Community Structure and Growing Stock Variations in *Quercus floribunda* Forest on Different Aspects of Garhwal Himalaya

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Abstract

The community structure and growing stock variations were studied in moist temperate *Quercus floribunda* forest on four different aspects and altitudes in Garhwal Himalaya during the year 1996. The total density and basal cover values in the tree layer varied from 250 to 340 trees/ha and 18.44 to 38.24 m^2/ha respectively. The maximum number of saplings (400 saps/ha) of *Quercus floribunda* were observed on the hill base of SE aspect, whereas, the lowest number of saplings (80 saps./ha) on the hill top of NW aspect. The maximum (1.8131) and minimum (1.4717) diversity values were reported for NE and SE aspects respectively. The highest total growing stock (349.0 m^3/ha) was observed on SW aspect. On NE aspect a strong positive correlation (r=+0.88) was observed between the growing stock values and diameter classes. Physicochemical properties of soils were found to be promising for the growth of *Quercus floribunda* forest on northern aspects as compared to southern aspects.

সারসংক্ষেপ

১৯৯৬ সনে গাড়োয়াল হিমালয় পাহাড়ের চারটি পাশ ও বিভিন্ন উচ্চতায় নাতিশীতোষ্ণ আর্দ্র *Quercus floribunda* বনাঞ্চলের সম্প্রদায়গত আকৃতি এবং সংখ্যা নির্ণয় করা হয়। বৃক্ষের মোট সংখ্যা হেক্টর প্রতি ২৫০-৩৪০টি এবং বৃক্ষ দ্বারা আচ্ছাদিত বনভূমি ১৮.৪৪ থেকে ৩৮.২৪ বর্গমিটার। *Quercus floribunda* এর সর্বাধিক সংখ্যক চারাগাছ (হেক্টর প্রতি ৪০০টি) দেখা গেছে পাহাড়ের গোড়ায় দক্ষিণ-পূর্ব পাশে এবং সর্বনিম্ন সংখ্যক চারাগাছ (হেক্টর প্রতি ৮০টি) দেখা গেছে পাহাড়ের উপরিভাগে উত্তর-পশ্চিম পাশে। সবচেয়ে বেশী (১.৮১৩১) ও কম (১.৪৭১৭) ডাইভারসিটি মান পাওয়া গেছে পাহাড়ের যথাক্রমে উত্তর-পূর্ব ও দক্ষিণ-পূর্ব পাশে। বিভিন্ন প্রকার উঠতি গাছের বিস্তৃতি সর্বোচ্চ (৩৪৯.০ ঘন মিঃ/হেঃ) পাওয়া যায় পাহাড়ের দক্ষিণ-পশ্চিম পাশে। উত্তর-পূর্ব পাশে উঠতি গাছের মান বনাম ব্যাস শ্রেণীর মধ্যে একটি উল্লেখযোগ্য ধনাত্মক সম্পর্ক (r=+০.৮৮) দেখা যায়। দক্ষিণ পাশের তুলনায় উত্তর পাশে *Quercus floribunda* বনের বৃদ্ধিতে মাটির ফিজিকো-কেমিক্যাল গুণাবলী খুবই উৎসাহব্যঞ্জক।

Key words: Aspect, diversity, growing stock, soil analysis, structure, temperate forest

Introduction

The *Quercus floribunda* Lindle (moru oak) forests are found fairly distributed from 1800 to 2600 m above sea level in the western Himalayan region in between the banj oak and kharsu oak forest types. This type is more luxuriant than the banj oak, and forms some of the finest moist temperate broad leaved forest cover types in this region. The height of trees with relatively long clean boles ranges typically from 20 m to over 30 m. But due to heavy lopping pressure for fuel and fodder the quality class of this type of forest has decreased considerably. As a result the area under these forests have dwindled markedly, particularly in recent years due to increased population pressure. The structure, diversity and regeneration of different oak forests of Kumaon Himalaya have been described by Upreti *et al.* (1985), Singh and Singh (1992) and Thandani and Ashton (1995). The oak forests of Garhwal Himalaya have been studied for structure, succession and impact of biotic stress by Rajwar (1988), Tripathi *et al.* (1991), Kusumlata and Bisht (1991), Agrawal *et al.* (1993), and Baduni and Sharma (1996).

In the present study, an attempt has been made to evaluate the growth performance of *Q. floribunda* with reference to growing stock variation on different aspects, slopes and altitudes in response to major physico-chemical properties of soil on four different aspects of Garhwal Himalaya.

Materials and methods

For the present study, four sites on different physiographic aspects with visually different associated vegetation in *Quercus floribunda* cover type were selected for the phytosociological and inventory studies in the district Pauri Garhwal. The North East (2550 m) and North West (2400 m) aspects of *Quercus floribunda* forest were analysed in Dudhatoli range, whereas, the South East (2260 m) and South West (2300 m) aspects were studied respectively at Bharsar and Chaunrikhal forest ranges of Pauri forest division of the district Pauri Garhwal (Fig. 1). The climate of the area is moist temperate receiving moderate to heavy snowfall from December to February. The mean annual rainfall was observed as 1825 mm with maximum rainfall during July-August and minimum in November. The mean monthly temperature in these zones ranged from 3^0C (January) to 17.5^0C (June).

The *Quercus floribunda* was found to be associated mainly with *Rhododendron arboreum* on all the aspects. Generally *Symplocus crataegoides, Prunus cornuta* and *Acer acuminatum* on NE aspect, *Abies pindrow* and *Lindera pulcherrima* on NW aspect, *Symplocus crataegoides* and *Fraxinus micrantha* on SE aspect and *Quercus leucotrichophora* and *Ilex dipyrena* on SW aspect were some of the associated major companion species.

The undergrowth generally comprised of *Berberis chitria, Berberis lycium, Prinsepia utilis, Daphne papyracea, Cotoneaster* spp. *Sarcococca saligna* and *Benthamidia capitata* with dense growth of *Arundinaria* spp. There were considerable number of climbers, which were found to grow in these forests due to humid atmosphere all the year around, the common ones were *Clematis nepalensis* and *Schisandra grandiflora.*

The phytosociological analysis of the vegetation was done on each site by using 10 randomly placed quadrats. The size (10 m x 10 m) and number of the quadrats were determined by the species area curve (Misra 1968) and the running mean method (Kershaw 1973). The vegetation was quantitatively analysed for frequency, density and abundance following Curtis and McIntosh (1950). The relative values of frequency, density and dominance were determined as per Phillips (1959). These values were summed to represent IVI (Importance Value Index) of individual species (Curtis 1959). The circumference at breast height (cbh) of trees (i.e. at 1.37 m) was calculated on individual tree basis. The individuals with cbh more than 31.5 cm were considered as trees, those with 10.5-31.4 cm as saplings and those with <10.5 cm as seedlings (Knight 1963).

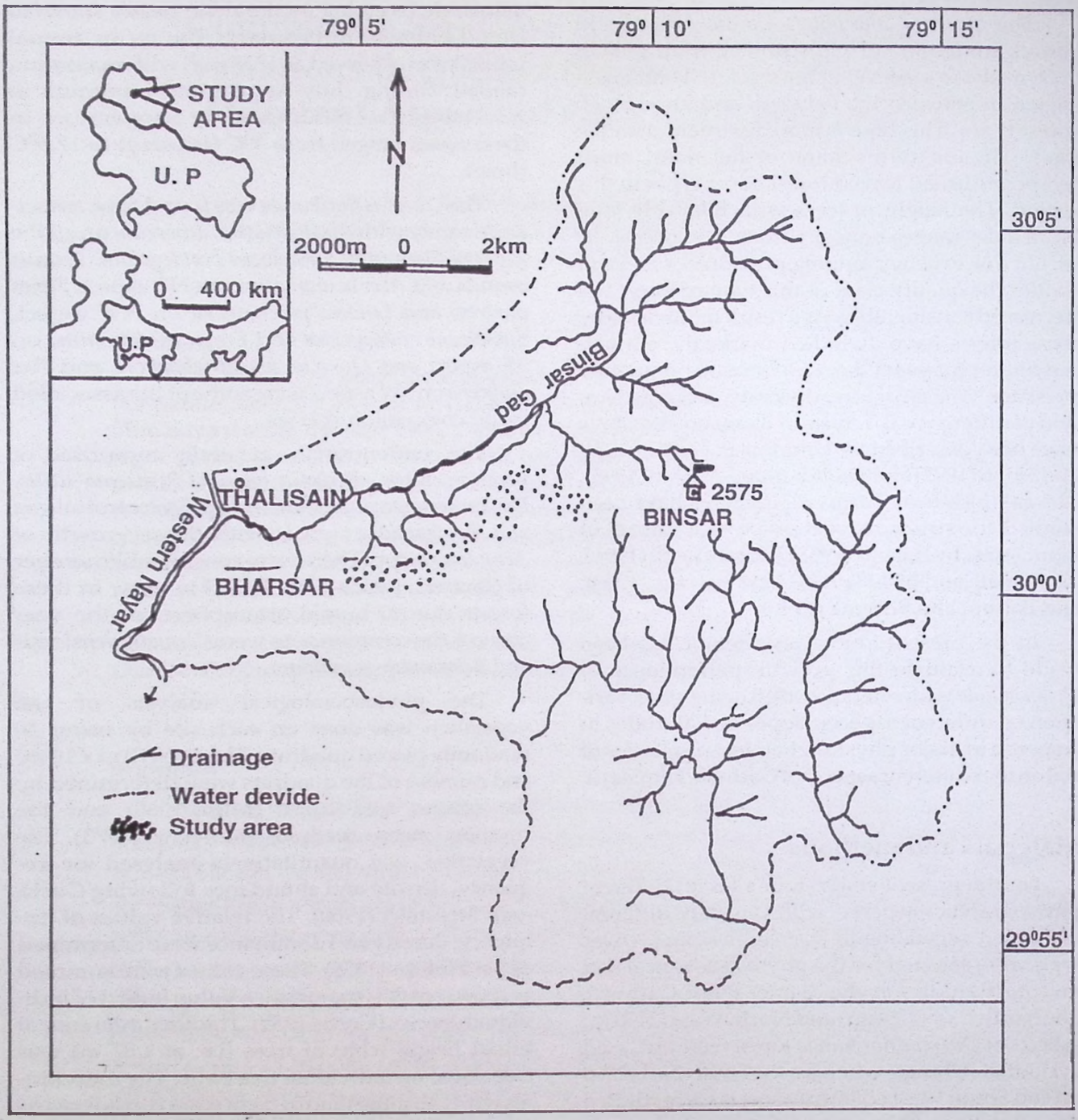

Figure 1. Location map of the study area.

The tree diversity (H) was determined by using Shannon-Wienner information function (Shannon-Wienner 1963). The concentration of dominance (cd) was measured by Simpson's index (Simpson 1949).

The total tree volumes were estimated with the help of standard volume equations or by standard volume tables using over bark diameter (d) at breast height (bh). The volumetric estimation of the important tree species was done on the basis of following standard volume tables/equations based on the Indian Forest Records released in the F. R. I. and F. S. I. publications for the respective species.

Abies pindrow	$V = 0.175070 + 0.226058\ D^2H$ (FSI 1985 b)
Acer spp.	$V = 0.38730 + 0.36230\ D^2H$ (FSI 1985 b)
Quercus floribunda	$V = 0.35601 + 0.351041\ D^2H$ (FSI 1985a)
Quercus leucotrichophora	$V = 0.014796 + 0.351041\ D^2H$ (FSI 1985 a)
Rhododendron arboreum	$V = 0.008169 + 0.298862\ D^2H$ (FSI 1985 b)

In very few cases, when the volume tables or volume equations for the desired species were not available, the volume was calculated by using volume tables/equations of similar species having similar height, form, taper, and growth rate.

The regression analysis between dhb classes and total growing stock data was done on the Microsoft Excel 1997 and Window 98 software programmes of computer for knowing the relationship between dbh and total growing stock values on each aspect.

The soil sampling was done along with forest sampling in the last week of September 1996, when the last monsoonic rains were over. The physico-chemical properties of the soil from each of the four study sites were analysed by collecting the samples from three different depths (surface : 0-10 cm; middle :11-12 cm; and lower : 21-30 cm horizons). The colour of the soil was directly detected with the help of Munsell Soil Colour Chart. The texture of the soil was assessed following USDA (1975). The moisture percentage and water holding capacity were determined as per Misra (1968) and the soil pH was measured with the standard paste technique using Ec and pH meters (Rhodes 1982). The organic carbon percentage was measured by potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement. Extractable phosphate was measured using sodium bicarbonate extracts (Oleson *et al.* 1954). Total nitrogen was measured using the standard Kjeldhal procedure (Bremner and Mulvaney 1982).

Results and discussion

Phytosociology

The maximum tree individuals of *Quercus floribunda* were observed on SE aspect (340 trees/ha) and minimum on NE and NW aspects (both 250 trees/ha). The maximum TBC (38.247 m^2/ha) was noticed on NW aspect and minimum (18.445 m^2/ha) on SW aspect. The maximum IVI (181.06) was observed on SE aspect and minimum (148.71) on SW aspect of the *Quercus floribunda* forest. The *Rhododendron arboreum* was found to be present (Table 1) as the main associated species on all the aspects (IVI 45.98 to 67.46). The moderate limits of the total basal cover (range 21.3- 83.8 m^2/ha) for extra moist temperate forest of the Himalaya have also been supported by the results of present study (Ralhan *et al.* 1982, Tripathi *et al.* 1991 and Bankoti *et al.* 1992).

The knowledge of the number of saplings per unit area is an index to the regeneration potential of the *Quercus floribunda* on different aspects. According to Singh and Singh (1992), the grazing by domestic animals has been noted as the basic cause of low oak regeneration in the central Himalayan forests. The highest number of saplings (400 saps./ha) of *Quercus floribunda* were observed on the hill base of SE aspect, whereas, the lowest number of saplings (80 saps./ha) were recorded on the hill top of NW aspect (Table 1). The regeneration potential in the Dudhatoli region (NE and NW aspects) was negligible due to close crown density and dense crown cover, which absolutely checked the germination of acorns. The

Table 1. Phytosociological analysis of *Quercus floribunda* forest on different aspects in Garhwal Himalaya.

Species	Aspect	Frequency (%)	Density (trees/ha)	TBC (m^2/ha)	Relative frequency (%)	Relative density (%)	Relative dominance (%)	IVI	Cd	H
Tree										
Quercus floribunda	North East	100	250	37.6099	40	52.08	79.44	171.52	0.3268	0.4610
Rhododendron arboreum		50	70	5.7210	20	14.58	12.08	46.66	0.0241	0.4174
Symplocos crataegoides		30	50	1.1436	12	10.43	2.41	24.54	0.0068	0.2973
Prunus cornuta		30	40	0.7961	12	8.33	1.68	22.01	0.0053	0.2762
Acer acuminatum		40	70	2.0738	16	14.58	4.38	34.96	0.0135	0.3612
									0.3765	**1.8131**
Sapling										
Quercus floribunda		60	200	0.7707	60	62.5	66.85	189.35	0.3979	0.4191
Rhododendron arboreum		40	120	0.3821	40	37.5	33.15	110.65	0.1360	0.5305
									0.5339	**0.9496**
Tree										
Quercus floribunda	North West	100	250	38.2474	40	51.02	78.65	169.67	0.3198	0.4649
Rhododendron arboreum		50	70	5.8962	20	14.28	12.12	46.40	0.0239	0.4162
Abies pindrow		50	60	2.5796	20	12.24	5.30	37.54	0.0156	0.3750
Lindera pulcherrima		50	110	1.9048	20	22.45	3.92	46.37	0.0238	0.4161
									0.3831	**1.6722**
Sapling										
Abies pindrow		60	240	1.2586	66.67	75	71.6	213.27	0.5052	0.3499
Quercus floribunda		30	80	0.4993	33.33	25	28.40	86.73	0.0426	0.4698
									0.5478	**0.8197**
Seedling										
Viburnum cotinifolium		60	24	0.8915	100	100	100	300	-	-
Tree										
Quercus floribunda	South East	100	340	23.0008	45.45	60.71	74.90	181.06	0.3642	0.4395
Rhododendron arboreum		60	120	5.7621	27.27	21.43	18.76	67.46	0.0505	0.4839
Sympolocos crataegoides		50	80	1.7639	22.72	14.29	5.74	42.75	0.0202	0.4003
Fraxinus micrantha		10	20	0.1840	4.54	3.57	0.60	8.71	0.0008	0.1480
									0.4357	**1.4717**
Sapling										
Viburnum continifolium		60	420	1.9968	37.50	52.94	41.54	131.98	0.1860	0.5231
Quercus floribunda		40	400	1.9672	37.50	29.41	40.93	107.84	0.1382	0.5305
Abies pindrow		60	240	0.8424	25.00	17.65	17.53	60.18	0.0387	0.4614
									0.3629	**1.5150**
Tree										
Qurecus floribanda	South West	100	290	18.4451	37.03	47.54	64.14	148.71	0.2456	0.5017
Rhododendron arboreum		60	80	3.0655	22.22	13.11	10.65	45.98	0.0234	04145
Quercus leucotrichophora		70	180	5.7787	25.92	29.51	20.09	75.52	0.0633	0.5007
Ilex dipyrena		40	60	1.4714	14.81	9.84	5.12	29.77	0.0098	0.3304
									0.3421	**1.7473**
Sapling										
Quercus floribunda		40	160	0.9286	40	44.44	66.52	150.96	0.2684	0.5393
Quercus leucotrichophora		40	160	0.2678	40	44.44	19.18	103.62	0.1297	0.5304
Rhododendron arboreum		20	40	0.1996	20	11.11	14.30	45.41	0.0148	0.3696
									0.4129	**1.4293**

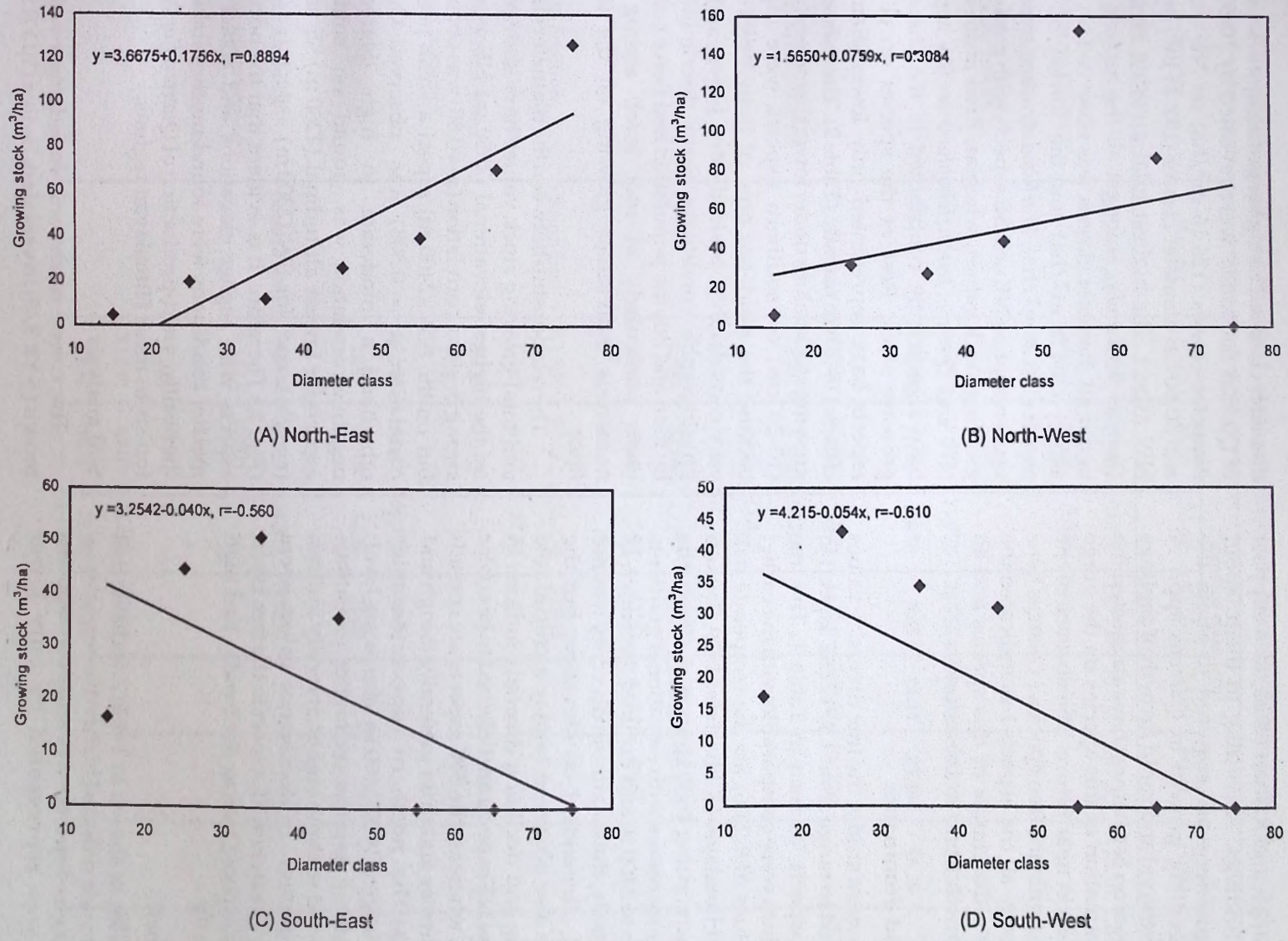

Figure 2. Relationship between DBH classes and Growing Stock value (m^3/ha) of *Quercus floribunda* forest on different aspects in Garhwal Himalaya.

findings of Singh and Ralhan (1985) also support the present findings. According to them, about 70% sloar radiations are required to attain the maximum seedling growth in *Quercus* spp. A high rate of survival and rapid growth of saplings of *Abies pindrow* on NW aspect have suggested the eventual domination of this species on the gorge valley portions in near future. The absence of the seedlings of dominant tree species (*Quercus floribunda*) on nearly all the aspects has indicated the formation of a dis-climax of this species and an abnormal growth trend in these forests.

Diversity and dominance

In the present study, the tree diversity values were observed to range from 1.4717 (SE aspect) to 1.8131 (NE aspect) as seen in Table 1. The tree diversity values were comparable with the earlier recorded values (0.8-2.06) for the temperate oak forests of the Himalayas (Rikhari *et al.*1989, Bankoti *et al.* 1992). According to Rikhari *et al.* (1989), the tree diversity increases with elevational gradients from 1900 up to 2400 m and declines thereafter. In the present study, the maximum diversity was not only found dependent on elevation, but the aspects were also observed to play a crucial role for increasing and declining diversity indices. In Himalaya, the NE aspects are believed to be cooler and moister, whereas, the SW aspects are considered to be warmer and drier generally (Singh and Singh 1992). The northern aspects on mid-elevational ranges (1900-2400 m above sea level) and the southern aspects on higher elevations have been found to show higher diversity indices. The concentration of dominance values were considerably greater on SE aspect in the tree layer, since on this aspect *Quercus floribunda* had high relative density.

Growing stock

The results, as shown in Table 2, indicate that *Quercus floribunda* reflected higher diameter classes on the northern aspects, whereas, on southern aspects it was represented by only lower diameter classes. The higher growing stock values of *Quercus floribunda* were revealed by 70-80 cm diameter classes (126.16 m^3/ha) on NE aspect, and 50-60 cm diameter classes (152.25 m^3/ha) on NW aspect. The highest total growing stock of *Quercus floribunda* amongst all the aspects and under all diameter classes was observed on NW aspect (304.26 m^2/ha) and the lowest on SW aspect (100.26 m^2/ha). The *Rhododendron arboreum* was present on NE and SE aspects with moderate growing stock values, whereas, *Abies pindrow* on NW and *Quercus leucotrichophora* on SW aspects have significantly contributed to the shares of growing stock. Rest of the species on all the aspects have represented only lower diameter classes (10-20 cm) mostly (Table 2). The maximum growing stock values under lower diameter classes (10-20 cm) on southern aspects were higher because the residence time of individuals may vary considerably, basically due to less suitable physiographic conditions, heavy discrimination by man and bovine population and fierce competition particularly at root level, among the numerous individuals growing on the forest floor.

The relationship between the diameter classes and total growing stock values have shown that on the highest elevational (2550 m) NE aspect a strong positive correlation (r=+0.88) was obtained, but on the NW (2400 m) aspect a weak positive correlation (r = 0.308) was observed. On the otherhand, a moderate to high degree of negative correlation was found on southern aspects for lowest altitudinal (2260 m) SE aspect (r=-0.56), and for SW (2300 m) aspect (r=-0.61) (Fig. 2.) Therefore, it is evident that the northern aspects with higher elevations and cooler and moister conditions were found more suitable for the healthy yield-production of *Quercus floribunda* forests in these Himalayan regions.

Soil analysis

The colour of the soil varied from reddish brown (5 YR 3/3) to very dark brown (10 YR 2/2).

Table 2. Growing stock estimation (m^3ha^{-1}) of *Quercus floribunda* forest on different aspects in Garhwal Himalaya.

Species	Aspect	Diameter class (cm)								
		10-20	20-30	30-40	40-50	50-60	60-70	70-80	Total (m^3ha^{-1})	(%)
Quercus floribunda	North East	-	4.536	10.616	25.775	26.751	69.528	126.16	239.75	87.90
Rhododendron arboreum		0.6992	6.889	1.336	-	12.29	-	-	21.01	7.70
Acer acuminatum		1.180	5.759	-	-	-	-	-	6.939	2.54
Rest of the species		2.761	2.268	-	-	-	-	-	5.029	1.84
Total		**4.640**	**19.452**	**11.952**	**25.775**	**39.041**	**69.528**	**126.16**	**272.73**	**100**
%		**1.70**	**7.13**	**4.38**	**9.45**	**14.31**	**25.49**	**46.25**	**100**	
Quercus floribunda	North West	0.7344	15.079	5.973	44.085	152.25	86.139	-	304.26	87.18
Rhododendron arboreum		0.8961	3.382	10.701	-	-	-	-	14.97	4.29
Abies pindrow		-	13.625	11.123	-	-	-	-	24.74	7.09
Lindera pulcherrima		4.959	-	-	-	-	-	-	4.959	1.44
Total		**6.589**	**32.08**	**27.797**	**44.085**	**152.25**	**86.139**	-	**349.0**	**100**
%		**1.88**	**9.19**	**7.96**	**12.63**	**43.62**	**24.68**	-	**100**	
Quercus floribunda	South East	11.505	39.094	38.634	35.631	-	-	-	124.864	84.60
Rhododendron arboreum		1.460	4.347	12.14	-	-	-	-	17.93	12.17
Symplocos crataegoides		2.415	1.179	-	-	-	-	-	3.594	2.43
Fraxinus micrantha		1.176	-	-	-	-	-	-	1.176	0.79
Total		**16.556**	**44.62**	**50.774**	**35.631**	-	-	-	147.581	100
%		**11.17**	**31.18**	**34.26**	**24.04**	-	-	-	100	
Quercus floribunda	South West	8.769	26.317	34.321	30.853	-	-	-	100.260	80.10
Quercus leucotrichophora		4.6213	10.821	-	-	-	-	-	15.442	12.33
Rhododendron arboreum		1.063	5.892	-	-	-	-	-	6.955	5.55
Ilex dipyrena		2.530	-	-	-	-	-	-	2.530	2.02
Total		**17.010**	**43.03**	**34.321**	**30.853**	-	-	-	125.214	100
%		**13.58**	**34.36**	**27.40**	**24.64**	-	-	-	100	

Table 3. Physico-chemical properties of soil of *Quercus floribunda* forest on different aspects in Garhwal Himalaya.

Aspect/horizon	Colour	Moisture (%)	Water holding capacity (%)	Texture class	pH	Organic carbon (%)	Phosphorus (mg/kg)	Potassium mg/kg	Available nitrogen (%)
North East									
Horizon A	10 YR 2/2	26.5	44.33	Loam	6.1	2.56± 0.54	7.65± 2.80	357.14± 105.83	0.22± 0.02
Horizon B	5 YR 3/3	22.0	38.88	Loam	6.1	2.40± 0.43	2.68± 1.02	290.18± 115.03	0.20± 0.10
Horizon C	7.5 YR 4/3	20.0	32.68	Loam	6.1	1.76± 0.25	8.09± 1.24	205.36± 40.80	0.15± 0.02
Mean		22.83±1.92	38.63± 3.37		6.1± 0.00	2.24± 0.42	6.14± 3.04	284.23± 76.06	0.19± 0.03
North West									
Horizon A	7.5 YR 3/3	22.0	28.60	Sandy loam	5:6	2.08± 0.30	8.00± 1.30	174.11± 35.36	0.17± 0.02
Horizon B	10 YR 3/3	19.5	32.43	Sandy loam	6.2	1.60± 1.10	6.60± 3.50	125.00± 32.96	0.13± 0.01
Horizon C	10 YR 3/3	28.0	36.24	Loam	5.8	2.56± 0.13	16.45± 7.51	178.57± 64.51	0.22± 0.02
Mean		23.17±2.52	32.42± 2.21		5.87± 0.18	2.03± 0.37	10.35± 5.33	159.23± 29.72	0.17± 0.43
South East									
Horizon A	7.5 YR 4/3	16.4	28.00	Sandy loam	6.1	2.26± 0.26	12.31± 2.79	239.28± 41.50	0.19± 0.03
Horizon B	10 YR 5/6	17.4	31.03	Loam	6.1	2.08± 0.22	4.84± 1.10	357.14± 112.03	0.17± 0.02
Horizon C	7.5 YR 4/4	19.5	38.46	Loam	6.2	1.60± 0.20	13.21± 4.75	357.14± 22.52	0.13± 0.03
Mean		19.37±1.10	32.50±3.11		6.13± 0.03	1.98± 0.34	10.12± 4.59	317.85± 68.05	0.17± 0.02
South West									
Horizon A	10 YR 4/3	16.4	18.91	Sandy loam	6.0	1.48± 0.49	4.48± 2.17	237.50± 15.00	0.14± 0.02
Horizon B	10 YR 3/4	15.2	21.93	Sandy loam	6.1	1.28± 0.28	8.00± 4.21	165.18± 32.50	0.11± 0.01
Horizon C	10 YR 5/4	18.00	26.78	Loam	6.1	2.08± 0.25	11.42± 2.38	102.68± 116.58	0.17± 0.03
Mean		16.53±0.81	22.54±2.29		6.07±0.03	1.61± 0.41	7.97± 3.47	168.45± 67.47	0.14± 0.34

The soils were sandy loam to loam in texture and slightly acidic to almost neutral in reaction with a pH range of 5.6. to 6.2, which is said to be the more favourable range for nutrients availability. The moisture percentage and water holding capacity of the soils were higher on the northern aspects due to occurrence of thick litter layers. On the southern aspects, a reverse trend (less number of tree individuals with lower rate of litter accumulation) was observed. The organic matter and total nitrogen percent ranges in the soil on all the aspects were recorded as 1.28% to 2.56% and 0.11% to 0.22% respectively. The presence of higher average moisture contents (22.83 ± 1.92% and 23.17 ± 2.52% and water holding capacities (38.63 ± 3.37% and 32.42 ± 2.21%), availability of higher average organic carbon (2.24 ± 0.42% and 2.03 ± 0.37% and nitrogen contents (0.19±0.03 and 0.17 ± 0.43%) in the soils of NE and NW aspects respectively, might have given birth to higher total growing stock values (272.73 m^3/ha on NE aspect and 349.0 m^3/ha on NW aspect) on the northern (cooler and moister) aspects, which had also supported almost entire range of diameter classes of *Q. floribunda* on these aspects. On the otherhand, the lower growing stock values on the southern (warmer and drier) aspects (147.58 m^3/ha on SE aspect and 125.214 m^3/ha on SW aspect) could be attributed to lesser prevalence of the aforesaid parameters in the soils (Tables 2 and 3). The maximum and minimum potassium values were reported for the surface horizon of NE (357.14 mg/kg) and the lower horizon of SW (102.68 mg/kg) aspects respectively. On the NE aspect the presence of more oak individuals, which are believed to be related to the higher potassium release (Tomlinson and Tomlinson 1990 and Sharpe *et al.*1992), resulted due to the atmospheric depositions which has induced a hazard in base cations caused by potassium deficiency due to leaching. In the less acidic soils, Tomlinson and Tomlinson (1990) observed that K was preferentially leached and thus was more likely to be deficient in relation to Ca, which was less readily leached. However, the persent results have shown that potassium concentration was higher on those areas, where broad leaved evergreen and deciduous species were predominant and least on the sites where needle leaved species were associated, which had clearly indicated the less release and fast uptake of potassium nutrients by coniferous species. Due to leaching properties of soil the maximum phosphorus contents were available in lower horizons of all the aspects (Table 3).

Conclusion

In *Quercus floribunda* forests of Garhwal Himalaya, the higher species diversity in tree layer was noticed on the higher elevational NE aspect (2550 m), because the higher elevations promote greater diversity (Sharma and Kumar 1992), whereas maximum dominance of the individuals of this species was encountered on lowest elevational SE aspect (2260 m). On the other hand the highest growing stock values of *Quercus floribunda* were recorded on NW aspect (2400 m) and lowest on SW aspect (2300 m), probably because this species prefers cold and moist conditions for its subsequent sound growth. The maximum number of saplings of *Quercus floribunda* were found growing on lowest elevational SE aspect (2260 m) and minimum on the drier SW aspect (2300 m). It is, therefore, recommended that for better survivorship of saplings on cooler and moister northern aspects the removal of unwanted ground competitors should be exercised. This view was also supported by Rao and Singh (1989) for central Himalayan regions, and by Quintana-Ascencio *et al.* (1992) for Mexican highlands. In the present study, the seedlings of *Quercus floribunda* were not observed on any of the aspects, perhaps due to prevalence of high biotic pressures on these sites. Therefore, there is an urgent need to conserve these oak forests, which are fast dwindling. To reduce the pressure on these oak forests suitable plantations of multipurpose tree species could be raised.

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