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Full Length Research Paper

Species diversity and regeneration of Tilonj Oak (*Quercus floribunda* Lindl.) dominated forests of Nainital in Kumaun Himalaya

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The present study deals with species diversity, and regeneration of *Quercus floribunda* Lindl forest lies in moist temperate sites in Nainital of Kumaun Himalaya. Tree, sapling and seedling density was 490-1190, 260-1280 and 100-670 ind.ha^{-1}, respectively. The species diversity of trees and shrubs density ranged from 0.421 to 1.177 and 310 to 1540 ind.ha^{-1}. The regeneration of *Q. floribunda* was J-shaped in forest site-1 and 2 while I-shaped (no regeneration) was reported for the forest site-3. The regeneration status of species in the studied forest sites indicates the impact of disturbances caused by anthropogenic activities. Thus, the presence of either seedlings or saplings and or also occurrence of new plant species in forest site-1 and site-2 predict the possible change in forest species composition in coming years while there was a very alarming condition in forest site-3 as new recruitments of tree species is evidenced by their absence. Thus, the above findings of *Q. floribunda* have shown that there is an urgent need to provide judicious inputs of management and conservation for sustaining the oak species in such forest sites of the region.

Key words: *Quercus floribunda*, species diversity, trees, saplings, seedlings, regeneration, moist temperate.

INTRODUCTION

Himalaya is one of the biodiversity hot spots in the world but the recent change in biodiversity and climate has been seen in every part of the globe which is caused by disturbances and faulty development activities. The variation in endemism species along the altitudinal gradient have shown that the changes in species diversity and microclimate of forest site in mountain region, also result to the integrated impacts of disturbance, poor conservation, faulty development and lack of appropriate management strategies. However, in the past, a lot of research works were done by many scientists focusing simply on their quantitative information but assessing the integrated effects of various factors was still not explored for the region. The various species of oaks are dominated in the forest communities throughout the mountain region of northern India (Stephenson and Saxena, 1984). There are five oak species viz., *Quercus leucotrichophora* A. Camus,

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Quercus floribunda Lindl., *Quercus lanuginosa* (Linn) Thuill, *Quercus semecarpifolia* Smith and *Quercus glauca* Thumb, which grow naturally between 1500 and 3300 m elevation in the Western Himalayan region and are regarded as climax species (Champion and Seth, 1968). The oak forest not only provides numerous ecosystem services but also serves as a lifeline for the local communities (Singh et al., 1984). Presence of oaks has been related with quality and quantity of spring water and considered best for water and soil conservation (Saxena and Singh, 1982). In Central Himalaya, oak forests support the subsistence agriculture and fulfill the need of agriculture implements, fire wood and leaf fodder of villagers in the region. Therefore, Oak forest acts as an important key in subsistence agricultural economy of hill people (Singh et al., 1984). Forest is the main source of livelihood for the local people in Uttarakhand, the human settlements practices in oak forests, lopping and felling as well as fire spreading in pine forests which reduced the area under oak forests (Champion and Seth, 1968). Biodiversity of forests is under great anthropogenic pressure and most of the species have become threatened and on the verge of extinction (Ram et al., 2004). In the Himalayan forest, various changes in structure, density, composition and regeneration due to biotic pressure have been reported in the Himalayan forest, that is, lopping, felling, collection of fuel wood, fodder and uncontrolled grazing (Kumar et al., 2004). Among the human influences, the commercial exploitation, agricultural requirements, forest fire and grazing pressure are the important sources of disturbance (Singh and Singh, 1992).

Population structure of a species in the forest conveys the regeneration behavior (Saxena and Singh, 1984). The presence of sufficient number of seedlings, saplings and young trees in a given population indicates the successful regeneration and tree regeneration can be predicted by the structure of their populations (Khan et al., 1987). According to Shanker (2001), regeneration status of individual tree gives the quantitative potential life-form at different stages and based on phyto-sociological reasons regeneration can be categorized into: (a) good, (b) fair, (c) poor, (d) no regeneration (Shankar, 2001). Theoretical population models predict that the shape of population size distributions results from the interaction between size-specific survival, growth and fecundity (Condit et al., 1998; Case, 2000; Caswell, 2001). If two populations differed in fecundity only, having equal growth and survival rates across size classes, then a larger population growth rate would produce a steeper negative size distribution (Condit et al., 1998). Population size distribution carries a wealth of demographic information and is frequently the most unequivocal and accessible attribute available for a population (Souza, 2007). The size distribution of a population is synthesis of the demographic events of recruitment, mortality and individual growth rates over time (Kelly et al., 2001).

The objective of the present study was to determine the vegetation analysis and regeneration status of Tilonj oak (*Q. floribunda*) dominated forests of Nainital in Kumaun Himalaya.

MATERIALS AND METHODS

The present study was conducted in moist temperate forests of Nainital in Kumaun region, Uttarakhand. The forest sites were located between 29°21' - 29°24' N latitude and 79°25' -79°29'E longitude. The three forest sites studied were site- 1, University Administrative Blocknear Sleepy hollow side, site-2, situated at University Administrative Block towards Tiffin top upper side and site-3, near Zoo forest between 2000 to 2500 m altitude. The sites aspects were NE and SW with a 26.5°, 12.5° and 50.55° slopes, respectively. Vegetation analysis of forest in each site was carried out by using quadrat method. The quadrat 10 x 10 m size was used for trees, 5 x 5m for shrubs and 1 x 1 m for herbs, placed randomly in each forest site. The sampling size and number of quadrat was determined as using Saxena and Singh (1982, 1984). Density was determined following Misra (1968) and Curtis and McIntosh (1950). In each quadrat, sampled tree species were categorized into: Trees (with >30 cm Cbh circumference at breast height, 1.37 m from ground level) and sapling with 10-30 cm above 1 m from ground and seedling <10 cm Cbh at 50 cm ground level placed randomly in each forest site were measured. Regeneration status of tree species was assessed following Shankar (2001). For the assessment of population structure of tree species based on seedling and sapling available in different tree, girth classes, that is, 30-60, 60-90, 90.0-120,120-150, >150cm were arbitrarily established based on Good and Good (1972).

Species diversity of trees in each forest site was determined by using Shannon-Weiner Index (Shannon and Weiner, 1963) and Concentration of dominance (Cd) was determined by Simpson's Index (Simpson, 1949).

$$H' = -\sum_{i=1}^{s} \left(\frac{Ni}{N}\right) 3.322 \log_2\left(\frac{Ni}{N}\right)$$

Where, H' = species diversity, Ni = total number of individuals species and N is total number of individuals of all tree species.

$$Cd = \sum_{i=1}^{s} (Ni/N)2$$

Where, Cd = concentration of dominance, Ni = total number of individuals of tree species and N = total number of individuals of all tree species.

RESULTS

Tree layer analysis

In forest site- 1, the total seven tree species *Q. floribanda* Lindl. exRehder, *Litsea umbrosa* Nees*, Asculus indica* Colebr. exCamb.Hook *Ilex dipyrena* Wall.*, Cedrus deodara* (Roxb. ex D. Don) G. Don*, Fraxinus micrantha* Lingelsh, *Rhamnus virgatus* Roxb were present. Total tree density of the forest site was 490 indha^{-1} of which *Q. floribunda* showed maximum density (300 indha^{-1}). Total

Table 1. Density (ind. ha^{-1}) of tree species in each forest site.

Species	Forest site-1			Forest site-2			Forest site-3		
	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling
Quercus floribunda	300	670	340	740	960	340	960	260	70
Litseaumbrosa	90	20	90	10	80	-		-	-
Fraxinus micrantha	10	60	80	-	70	20		-	-
Aesculus indica	10	20	-	-	20	10		-	-
Ilex dipyrena	40	40	30	-	30	60		-	-
Cedrus deodara	10	-	-	-	50	10		-	-
Rhamnus virgatus	30	-	-	-	-	-		-	-
Acer oblangum	-	-	110	10	-	-		-	-
Prunus ceresoides	-	-	10	10	30	20		-	-
Pyruspashia	-	30	-	-	10	--		-	-
Grevillia robusta	-	-	10	-	-	-		-	-
Quercus leucotrichophora	-	10	-	-	20	10	220	-	30
Rhododendron arboreum	-	-	-	20	-	-	10	-	-
Cupressus torulosa	-	-	-	10	10	-	-	-	-
Total	490	850	670	800	1280	470	1190	260	100

Table 2. Diversity (H') and concentration of dominance (Cd) of tree species in each forest site.

Tree layer	Forest site-1		Forest site-2		Forest site-3	
	H	Cd	H	Cd	H	Cd
Trees	1.769	0.423	0.553	0.861	0.421	0.686
Saplings	1.234	0.632	1.518	0.577	0	1
Seedlings	1.947	0.319	1.455	0.530	0.881	0.580

seven sapling species, that is, *Q. floribunda, L. umbrosa, A. indica, I. dipyrena, F. micrantha, Pyrus pashia* Buch.*,Q. leucotrichophora* A. Camus were present. The total density of saplings was 850 indha^{-1}, of which *Q. floribunda* showed maximum density, that is, 670 indha^{-1}. Total seven seedling species, that is, *Q. floribunda, L. umbrosa, A. oblongum, I. dipyrena, Prunus ceresoides* D. Don*, F. micrantha, Grevillia robusta* A. Cunn. were present. Total density of seedlings was 670 indha^{-1} of which *Q. floribunda* showed maximum density (340 indha^{-1}) (Table 1). The species diversity and concentration of dominance for trees, saplings and seedlings was 1.769, 1.234, 1.947 and 0.423, 0.632, 0.319, respectively (Table 2).

In forest site- 2, the total six tree species, that is, *Q. floribunda, A. oblongum, L. umbrosa, Rhododendron arboretum* Smith.*, P. cerasoides* and*C. sustorulosa* D.Don were present. The tree density of forest site was 800 indha^{-1}, of which *Q. floribunda* showed maximum density (740 indha^{-1}). The total 10 sapling species, that is, *Q. floribunda, Q. leucotrichophora, C. deodara, I. dipyrena, A. indica, L. umbrosa, F. micrantha, P. cerasoides, C.torulosa and P. pashia* were found.

The total saplings density was 1280 indha^{-1}, of which *Q. floribunda* showed maximum density (960 indha^{-1}). The seedlings of seven species viz., *Q. floribunda, Q. leucotrichophora, C. deodara, I. dipyrena, A. indica and F. micrantha* were reported in the forest site (Figure 2). The seedling density was 470 indha^{-1}, of which *Q. floribunda* showed maximum density, that is, 340 indha^{-1} (Table 1). Species diversity and concentration of dominance of trees, saplings and seedlings was 0.553, 1.518, 1.455 and 0.861, 0.577 and 0.530, respectively (Table 2).

In forest site-3, total three tree species viz., *Q. floribunda, Q. leucotrichophora* and *R. arboreum* were reported. The total tree density was 1,190 indha^{-1}, of which *Q. floribunda* showed maximum density (960 indha^{-1}). Only *Q. floribunda was* reported in sapling stage with density of 260 indha^{-1}.

The seedlings of *Q. floribunda and Q. leucotrichophora* were present the total density of seedlings was 100 ind.ha^{-1}, of which *Q. floribunda* showed maximum density (70 indha^{-1}) (Table 1). Species diversity concentration of dominance for trees, saplings and seedlings was 0.421, 0.00, 0.881 and 0.686, 1.00, 0.580, respectively (Table 2).

Shrub layer analysis

In forest site-1, the total nine shrub species, that is, *Urtica parviflora* Roxb*, Hypericum oblongifolium* Choisy*, Rosa maschata* J. Herrm*, Urtica dioica* L.*, Berberis asiatica* Roxb.ex D. Don*, Arundinaria falcate* Nee*, Desmodium elegans* D.C*, Sarcococa saligna* Muell. Arg and *Senecio nudicaulis* Buch.-Ham. exD. Don were present. The total shrubs density was 1540 indha^{-1}, of which *S. saligna* showed maximum density (690 indha^{-1}).

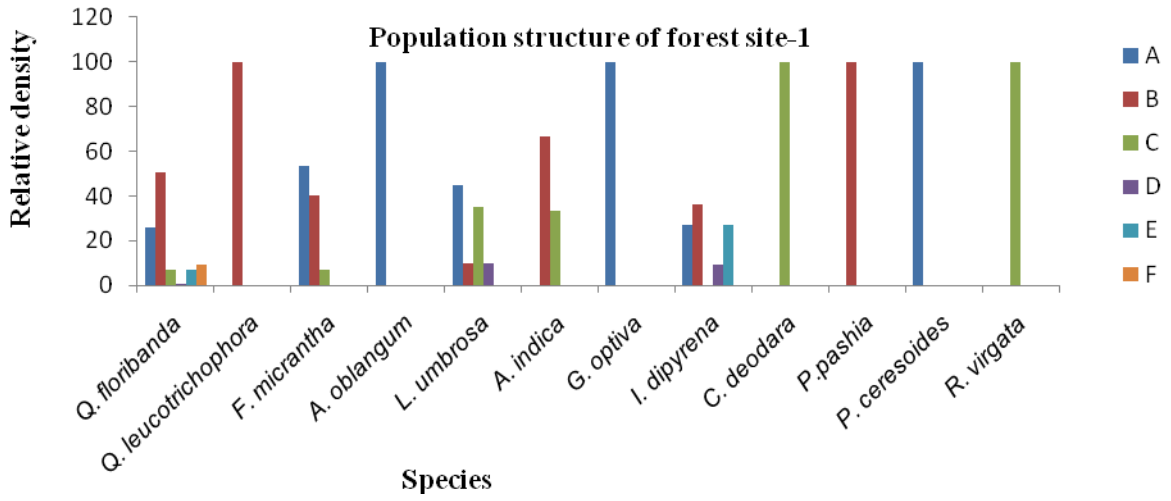

Figure 1. Population structure of all species (A- seedling, B- sapling, C- 30.1-60 cm, D- 60.1-90 cm, E- 90.1-120 cm and F-120< are different girth classes) in site 1.

Total species diversity and concentration of dominance was 2.518 and 0.260, respectively (Table 3).

In forest site-2, a total of eight shrub species, that is, *U. parviflora, Hypericum cernuum* Roxb*, Rosa micrantha* Lindll*, U. dioica, A. falcata, S. saligna, Daphane papirasea* Wall and *Indigofera heterantha* Wall. exBrandis were present. The total shrubs density was 1070 indha^{-1}, of which *S. salisena* showed maximum density (230 indha^{-1}). Species diversity and concentration of dominance of shrub was 2.82 and 0.223, respectively (Table 3).

In forest site-3, total five shrub species, that is, *C. coccinea, H. oblongifolium, Rubus ellipticus* Smith*, B. asiatica* and *Pyracantha crenulata* (D. Don) M. Roem were present. Total density of shrub was 310 indha^{-1}, of which *H. oblongifolium* showed maximum density (110 indha^{-1}). Species diversity and concentration of dominance of shrub was 2.126 and 0.249, respectively (Table 3).

Herb layer analysis

In forest site-1, total thirteen herb species were present, that is, *Strobillanthus atropurpurem* Nees*, Gallium aparina* L.*, Oxalis latifolia* BHK*, Achyranthes bidentata* Blume*, Argemone maxicana* L.*, Eulate amallis* (Griseb). O. Kuntze*, Justica simplex* D. Don*, Erigeron annua* (L). Pers.*, Carex condensate* Wahlenb.*, Viola canescens* Wall, *Ocimum sanctum* Linn*, Apludamutica* Linn. and *Arthraxon prionodes* Steud. Dandy. Total herbs density was 43.70 indm^{-2}, of which *A. mutica* showed maximum density (12.50 indm^{-2}). Species diversity and concentration of dominance was 3.05 and 0.161, respectively (Table 4).

In forest site-2, total seven herb species were present, that is, *S. atropurpurem, G. aparine, A. bidentata, V. canescens, A. prionodes, E. annua* and *Thalictrum foliolosum* DC. Total herb density was 14 ind m^{-2}, of which *A. bidentata* showed maximum density (5.7 indm^{-2}). Species diversity and concentration of dominance of herbs was 2.402 and 0.237, respectively (Table 4).

In forest site-3, total ten herbspecies such as *A. mutica, E. malis, C. condensate, G. aparine, A. bidentata, V. canescens, A. prionodes, E. annua, O. latifolia*and *T. foliolosum* were present in the forest site. Total herbs density was 49.10 indm^{-2}, of which *A. mutica* showed maximum density (25.10 indm^{-2}). Species diversity and concentration of dominance of herbs was 2.424 and 0.303, respectively (Table 4).

Population structure

In forest site-1, *Q. floribunda*, *I. dipyrena, P. pashia, Q. leucotrichophora* and *A. indica* showed the J-shaped (poor regeneration) because of lesser number of seedlings and trees than saplings. *F. micrantha* depicted reverse J-shape (good regeneration) and *L. ambrosa*has showed U shape (fair regeneration) with high number of seedlings but the conversion of seedlings into saplings was not adequate. *P. cerasoides, G. optiva* and *A. oblongum* were new invaders to the site as represented only by seedlings. *R. virgata* and *C. deodara* showed I-shape (noregeneration, only adult tree) in this forest site (Figure 1).

In forest site-2, *I. dipyrena,* indicates reverse J-shape (good regeneration), there was only presence of seedlings shown in the forest site. The *Q. floribunda*, *P. cerasoides, Q. leucotrichophora, C. deodara, F. micrantha, C. torulosa*, *L. umbrosa, A. indica* and *P. pashia* showed the bell shape or J-shape (poor

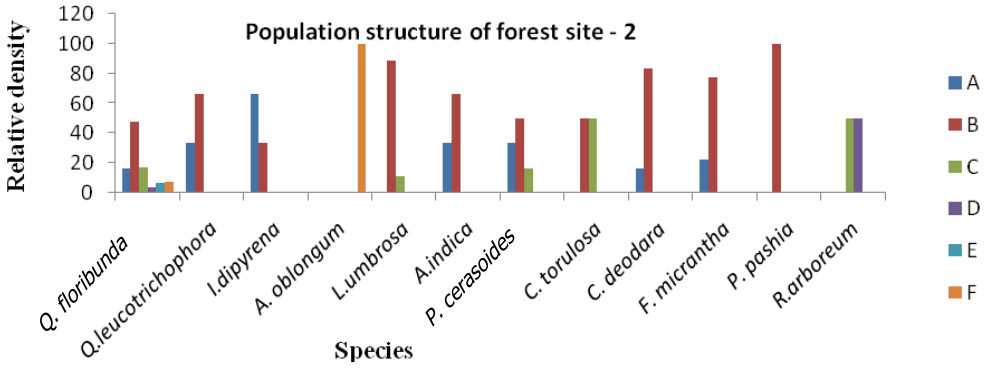

Figure 2. Population structure of all species (A- seedling, B- sapling, C- 30.1-60cm, D- 60.1-90 cm, E- 90.1-120cm and F-120< are different girth classes) in site 2.

Table 3. Density (ind ha^{-1}), species diversity and concentration of dominance of shrubs species in forest site.

Species	Forest site-1			Forest site-2			Forest site-3		
	D	H	Cd	D	H	Cd	D	H	Cd
Urtica parviflora	150	0.326	0.009	150	0.397	0.019	-		
Hypericum oblongifolium	180	0.362	0.014	-	-	-	110	0.529	0.126
Rosa maschata	40	0.136	0.001	-	-	-	-	-	-
Urtica dioica	60	0.182	0.001	70	0.256	0.004	-		
Berberis asiatica	150	0.326	0.009	-			40	0.381	0.016
Arundinaria falcate	120	0.287	0.006	50	0.208	0.002	-	-	-
Desmodium elegans	130	0.299	0.007	-			-	-	-
Sarcococas aligna	690	0.519	0.200	230	0.477	0.046	-	-	-
Senecio nudicaulis	20	0.081	0.013	-	-	-	-	-	-
Hypericum cernuum	-	-	-	80	0.280	0.075	-	-	-
Daphane papirasea	-	-	-	90	0.300	0.007	-	-	-
Indigofera heterantha	-	-	-	220	0.470	0.042	-	-	-
Rosa micrantha	-	-	-	180	0.432	0.028	-	-	-
Colquhounia coccinea	-	-	-	-	-	-	20	0.253	0.0042
Rubus ellipticus	-	-	-	-	-	-	60	0.459	0.037
Pyracantha crenulata	-	-	-	-	-	-	80	0.504	0.066
Total	1540	2.518	0.260	1070	2.82	0.223	310	2.126	0.249

regeneration). *A. oblongum* and *R. arboreum* represented no regeneration, only trees were present.

In forest site-3, the*Q. floribunda* and *Q. leucotrichophora* showed U-shape (fair regeneration, that is, seedlings>saplings<adult trees), these species is represented by young tree class while absence of saplings indicates that seedlings failed to attain the sapling stage due to climatic and anthropogenic pressure. *R. arboreum* was only represented by single adult tree class showing no regeneration (Figure 3).

DISCUSSION

The present study tree species density was 490 to 1190 ind ha^{-1}. These values are higher than 760 ind ha^{-1} reported for natural oak forest (Rawat and Singh, 1988), 349 ind ha^{-1} for Western Himalaya forest (Saxena and Singh, 1984), 930 indha^{-1} for *Q. floribunda* forest (Kumar and Ram, 2005) and 260-780 ind ha^{-1} for disturbed forest and 460-970 ind ha^{-1} for protected forests of Nainital catchment (Bargali et al., 2013). but present estimates are on the lower side than 1330 ind.ha-1 reported for Oak and Pine mixed forests(Lodhiyal and Lodhiyal, 2012) and 920-1345 ind ha^{-1} for natural Oak dominated forest (Lodhiyal et al., 2013). The *Q. floribunda* was the dominant tree species in the studied forest site which was 300-960 ind ha^{-1}, which accounted 61-92% of the total tree density.

Density of saplings in this forest site ranged from 260 to 1280 ind ha^{-1}, which was higher than 760 ind ha^{-1} reported for oak forest (Rawat and Singh, 1988). The

Table 4. Density (ind. m^{-2}), species diversity, concentration of dominance of herb species at forest site.

Species	Forest site-1			Forest site-2			Forest site-3		
	D	H	Cd	D	H	Cd	D	H	Cd
Strobillanthus atropurpurem	8.4	0.457	0.037	2.0	0.401	0.020	-	-	-
Oxalis latifolia	1.6	0.176	0.001	-	-	-	2.4	0.212	0.002
Gallium aparina	2.0	0.205	0.002	1.3	0.319	0.009	3.4	0.266	0.005
Achyranthes bidentata	0.8	0.106	0.001	5.7	0.528	0.166	2.1	0.194	0.002
Argemone maxicana	1.0	0.124	0.001	-	-	-			
Eulate amallis	3.8	0.306	0.008	-	-	-	1.6	0.176	0.001
Justica simplex	0.2	0.036	0.001	-	-	-			
Erigeron annua	0.6	0.085	0.001	1.1	0.286	0.006	1.4	0.146	0.001
Arthraxon prionodes	2.9	0.258	0.004	1.1	0.286	0.006	3.0	0.246	0.004
Carex condensate	5.4	0.371	0.015	-	-	-	7.5	0.415	0.024
Viola canescens	3.6	0.295	0.007	2.4	0.435	0.029	1.7	0.168	0.002
Ocimum sanctum	0.9	0.115	0.001	-	-	-			
Apluda mutica	12.5	0.516	0.082	-	-	-	25.10	0.495	0.261
Thalictrum foliolosum	-	-	-	0.4	0.147	0.001	0.9	0.106	0.001
Total	43.70	3.05	0.161	14	2.402	0.237	49.10	2.424	0.303

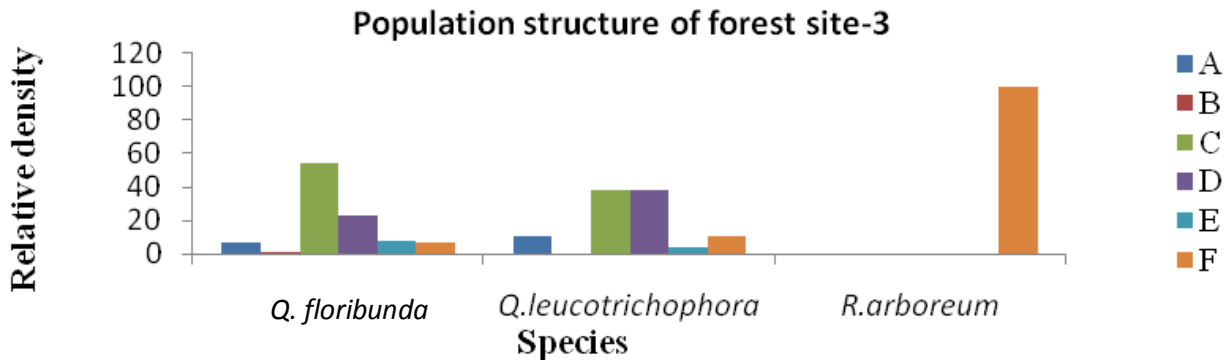

Figure 3. Population structure of all species (A- seedling, B- sapling, C- 30.1-60cm, D- 60.1-90 cm, E- 90.1-120cm and F-120< are different girth classes) in site 3.

sapling density was lower than 2061 ind ha^{-1} for *Q. floribunda* forest of Government House in Nainital (Saxena and Singh, 1984) and falls within the range 788-1718 ind ha^{-1} of Central Himalayan forest (Singh et al.,1987).

Seedling density was 100- 670 indha^{-1} in the forest site. These values are much lesser than 2030 ind ha^{-1} reported for Oak forest (Rawat and Singh, 1988),10899 ind ha^{-1} for *Q. floribunda* forest by Saxena and Singh (1984), 12750 ind ha^{-1} for *Q. floribunda* forest of Government House in Nainital (Singh et al., 1987). The present values indicate very poor regeneration of tree species in the forest sites.

Shrub density ranged from 310 to 1540 ind ha^{-1}. These values are on the lesser side than 1060 to 4250 ind ha^{-1} reported for oak forests of central Himalaya (Rawat and Singh, 1988). Herb density ranged from 14.0 to 49.0 ind m^{-2} (during winter season). The number of herbaceous species varied from 7 to 13.

Species diversity of trees in the studied forest sites ranged from 0.421 to 1.177 which falls within the range of 0.46 to 2.02 reported for oak forest in Nainital of Kumaun Himalaya (Ralhan et al., 1987), 1.2 to 2.7 for Central Himalayan forests (Kumar and Ram, 2005) and 0.78 to 3.45 for Garhwal Himalayan forests (Raturi, 2012) and 0.757-1.500 reported for natural oak mixed forests (Lodhiyal et al., 2013).

All the studied forest sites had shown J-shape (poor regeneration, that is, seedlings>saplings<adult trees) in sites-1 and 2, which indicates that forest sites has reproduced well in the immediate past but forest site need management and conservation. The forest site-3 showed very less number of seedlings and saplings and represented only by few tree classes with no regeneration. In forest site-1, only 8.33% species had shown reverse J-shape (good regeneration), 8.33% U, reverse bell shaped (fair), 16.7% no regeneration and

41.7% J-shape (poor regeneration), while 25% of species were new invaders to the forest site. In forest site-2, 8.3% showed reverse J-shape (good regene-ration), 75% species showed J-shape (poor) and 16.7% I-shape (no regeneration, only adult tree were found). At forest site-3, 66.7% species showed U shape or reverse bell shaped (fair regeneration, seedlings> saplings< adults trees) and 33.3% showed no regeneration.

Q. floribunda was dominant tree species in all the studied forest sites, which has shown J-shape (poor regeneration) at forest sites-1 and 2, and I-shaped (no regeneration) at forest site-3. The higher percent of J-shaped (poor regeneration) tree species in all the forest sites indicates heavy anthropogenic pressure on forest type species for fuel and fodder.

Oak forests are one of the important forests in Western Himalaya, as the oak tree provides various sustainable options to the village community residing in the region. Forest gives direct and indirect benefits to the community and also conserves the ecosystem landscape. Oak is most important precious gift of nature not only from the villager's point of view for their fuel and fodder and water resource needs but also designates specific living structure of ecosystem.

Wherever in the hills, the oaks are present, they depict the quality of organic soil fertility and the sign for community livelihood sustainability in the region. The present study shows that forests are in a very alarming situation as *Q. floribunda* forest has showing J-shape (poor or no regeneration) in the studied forest sites. Therefore, it is very essential to develop proper management and conservation strategies for maintenance of oak species and their sustainability in the forest of the region.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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