of original number of individual surviving to the next stage, survivorship, $l_x = a_x/a_0$; d_x : the proportion of original number of individual dying during each life class, mortality, $d_x = a_x - a_0/a_x$; q_x : the survivorship from one size class to next, $q_x = d_x/l_x$; L_x : mean number of survived individual from one size class to next, $L_x = (l_x + l_{x+1})/2$; T_x : the total number of survived individuals from one age class to another, $T_x = \sum L_x$; and e_x : the life expectancy at age x , $e_x = T_x/l_x$.

individual of *Q. floribunda* in 101–150 cm size class were also well represented (260 ± 29.21) in *Q. floribunda* stand. Density of mature individuals of both species was better for 51–100 cm size class in *Q. semecarpifolia* stand. In *Q. floribunda* stand, density of dominant species was higher for the individuals of 101–150 cm size class. The proportion of individuals having low survival was high in seedlings size class while saplings were noted to have better life expectancy and survivorship for both the species in both stands. Individuals of *Q. floribunda* belonging to the 201–250 cm size class were absent in *Q. semecarpifolia* stand (Table 3).

Phenology

Vegetative phenophase including shoot and leaf bud initiation/elongation and simultaneous leaf fall in *Q. semecarpifolia* and *Q. floribunda* was initiated in April and May. Male and female floral spikes blossomed consequently after the development of new shoots. Fruiting in *Q. semecarpifolia* and *Q. floribunda* occurs during May to July and fruits set in the previous year were maturing during June and July. Seeds dispersal was started June onwards to July. Seedlings emergence from freshly fallen acorns commenced during July–August and some time it was continuing up to September.

Discussion

Quercus semecarpifolia and *Q. floribunda* were observed to prefer diverse aspects. *Q. semecarpifolia* was growing in the habitat along south-east facing aspects with moderate slopes while, *Q. floribunda* was growing along south aspects with sharp slopes. *Abies spectabilis* and *Taxus baccata* were main conifers associated with *Q. semecarpifolia* while none of the conifers were found associated with *Q. floribunda* in selected study area. Frequency, density, abundance and distribution patterns indicated that the distribution of *Q. semecarpifolia* and *Q. floribunda* was regular in home stands. High density of the individuals of particular size class such as 51–100 cm size class (*Q. semecarpifolia*) and 101–150 cm size class (*Q. floribunda*) in the stands dominated by these species was important characteristic in selected sub-alpine area. Presence of few seedlings as compared to mature trees has indicated that interrupted regeneration pattern is common for the oaks in the SAF area. Periodic production of seeds by the oaks in the sub-alpine forest may be the reason for better seedlings establishment (Singh et al. 2011). Reports are also available on continuous nature of regeneration in the *Quercus* species (Selvi and Valleri 2012). Oligoarchic tendency and preferences of diverse aspect by oaks is reported to be an interesting character (Shrestha 2003).

Q. semecarpifolia and *Q. floribunda* in dominant stands showed the low seedling-tree ratio as compared to the stand not dominated by these species. Saplings (%) of *Q. semecarpifolia* and *Q. floribunda* were less in the stands selected as to the seedlings percentages. Almost 39 % seedlings of *Q. semecarpifolia* and 21 % seedlings of *Q. floribunda* were able to survive up to sapling stage. Majority of the biological events in *Q. semecarpifolia* and *Q. floribunda* were in the optimum phase during July and August. Spatial distribution of *Quercus semecarpifolia* and *Q. floribunda* in relation to ambient eco-physiological conditions seems to be a useful potential for thriving. Protection of branches from massive lopping for adequate seeds production and avoiding over grazing for reducing trampling damages may be useful for management of oaks forest (Shrestha 2003).

Conclusion

Distribution of *Q. semecarpifolia* and *Q. floribunda* was observed to be specific in relation to the habitats preferences. Successful establishment of seedlings, tendency to form pure stands and completion of important vegetative and reproductive phenophases during favourable season seems to be an eco-physiological adaptation of *Quercus semecarpifolia* and *Q. floribunda* in the selected SAF area of western Himalaya.

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