

FLORISTIC DYNAMICS AND DISTRIBUTION PATTERN OF WOODY PLANTS IN KINNAUR

Thesis

by

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2004



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CERTIFICATE-I

This is to certify that the thesis entitled “**Floristic dynamics and distribution pattern of woody plants in Kinnaur**” submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY in FORESTRY (Tree Improvement and Genetic Resources)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Ms. Poonam Sharma (F-98-2-D)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.


The assistance and help received during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Dated : January, 2004

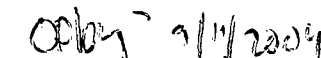

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This is to certify that the thesis entitled "**Floristic dynamics and distribution pattern of woody plants in Kinnaur**" submitted by **Ms. Poonam Sharma (F-98-2-D)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY in FORESTRY (Tree Improvement and Genetic Resources)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.


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(Poonam Sharma)

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INTRODUCTION

Natural forests being a mosaic of a wide variety of ecosystems harbor an unprecedented range of diversity in the plant communities that are of social, economic, cultural and scientific importance. National sovereignty over biological resources and unprecedented biotechnological advancements have shifted the focus of scientific world from primarily a few economically useful plants to a wide range of taxonomic groups including wild relatives of cultivated plants and lesser known lichens and bryophytes (Ghate *et al.*, 1999). India, along with 125 countries is a party to Convention on Biological Diversity (CBD) and therefore committed to undertake identification and monitoring of the components of biological diversity for their efficient conservation and sustainable use (Gadgil, 1994).

Biodiversity has attracted attention of people in general and scientific community in particular because of the growing awareness of its importance on the one hand, and the anticipated massive depletion on the other. About 20 per cent of all species are expected to be lost within 30 years and 50 per cent or more by the end of 21st century (Myers, 1993). However, Stork (1997) has mentioned even surprising extinction rates as high as 30 per cent per decade of global species.

The current estimates of the total number of species on earth vary from 5 to more than 50 million (May, 1988), with a more conservative figure of 13.6 million species (Hawsworth and Kalin-Arroyo, 1995). Of these only 1.76 million have yet been described and awarded scientific names (Singh, 2002). Thus, our knowledge of diversity is remarkably incomplete. Moreover, diversity is not uniformly distributed on the earth; it increases from poles to equator and from high elevation to low elevations. Diversity is greater on continents than on islands

and rather low in habitats with extreme environmental conditions such as deserts, hot springs etc. (Singh, 2002).

The district of Kinnaur in Himachal Pradesh is endowed with the lower side of the extreme environmental conditions. The general climate is dry-temperate, snowy and frigid. The elevation is 2200 m amsl with maximum annual precipitation of around 1000 mm and minimum around 200 mm, most of which occurs during the months of January to March in the form of snow. Upper ridges remain mostly covered with snow throughout a greater part of winter. Himalayan soils constitute a distinct category being immature in their development (Puri, 1960). Soils are shallow, stony and rocky, mostly poor in fertility and prone to erosion due to glaciers. Dark gray, brown forest soils are most common and have moderate amount of organic matter at the surface.

Vegetation here shows a great variation, mesophytic on northern aspects, otherwise it is more xerophytic in dry and arid regions (Puri, 1960). The forests of this region have been classified into Subtropical pine forest (Group 9) to Sub-alpine forest (Group 14) and Moist and Dry alpine scrub (Group 15 & Group 16) according to Champion and Seth's (1968) classification of forest types. The tract, however, has been divided into three main climatic zones:

- Wet Zone – deodar occurs on well-drained sites and on ridges and spurs generally forming an admixture with kail, spruce and fir. In the depressions, broad-leaved species like horse chestnut, hazel nut, maple, bird cherry and walnut are prominent.
- Dry Zone – deodar reaches its optimum development and forms large areas of pure forest.
- Arid Zone – deodar develops well only on cool aspects and comparatively at higher elevation.

Trees are able to dominate the woodland community and determine the broad pattern of stratification largely because of their great biomass and the fact that the tree canopy forms the uppermost layer of the plant community. The

upper stratum consists of relatively large overstorey trees, which dominate the community by shading and, therefore determine the number of other strata and kinds of plants composing the lower strata. Dominant species not only make a major contribution to the total biomass of the community, but also tend (as an individual or a population) to ramify throughout the edaphic and aerial environments and to influence the identity, quantity and local distribution of the associated flora and fauna (Gramie *et al.*, 1988).

Floristic studies of communities, particularly on trees and shrubs based on quantitative information and on the patterns of spatial distribution are indispensable for any meaningful monitoring and subsequent conservation and sustainable management of bioresources. The number of species or any other higher ranks of taxonomic organization in a site (species packing or alpha-diversity) and their compositional changes across different habitat types (species turnover or beta-diversity) within a landscape are important parameters of biodiversity that have wide applications such as environmental monitoring and conservation evaluation (Magurran, 1988; Pressey *et al.*, 1994; Negi, 2000). Also the study of interspecific association of trees and shrubs and their correlation analysis provide us information about the functioning of the ecosystem. Understanding the relationship between forest overstorey and understorey communities is essential for predicting changes in the abundance and distribution of understorey plants through successional time and in response to forest management (McKenzie *et al.*, 2000)

In addition to documentation of the species diversity, it is important to know the scatteredness among the individuals of dominant tree species for meaningful interpretation. The spatial structure of plants is a legacy of the spatial arrangement of parent plants and of the interactions that have taken place between plants in the past. Plant interactions together with abiotic factors also mould the 'performance structure' of populations. The age structure and hence the diameter distribution of tree populations reflect both past opportunities for

recruitment and the mortality risks to which each recruit has subsequently been exposed. By studying the diameter class distribution in a natural forest, Shimano (2000) was able to estimate not only the number of juveniles in each dominant tree species populations but also the size-dependant mortality operating there.

Quantification of diameter distribution and its relationship to site, stand composition, age and density is often valuable for both economic and biological purposes (Bailey and Dell, 1973). Applications of the use of diameter distribution to describe forest stand structure are well known and numerous. Not only are these methods applicable to modeling stand dynamics, but they also arise in the context of sampling when a certain parametric form is hypothesized for the diameter distribution of the stand sampled (Gove and Patil, 1998). Growth and yield predictions are essential to forest management. It has long been recognized that the size distribution of future yields is essential to the successful solution of a broad array of problems associated with effective management. Fitting statistical distribution to experimental data relating to diameter is useful in the sense that it gives us a summary of data which is easier to manipulate than the raw data itself (Aitchison and Brown, 1957). Once the statistical distribution is fitted we can estimate the number of trees in a particular class of diameter or number of trees within a specified diameter range.

Studies on these aspects of ecology in Western Himalayas especially the high altitudes of Kinnaur, the Northwestern frontier of Himachal Pradesh, are wanting. The present study “**Floristic Dynamics and Distribution Pattern of Woody Plants in Kinnaur**”, therefore has been carried out with the following objectives:

1. To study magnitude of species diversity of the plant resources,
2. To determine the frequency distribution pattern of woody species using appropriate statistical distributions,
3. To study association of vegetational components with abiotic factors viz. altitude, rainfall, slope and type of soil.

REVIEW OF LITERATURE

The richness and variety in a word, the diversity of natural ecological communities have never been more valued than they are now, as they become increasingly threatened by the environmental crises. In the past studies on biological diversity have been descriptive and concentrated at higher spatial scales e.g. regional and global (May, 1988; Raven, 1987; Daily, 1995; Groombridge, 1992; Hammond, 1995; Heywood, 1995). A great deal of time and expertise has been expended on the compilation of species list for particular habitats, but the consequent increase in our understanding of the structure and functioning of communities has been meager (Southwood, 1978). The current focus of ecological studies, therefore, is shifting from higher spatial scales to locally manageable landscapes at which landuse decisions and management policies are most often implemented (Rickklef and Shluter, 1993; Nagendra and Gadgil, 1999; Negi, 1999). One such effort has been undertaken to explore the floristic composition of a small part of Western Himalaya. The literature relevant to this subject has been reviewed under different headings.

2.1 SPECIES DIVERSITY: COMPONENTS AND MEASURES

The two components of diversity viz., alpha-diversity or species-packing and beta-diversity or species turnover are measured using different indices to characterize community structure and its dynamics. Alpha-diversity is the species diversity within a site whereas, beta-diversity refers to the rate and extent of change across sites, but not necessarily along a particular environmental gradient (Whittakar, 1972; Magurran, 1988).

Indices of richness, diversity and equitability are an abstraction of the highly complex structure of communities. Attempts to describe a complex

community structure by one single attribute can be criticized because so much valuable information is lost (Begon *et al.*, 1990). However, these indices help in understanding community structure and its functioning in the environment it is exposed to. These indices have widely been used by ecologists working with the forested ecosystem.

There are various factors shaping landscapes' diversity. Latitudinal gradient being the most prominent of such factors. In the majority of groups examined, species richness increases along a gradient from pole to equator. Tropical and sub-tropical forests are rich in species' diversity. Ecological investigation by Knight (1975) revealed higher Shannon-Wiener index values for young ($H'=5.06$) and old ($H'=5.40$) stands in a tropical ecosystem. Tropical forests of Silent Valley also exhibited (Singh *et al.*, 1981) a higher degree of species diversity ($H'=4.89$) and lower estimate of concentration of dominance ($C=0.06-0.14$). A comparatively lower estimate of Shannon-Wiener ($H'=2.95$) index of diversity was recorded by Chandrashekara and Ramakrishnan (1994) in the tropical wet evergreen forest. However, a lower value of concentration of dominance ($C=0.085$) indicated a lower dominance exhibited by any single species and hence an equitable distribution. Xu *et al.* (2001) found a high diversity of tree species in a subtropical evergreen broad-leaved forest. A total of 54 overstorey species of 24 families and a total of 63 understorey species of 26 families were identified. The diversity and equitability index of species were 4.15 and 0.72 for the overstorey plots and 4.72 and 0.79 for the understorey subplots, respectively. A high value of Shannon's H (2.98) and equitability (0.81) and lower Simpson's index of dominance (0.07) was estimated by Seetharam *et al.* (2000) in a dry deciduous forest. Temperate forests on the other hand are characterized by lower species diversity and greater dominance by one or a few species of trees. On the basis of findings by many workers, Pande (2001), has put the range of Shannon index for temperate forests between 1.16 to 3.40, very much lower than that for tropical forests. The value of concentration of

dominance was reported as high as 1.00 indicating a complete dominance of the stand by only one species, which is unheard of in a tropical ecosystem.

Marquez *et al.* (1999) studied the stand composition in mixed pine oak woods and this study also, confirmed lower species diversity for temperate forests i.e. 68 per cent of the plots had 3 to 5 species, although species number ranged from 1 to 9. The two most common species at each site, *Pinus teocote* and *P. durangensis* accounted for 83 per cent of the total basal area, indicating that these species can be used to physiognomically characterize the forest there. A lower value of diversity index ($H'=2.0248$ for tree layers and $H'=2.9021$ for shrub layer) was also reported by Zhang MuMing *et al.* (1999). They also find a lower evenness index (0.3916 and 0.5491 for trees and shrub layers, respectively), indicating an uneven sharing of available resources by different species. The ecological dominance for trees and shrubs was 0.3946 and 0.1503, respectively. The lower diversity in temperate vegetation could be attributed to lower rate of evolution and diversification (Simpson, 1949; Fisher, 1960) and severity in environment (Connell and Oris, 1964).

Peculiarities of Himalayan forest ecosystems have attracted the attention of various ecologists and a plethora of literature is available. Ralhan *et al.* (1982), were among those who studied the vegetation structure of montane subtropical and temperate forests of Himalayas. Their studies revealed a total of five forest types viz. *Pinus roxburghii*, *Quercus floribunda*, *Q. lanuginosa*, *Q. leucotrichophora* and *Q. semicarpifolia* on the basis of IVI. The total tree basal cover ranged from 2686.7 to 6045.8 cm². The composition of tree and shrub layers differed markedly among various types of forests. *Q. floribunda* forest supported the largest shrub population while *P. roxburghii* and *Q. semicarpifolia* were poorest in this regard. *P. roxburghii* forest indicated zero diversity ($H'=0$), whereas, *Q. floribunnda* forest on basal cover basis and *Q. leucotrichophora* forest on density basis had maximum diversity ($H'=2.0234$ and $H'=1.9284$, respectively). Among the oak forests, *Q. floribunda* forest indicated relatively

greater equitable share of resources among the associated species (concentration of dominance = 0.319). On the basis of similar study Singh *et al.* (1991) were able to recognize the following types of forest communities; *Q. incana*, *Rhododendron arboreum*, *Cedrus deodara*, *Pinus roxburghii*, *Q. incana*, *Q. dilatata*, *Picea smithiana*, *Pinus wallichiana*. On the basis of IVI, Pandey and Joshi (1998) were able to identify five forest communities viz., *Pinus roxburghii*, *Cedrus deodara* mixed *P. roxburghii*, *P. roxburghii* mixed *Q. leucotrichophora*, *Q. leucotrichophora*, and *Q. leucotrichophora* and *Q. leucotrichophora* dominated mixed broad-leaved forest. Tree layer diversity (H') varied from 0.213 to 2.917. The value of concentration of dominance varied from 0.223 to 0.466. The richness of woody species, as reported by Rawat and Bhainsora (1999) was highest in the Shiwaliks (62) followed by Doon Valley (56) and the outer Himalaya (54).

Chauhan *et al.*, 2001 used TWINSpan to classify sal (*Shorea robusta*) forests of Doon Valley in five different associations. The values of IVI for *Shorea robusta* ranged from 65.30 to 282.28. The species association of *S. robusta* and *Syzygium cumini* was also established by TWINSpan. The species diversity showed maximum alpha-diversity (21) at Site-I. The species diversity (H') ranged between 0.09-2.27 and evenness ranged between 0.02-0.84. While studying community characteristics of a tropical mountain rain forest, Yide (1997) showed that the species diversity was inversely proportional to importance value of dominant species. The lower the diversity, the similar was composition and layer structure of forest community and higher was the stem wood productivity of the stand. Xu *et al.* (2001) showed that the diversity index for the overstorey was significantly correlated to the basal area of tree over 20 cm DBH ($P < 0.05$) and importance value of *Castanopsis sieboldii* ($P < 0.001$), while for understorey the diversity index was not correlated to the structural parameters (all $P > 0.16$). The size distribution pattern and age structure indicated differences in regeneration strategies for canopy dominants.

The character of dominant tree species with respect to its aggressiveness becomes sometimes the most important determinant of species richness. Baduni and Sharma (1997) showed that the highest diversity in the tree layer was observed in *Quercus leucotrichophora* and *Cupressus torulosa* forests while *Pinus roxburghii* stands had the least diversity values. Ralhan *et al.* (1982) found even no diversity ($H'=0$) in *P. roxburghii* stands. *Acacia catechu* plantation exhibited (Verma, 2000) higher ($H'=3.795$ and $C=0.095$) species diversity of ground flora than *Tectona grandis* plantation ($H'=3.595$ and $C=0.110$). A study by Verma (2001) showed that the ground flora under *Albizia lebbeck* had highest diversity index (3.562) than *Cleistanthus collinus* (3.134).

2.2 FACTORS AFFECTING SPECIES DIVERSITY AND STRUCTURAL PARAMETERS: ABIOTIC AND BIOTIC

While studying a mountain forest ecosystem, Hwan *et al.*, 1999 found that the altitude and soil factors were the major variables explaining the differences in the species diversity in the whole forest. Species diversities of the plant communities were also affected by topography and disturbance. ZhengSheng *et al.* (1998) reported that the differences of species diversity indices became larger with forest types from montane coniferous forests to montane coniferous and broad-leaved mixed forests, to hilly and low mountainous evergreen broad-leaved forests. Vegetation changes seemed to be correlated with two major climate gradients: (i) a temperature gradient (altitude) and (ii) a moisture gradient. Species richness, canopy height and stem diameter decreased with increasing altitude (Kapplle *et al.*, 1995). In a study of plant diversity of tropical sal forest Dumetz (1999) observed that the floristic composition is correlated with the abiotic factors of rainfall, latitude and soil composition.

The basal area and volume of pine decreased with increasing altitudes while the proportion of spruce on those sample plots where it was present increased. Birch was present at an equal frequency at all altitudes. The floral composition and the between species abundance changed with increasing

altitude (Leppaniemi *et al.*, 1998). Vazquez and Givnish (1998) also studied the altitudinal gradient in tropical forest composition, structure and diversity. They found that forest composition varied continuously with altitude. Based on Shipley and Keddy test, ordination via reciprocal averaging and altitudinal trends in Sorenson's similarities of samples at adjacent altitudes support the individualistic hypothesis of plant community organization. Understorey herbs, shrubs and vines showed maximum decline in species numbers with increasing altitudes. This pattern is hypothesized to result from the more open, more frequently disturbed and more completely deciduous canopies at lower, drier altitudes. The proportion of evergreen woody plants was greater at higher altitudes reflecting less seasonal aridity and greater soil leaching (in cloud forest). The proportion of endozoochorous species increased with altitude, while that of pterochorous and ectozoochorous species decreased reflecting trends in the hypothesized efficacy of these mechanisms of seed dispersal. The total basal area of woody plants (>2.5 cm dbh) and basal area per tree, both increased roughly 4 times between 1500 m to 2500 m altitude. Species richness decreased sharply with altitude due mainly to a decrease in terrestrial herbs and to a lower extent, shrubs and vines. A cascading series of effects of altitude on soil fertility, antiherbivore defenses and level of density-dependent mortality may account for the observed drop in diversity with altitude and would be consistent with lower beta-diversity and greater basal area at higher altitudes.

Bhandari *et al.* (1998) while studying vegetation structure in Garhwal Himalayas found *Pinus roxburghii* as a dominant tree species within 1400 m to 1800 m amsl altitude. Total basal area among the stands ranged from 23.05-63.00 m²/ha and total density between 660-880 plants/ha. Community diversity ($H'=2.52$) was highest in the middle of the gradient. In a similar study, Singh *et al.* (1991), found that the density (trees/100 m²) in temperate forest varied from 7.83 to 13.8, basal cover (cm²/100 m²) from 1515.67 to 9895.18, while diversity index (0.932-2.844) and concentration of dominance (0.567-0.150) confirmed the temperate nature of the forest.

Within the Shiwaliks, the tree densities (ha^{-1}) according to Rawat and Bhainsora (1999) varied among valley bottom (260.9 ± 64.1), middle slope (265.7 ± 77.9) and Shiwalik ridge (254.6 ± 100.7). However, tree densities in Doon Valley (640.0 ± 253.9) and the outer Himalaya (643.7 ± 257.7) were much higher than in the Shiwaliks. Sundarapandian and Swamy (2000) reported that stem density and basal area of the evergreen forests was $748 \text{ trees ha}^{-1}$ and $81.38 \text{ m}^2 \text{ ha}^{-1}$, while the forests at higher altitude showed higher density and lower basal area ($1173 \text{ trees ha}^{-1}$, $72.72 \text{ m}^2 \text{ ha}^{-1}$). The 'L' shaped curve of different DBH classes of trees and saplings indicated good regeneration. Pande (2001) obtained a higher value of tree density ($885\text{--}1111 \text{ ha}^{-1}$) in a moist temperate Himalayan forest. The total basal area was found to be ranging from $56.42\text{--}126 \text{ m}^2 \text{ ha}^{-1}$. Shannon-Wiener diversity index ranged between 1.80-2.33 for trees, 2.23-2.57 for shrubs and 2.54-2.99 for herbs.

Metz (1997) ordinated little disturbed stands of temperate forests with Detrended Correspondence Analysis and axes correlated with environmental variables. Three of the stands on lower elevation or more mesic sites were dominated by *Q. oxyodon* and four by *Tsuga dumosa*. The first and second ordination axes correlated highly with elevation and aspect, respectively. In the highest stand *Abies spectabilis* was almost as important as *Tsuga*.

Beta-diversity as a measure of species turnover across the sites was measured by Bhandari *et al.* (1998). They found that there was no significant difference in the species composition across the stands along altitudinal gradient within an elevational range of 1400 m to 1800 m above msl. Vazquez and Givnish (1998) indicated that community composition varied roughly 6 times as rapidly with altitude as with the same distance horizontally. Species composition of sample plots within an altitudinal band showed greater horizontal turnover at lower altitudes, showing that low altitude forests are not only locally more diverse, but spatially more patchy. Similarity indices as the measure of beta-

diversity were used by Ferreira and Prance (1998). The study showed the similarity indices at family level varied from 67-87 per cent and at species level varied from 26-44 per cent. In Hyeop *et al.* (1999) found the range of similarity index between altitudinal belts as 42.0-71.8 per cent. However, they found that with increasing altitude, number of species, species diversity and evenness increased, suggesting interference by man was relatively severe at lower elevations.

Species variation showed positive correspondence with altitude and distance to tree line. Hofgaard and Wilmann (2002) noticed that topography is an apparent factor only in a zone just above the tree line and there is no correspondence between species occurrence and altitude in this zone. The importance of aspect is only evident at high altitudes, where plant communities are most exposed to abiotic environmental factors. Under the alpine conditions the main structuring force for vegetation composition is changed from being mainly biotic to abiotic. *Helicteres isora* and *Terminalia paniculata* were the dominant species with regular distribution in all the sampling sites (Manjunatha *et al.*, 2001). They suggested that the composition and structure of the plant community are governed by topographic and biotic factors.

Effect of microclimate in determining species richness at local level was very much evident by the findings of Sarycheva (1998). He found that the black alder (*Alnus glutinosa*) communities were characterized by large species diversity. The cause of such diversity is the complicated spatial structure. Spatial structure is presented by five elements (microsites) distinguished by size, time of existence, cause of origin and ecological conditions. Differences in ecological conditions between various microsites cause differences in species composition. The general environmental variance between sites provided a measure of environmental heterogeneity and this could be partitioned into a specific variance (mean environmental variance of a species) and an environmental covariance. Species diversity increased with general environmental variance because the

specific correlation of performance decreased as general environmental variance increases (Bell *et al.*, 2000).

The whole of the trends in ecological diversity can be summarized in the form of findings of Brockway (1998). He found that the plant species richness and diversity were generally lower in communities characterized by environmental extremes (excessive or scarce moisture and severely cold high altitude) than in mesic environments at low to middle altitudes. Evenness among plant species was greatest at higher altitudes where severe climate limited the ability of any single or a group of species to dominate. Species turnover rates were also higher near the environmental extremes. High turnover rates among mountain hemlock (*Tsuga mertensiana*) associations were attributed to highly variable topography and local microclimates, which resulted in substantial geographical isolation and species specialization among site types. Moisture appeared to have the most influence on species richness and sequential turnover rates at high altitudes where, available water is seasonally limited by low temperatures. Temperature had the greatest influence on overall species turnover throughout the landscape. Patterns of forest plant diversity appear to be the result of environmental conditions at larger scales and complex interactions among biological and physical variables at smaller scale within an historical extent of stochastic disturbance events.

In montane forests aspects also influence species richness, diversity and composition of communities. Findings of Metz (1997) indicated that *Quercus semicarpifolia* and *Rhododendron arboreum* were second and third most important species on *Tsuga*-dominated south-west facing stands. Baduni and Sharma (1996) also emphasized the importance of aspect, altitude and slope on species composition in moist temperate forest of *Quercus semicarpifolia*. The total basal area was highest (5733.48 cm²/100 m²) on the NE facing slope. *Q. semecarpifolia* was associated with *Rhododendron arboreum* as main companion species on all the faces except the SE. Pande and Joshi (1998)

found that *Pinus roxburghii* was the dominant species at lower elevation of east and south aspect and *Quercus leucotrichophora* at higher elevation of north aspect. Regeneration of *Cedrus deodara* was very poor in all the stands, while that of *P. roxburghii* was better on the south and east aspect and of *Q. leucotrichophora* on north aspect.

In Himalayas, zonation plays an important role in species distribution and subsequent variation in species diversity with altitude. Chandraprakash and Uniyal (1999) studied the structure of forest vegetation along an altitudinal gradient in the valley of flowers. The findings of the study confirmed the zonation in Himalayas. The dominant species in the Himalayan moist upper temperate forest (HMUTF, 2550 m-3000 m) were *Acer caesium*, *Rhododendron arboreum*, *Corylus jacquemontii*, *Pyrus vestita* and *Juglans regia*. Those in sub-alpine fir forest (SFF, 3000 m-3250 m) were *Abies pindrow* and *Taxus wallichiana* and the dominants in sub-alpine Birch forest (SBF, 3300 m-3600 m) were *Betula utilis*. The average tree density increased with the altitude, while average basal area decreased with altitude. The indices of tree species diversity and richness decreased with increasing altitude. In terms of shrub density *Princepia utilis* and *Rosa macrophylla* were the dominant shrub species in HMUTF. *R. macrophylla* and *Aster peduncularis* in SFF and *A. peduncularis*, *Gaultheria trichophylla* and *Ribes glaciale* in SBF. According to descending trend in resource utilization by dominant tree species, Pande (2001) identified three communities: *Aesculus indica-Picea smithiana-Machilus odoratissima-Betula alnoides* at Site-I (1825 m altitude). *Quercus leucotrichophora-M. odoratissima, Pieris ovalifolius-Aesculus indica-Rhododendron arboreum* (Site-II, 1925 m) and *R. arboreum-Carpinus viminea-Symplocos paniculata* (Site-III, 2070 m).

Factors besides latitude, altitude and aspect also influence the species composition diversity and structure of a community. Pitkanen (1998) used discriminate analysis to determine stand variables that best describe the community classes. He listed the significant variables in the classification in

order of importance as: the number of coniferous and broad-leaved tree species, prescribed burning, site fertility, topography, mean diameter of trees, dominance of tree layer by spruce, number of canopy layer, soil type, drainage and artificial regeneration. This artifact was shown to be related to the approximate geometric distribution of abundance in most plant communities.

According to Chandraprakash and Uniyal (1999), the low tree density (338 trees ha⁻¹) and high basal area (49.76 m² ha⁻¹) in Sub alpine fir forest (SFF) is attributed to high biotic interference and dominance of coniferous species. Drobner *et al.* (1998) tested the popular hypothesis that with decrease in stress, biomass increases and evenness of the community decreases. They found that evenness was lower in sites with higher biomass.

There was lower diversity (H' & J') at the site, which had been burned, and a higher diversity at the site, which had been selectively cut. Moreover, the diversity of the understories was higher than that of overstories in the site burned and the opposite occurred where selective cut was employed (Sano and Ohtsuka, 1998). Jiang Guo *et al.* (1998) showed that tree species diversity varied with the degree of perturbation. Higher perturbation resulted in least diversity. The diversity indices also varied with stand age, increasing from 16 years to 23 years old and then decreasing at 36 years.

Rawat *et al.* (1999) from their studies in the NW Himalaya reported that the least disturbed sites (Shola Van) had a moderate tree density (448.50±165.40 ha⁻¹) while protected and artificially stocked forest at Gopeswar had the highest tree density. The richness of woody species was the highest (39) at fringe forest followed by old growth forest (34), mesic site (32), secondary scrubs (18) and artificially raised forest following the landslide (15). The diversity of tree species was the highest in old forest (H'=2.297) while village forest at Gopeswar had the least diversity of tree species (0.651). However, old growth forest had the least shrub diversity (H'=0.775) while mesic and slightly disturbed

forest of Mandal had the highest shrub diversity ($H'=2.743$). Habitats characterized by a moderate level of disturbance provides more opportunity for species turnover, colonization and persistence of high species richness. InHyeop *et al.* (1999) found the range of similarity index between altitudinal belts as 42.0-71.8 per cent. However, they found that with increasing altitude, number of species, species diversity and evenness increased, suggesting interference by man was relatively severe at lower elevations. Agni *et al.*, 2000 studied the regeneration pattern, tree diversity and qualitative characters of forests and found that total tree density varied from 4.3 to 11.2 trees/100 m² and tree diversity varied from 0 to 2.18. Absence of young regeneration of all the important dominant species showed the inability of these forests to produce progenies owing to repeated burning by the State Forest Department and severe biotic pressure by both wild and domestic animals.

Species with a narrow niche were confined to a single habitat type and remained at or near their initialization sites. Broader niches resulted in increasing niche overlap and competition, but enhanced species mobility (Plotnick and Gardner, 2002). While investigating the effects of variation in landscape heterogeneity and disturbance on patterns of species abundance, they found that disturbance events removed species from affected sites, but did not otherwise alter habitat characteristics. Although, intermediate levels of disturbance frequency and extent increased the probability of species co-existence.

Using the 2x2 contingency table Zhang and Zhang (1999) investigated the interspecific association of species in evergreen broad-leaved forests, the results showed that the chi-square test, together with the association coefficient was an effective method for measuring species associations in the subtropics. The results could provide a theoretical basis for choosing tree species for mixed silviculture.

Interspecific association was analyzed using chi-square test, association coefficient and percentage of co-occurrence (Zhang and Zhang, 2001). Results showed a positive association among *Celtis tetrandra* and *Euscaphis japonica*, *Quercus glauca*, and *Adinandra millettii* and *Diospyros oleifera*, *Q. glauca* and *Lindera communis* and *Aralia chinensis* and *Rhus chinensis*. The *Alsophila spinulosa* population was negatively associated with *Machilus kwangtungensis*, *Adinandra millettii* and *Celtis tetrandra*.

Interspecific association was studied by Singh *et al.*, 1988 in the vegetation of Mudumalai wild life sanctuary in Tamil Nadu. While studying interspecific association in the Korean Pine (*Pinus koraiensis*) forest, Sun *et al.* (1996) found that there were respectively, 9 and 19 pairs of significantly associated species in the tree and shrub layers.

2.3 FREQUENCY DISTRIBUTION

Two communities composed of the same plant species can differ greatly in structure depending on their relative abundance distribution. Communities in which species are more or less equal in abundance are said to exhibit evenness or equitability. Communities with one or two very abundant species and many rare ones are said to exhibit pronounced dominance. Dominance - diversity curves are used for displaying relative abundance. These curves ranged from steeply oblique approximating geometric series to less steep geometric slopes approaching to a sigmoid form on stand 2 of mixed conifer forest and stand 1 of pine mixed broadleaf (Sunil Kumar *et al.*, 2001). They opined that steeply oblique curves generally appear for communities of low density, which have vigorous environment and are characterized by only a few species scattered along the logarithmic scale of relative importance. In contrast, the less steep geometric slopes appear for communities of less severe environment and moderate species diversity. They found that the curves for seedling and sapling

on different stands generally showed steeply oblique geometric series, thereby a low level of diversity.

Dominance - diversity curves for tree layer (on the basis of IVI) have been drawn to interpret the community organization in terms of resource share and niche space (Ralhan *et al.*, 1982). The curves for all the forests fit the geometric series which conforms to the niche pre-emption hypothesis (Whittaker, 1972). *Pinus roxburghii* forest indicated single species dominance, which was also pronounced in *Quercus semecarpifolia* forest. Among the oak forests, *Q. floribunda* forest indicated relatively greater equitable share of resources among the various species. The dominance-diversity curves for the shrubs indicated a behaviour almost similar to that of the trees. Singh *et al.* (1991), and Pande and Joshi (1998) also found the geometric series for these curves and they supported the hypothesis of Whittaker (1972) that the geometric form is often shown by vascular plant communities with low diversity. Further elaboration of geometric series is presented by Marquez *et al.* (1999), who found that *Q. sideroxylo* was the most common of oak species recorded. In 88.4 per cent of the sites, the first species occupied half of the total basal area, the second species occupied half of the remaining basal area and so forth until the last species. This pattern was described using a geometrical mathematical model that can be used for forest management.

However, Chang Fu *et al.* (2000) found that dominance - diversity curve for each forest conformed to a log-normal distribution. Findings of Pande (2001) also deviated from geometrical series. He found that the curves approached towards log-normal series for all the sites except site-I for shrub species, which followed log series. The log series indicate that moderately common species reflect most closely the nature of the environment and abundant species fluctuate less violently from time to time. A log series should, however, result if the intervals between the arrival of these species were random rather regular. It is applicable in the situations where one or a few factors dominate the ecology of

the community. Whereas, in the log-normal distribution, a large number of factors determine the number of species in a community. Moreover, the multidimensional niche space of a taxon being subsequently split by the counterpart species resulted in more competition as evidenced by most of the sites under study. Further, if these curves are related with diversity indices, it is obvious that log-normal series represent high diversity condition as compared to log-series.

The spatial dispersion of individuals in a species is central in ecology theory. Patchiness, or the degree to which individuals are aggregated or dispersed, is crucial to how a species uses resource, to how it is used as a resources, and, to its reproductive biology (Condit *et al.*, 2000). The degree of aggregation in the distribution of 1768 tree species was examined by them based on the average density of nonspecific trees in circular neighborhoods around each tree. When all individuals larger than 1 cm. in stem diameter were included, nearly every species was more aggregated than a random distribution. Considering only larger trees (> 10 cm. in diameter), the pattern persisted, with most species being more aggregated than random. Rare species were more aggregated than common species, the degree of clumping correlated negatively with species density. Species whose seeds are dispersed by animals were assumed to be better dispersed than wind or explosively dispersed species, and canopy trees were assumed to have well - dispersed seeds relative to understorey treelets. It was also found that dipterocarps were strikingly more aggregated than non-dipterocarps. Finally, the observation that aggregation was weaker in larger diameter classes supports the notion that herbivores and plant diseases play a role in reducing aggregation.

A patch dynamics perspective of old growth forest stands was investigated by Busing (1998). Stands tended to have 10-20 tree species per hectare and at least 5 species had biomass levels > 10 t ha⁻¹, which indicated high evenness. When all species were combined, juveniles showed aggregation and adults were

often hyper - dispersed. Juveniles of all major species exhibited aggregation. Several species exhibited regeneration near conspecific adults. This pattern suggested limited mobility for such species within the shifting mosaic. While doing phyto-sociological analysis of shrub vegetation under different forest communities around Shimla (HP), Singh *et al.* (1991) found that shrub species had heterogeneous nature with contagious distribution pattern. Random and regular distribution patterns were altogether absent. Dominance diversity curves generally followed geometric series.

Ralhan *et al.* (1982) used a simpler method: abundance frequency ratio for determining spatial dispersion of individuals in a species. The forests were characterized by a preponderance of contagious distribution and rarity of regular distribution. Their findings conformed with the hypothesis of Odum (1971). According to him clumped distribution is the commonest pattern in nature, random distribution is found only in very uniform environments and regular distribution occurs where severe competition between the individuals exists. Contagious distribution depends on the (i) local habitat differences (ii) daily and seasonal weather changes and (iii) reproductive processes. Tanouchi and Yamamoto (1995) divided the species found in the canopy into three groups based on size and spatial distribution patterns and density in each tree size. Group A (*Distylium racemosus*, *Persea japonica*) showed a high density, nearly random distribution and an inverse J-shaped size distribution; Group B (*Quercus salicina*, *Q. acuta*, *Q. gilva*) were distributed contagiously with conspicuous concentration of small trees (>50 cm dbh); species in group C included fast growing pioneer and shade intolerants (e.g. *Cornus controversa*, *Carpinus tschonoskii*, *Fagora ailanthoides*) which formed large clumps.

The arrangement of trees within a stand by location and age (stand structure) is in part determined by the life history strategy of the species and disturbance history of the stand. Spatial characteristics of stand structure in *Pinus torreyana* have been studied by Wells and Getis (1999) with known

disturbance histories of fire and grazing in three stands. They found that young trees tend to be more aggregated than old trees within the same stands on otherwise ecologically similar sites. It was hypothesized that the distribution of oaks (*Quercus robur*) with their potential to establish in many habitats, depends on the behavior of the dispersing animals to a greater extent than micro-habitat conditions. An investigation was done by Frost and Rydin (2000). They found that the oak trees were spatially aggregated in a small-scale context. An association was found between the oak trees and animal dispersers and they concludes that seed dispersing animals seen to be of importance for oak distribution even though animal activities seen to differ between sites. In another study it was found that most species showed significantly aggregated patterns and only two species, *Payena lucida* and *Scaphium macropodium* were randomly distributed (Niiyama *et al.*, 1999).

Spatial distribution pattern of chinese fir (*Cunninghamia lanceolata*) and its associated tree species was aggregated (Guang Qui *et al.*, 2002). They suggested that main reason of aggregated distribution in low tree class was environment. While in the high tree class it was environment or aggregation nature itself. A regular pattern was noticed in the dominant trees of *Fagus sylvatica*, which is a consequence of intense interspecific competition at local level (Rozas and Fernandez-Prieto, 2000). Mortality occurs mainly within the dense group of small trees, which produce a broad regular pattern. The random spatial pattern of dominant beeches seems to be characteristic of old-growth forests and could be a consequence of either self-thinning processes or exogenous factors.

Liu Jin Fu and Hong Wei (1999) used Weibull Model and indexes of aggregation ($C.I_s$ and M^*) respectively to simulate the spatial pattern and to estimate the intensity of clumping in 3 *Castanopsis kawakamii* populations. The results showed that all populations at different stages of development conformed to the Weibull distribution. Furthermore, the shape parameters 'C' declined with

increasing index of aggregation, indicating that 'C' may be used to estimate clumping intensity. In another study (Liu Jin Fu *et al.* 1999) the spatial distribution pattern of *C. kawakamii* populations from 3 different mixed forest types in Fujian Province was studied in sample quadrats using indexes of aggregation (C , I_{δ} , C_M , M^*) and Imao's regression method (M^*-M). The spatial distribution pattern of the adult (tree class) in the population was of the random type in populations of *C. kawakamii/Schima superva*, but of the clumped type in *C. kawakamii/Masson pine/Castanopsis carlesii*. In seedling class, the spatial patterns were of the clump type in all the three populations. The distribution pattern of Morista's Index was used by Byun Kango *et al.* (1999) and it showed that *Carpinus coreana* distributed randomly in the tree and sub tree layers and regularly in the shrub layer.

The size variation of individuals is an important aspect for describing community structures; it also indicates the establishment process and shade-tolerance of a population and from it the inter-species relationship can be derived. Xu *et al.* (2001) reported that the distribution pattern of *Castanopsis sieboldii* was unimodal, which had the largest population size in the sampling plots. Moreover, *C. sieboldii* had a large seedling and sapling population and can regenerate from stump sprouts. Those characteristics of *C. sieboldii* may have enabled it to maintain its dominance through the process of gap regeneration. *Schima wallichii* had a small population size with few saplings and seedlings in the stands. The distribution pattern of *S. wallichii* was sporadic type, which indicates that *S. wallichii* is a light demanding species and cannot maintain itself under a closed canopy. However, the distribution of *Distylium racemosus* presented a clear reverse - J type and it had many saplings and seedlings in the stands. This species, regarded as shade – tolerant, can regenerate under a densely closed canopy. These results suggest that in the population dynamics of the succession process, *C. sieboldii* and *D. racemosus* are a self-maintaining type and *S. wallichii* is a gap or opening dependent type. Based on similar study Ralhan *et al.* (1982) predicted the future trend in species composition. The

composition of *Pinus roxburghii* forest will remain the same while in the *Quercus leucotrichophora* forest, *Q. leucotrichophora* and *Rhododendron arboreum* may disappear from the forests, whereas *Q. floribunda* may emerge as dominant species. In *Q. semecarpifolia* forests, the complete absence of seedlings of any species poses the danger of complete replacement of the forest by a scrub or grassland vegetation.

Killeen *et al.* (1998) observed that most canopy and understorey tree species had a population structure characterized by numerous juveniles and relatively few large trees, while emergent species tended to have a size class distribution with relatively few juvenile individuals. Chandrashekara and Ramkrishnan (1994) studied the size class distribution of seedlings, saplings and mature trees, which showed a negative exponential distribution with a clear preponderance of stems of small girth classes. In the stand type studies by Byun Kango *et al.* (1999) reported that according to dia-distribution, *Carpinus coreana* in the forest will gradually decline and be replaced by a *Quercus* community.

Shimano (2000) used power function to explain forest structure. A power function ($Y = ax^b$ where Y = stem density, x = DBH class, and a & b = constants), fits the distribution better than an exponential function ($Y = ae^{bx}$). The parameter b in the power function is approximately -2. This means that the natural forests studied have a patch mosaic structure and that tree cohorts regenerate from gaps. Parameter 'a' implies the number of juveniles and 'b' means size dependent mortality. The value of -2 for parameter b means that when trees in a given DBH class double their DBH, the density of size class should decrease by one forth. This phenomenon results from self-thinning and is caused by horizontal space competition among trees called the tile model. In a typical natural forest dominated by deciduous broad-leaved tree species, trees are recognized as pioneer or climax species by the parameters describing their regeneration patterns. When the power function model was applied to the DBH-class distribution of each dominant species, in pioneer species parameter 'a' was

high and 'b' was less than -2 , suggesting that there are too many juveniles, but mortality is high. On the other hand, in climax species parameter 'a' had a low value and value of 'b' was larger (-ve, but close to zero), suggesting that there are not many juveniles, but mortality is low.

The diameter distribution of the growing stock is an essential starting point in many forest management planning problems. Normal, log normal, beta, gamma, Weibull, S_B , binomial, Johnson etc. are some of the statistical distribution functions which can be fitted to the diameter data. In the study by Zhang *et al.* (2001), a finite mixture of two Weibull distributions: is used to describe the diameter distribution of the rotated sigmoid, uneven-aged forest stands. Four, example stands are selected to demonstrate model fitting and comparison. Compared with a single Weibull or negative exponential function, the finite mixture model is the only one that fits the diameter distributions well and produces root mean square error at least four times smaller than the other two. The results show that the finite mixture distribution is a better alternative method for modeling the diameter distribution of rotated sigmoid, unevenaged stands.

Navar *et al.* (1996) developed a growth model based on fitting a diameter distribution function to diameter classes of uneven aged forest stands. The diameter classes were characterized by the three-parameter Weibull probability density function. Predicting average DBH results in estimates of total wood volume and the diameter class distribution. Total wood volume was estimated with the predicted parameters plus one standard error. These preliminary results showed that the growth model can be used to forecast forest growth of the irregular forest stands. Tewari (2000) tested Normal, Weibull and S_B distribution functions for predicting class distributions of 251 trees of *Acacia tortilis*. Absolute deviation indicated that the normal distribution, though simpler, produced better results followed by S_B while Weibull was the poorest. He also argues that if the distribution is unimodal or largely skewed, a situation often encountered in the normal forests and in the plantations under silvicultural management, it is

assumed that Weibull and S_B distributions are likely to give better results than the normal distribution.

Kangas and Maltamo (2002) compared beta and Weibull distribution describing basal area diameter distributions in 535 stands dominated by *Pinus sylvestris* and *Picea abies* in Eastern Finland. Parameters for both 2- and 3-parameter approaches of the Weibull distribution were estimated using the method of maximum likelihood. Models for these parameters were derived using regression analysis. For the beta distribution, regression models were formed for the minimum, maximum and standard deviation of diameter within individual stands. The distributions obtained were compared using diameter sums and estimates of the proportion of saw timbers. The results did not reveal any major difference between the suitability of the beta and 2-parameter approach of the Weibull distribution. The 2-parameter approach of the Weibull distribution gave better results than the 3-parameter approach. The construction of a tree girth distribution model for *Picea abies* plantations from 141 sample plots of 1000 m² is described by Lejeune (1994). Effects of the theoretical distribution (normal and Weibull distribution are compared) and estimation methods are analyzed. Despite the higher flexibility of the Weibull distribution, its use did not give a more accurate prediction of the tree size distribution. The small number of the samples measured in the plots may be the primary cause of the inaccuracy considering the data analyzed. The normal distribution, which is easier in use, appears to be more suitable for the creation of a distribution model for such stands.

The parameters of 5 theoretical distributions (binomial, normal, Weibull, Johnson and beta) were determined for individual dbh distributions from data from 84 sample plots in *Abies alba* stands, for all species together and separately for *A. alba* alone. The binomial normal distribution was useful for modeling dbh distribution in single species fir stands, but was not the optimum solution for every developmental stage where the population was <90 per cent. The best fit

was obtained for Johnson distribution (Zasada, 1995). XueLi and Hagihara (1994) studied size distribution in *Pinus densiflora*. The skewness of tree height distribution showed positive value which means that the distribution was more or less L shaped and in addition the skewness decreased with increasing mean tree height indicating that smaller trees die as the stand grew. This trend is consistent with the asymmetric (one - sided) competition hypothesis that self-thinning is driven by competition for light. The tree height distribution was analyzed using the Weibull distribution. The location parameter $\lambda_{\min.}$ of the Weibull distribution increased with increasing stand age, and the scale parameter 'a' tended to increase slightly with increasing stand age. The range of the shape parameter 'b' of the Weibull distribution corresponds to that of the Skewness.

Lindsay *et al.* (1996) studied permanent sample plots of *Pinus radiata* which showed that the goodness of fit improved on average by 15 per cent and suggested that the method could be embedded in diameter distribution growth-and - yield system to good effect. In this opinion Weibull distribution is commonly used in forest modeling being most popular and versatile has the distinct advantage that its parameters are readily estimable. Chen and Tsrong (1998) used parameters of Weibull density function to study the dynamics of stand structure of eleven major tree species. The diameter distribution was skewed to the right (larger diameters).

MATERIALS AND METHODS

The investigations were carried out in the Department of Tree Improvement & Genetic Resources of Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan (HP) during 2001 and 2002. This chapter will be dealt with under the following heads.

3.1 STUDY AREA

3.2 EXPERIMENTAL METHODOLOGY

3.2.1 Species diversity

a) α - diversity

- I. Species richness (S)
- II. Shannon index (H')
- III. Simpson's index of dominance (C)
- IV. Evenness or equitability (J')

b) Importance value index (IVI)

c) Spatial distribution

d) Niche width (B_i)

e) β - diversity

- I. Sorenson's Index of Similarity (s) between two communities
- II. Jaccard's Index of Similarity (J)
- III. Chord distance between two communities

f) Interspecific association

3.2.2 Frequency Distribution

3.1 STUDY AREA

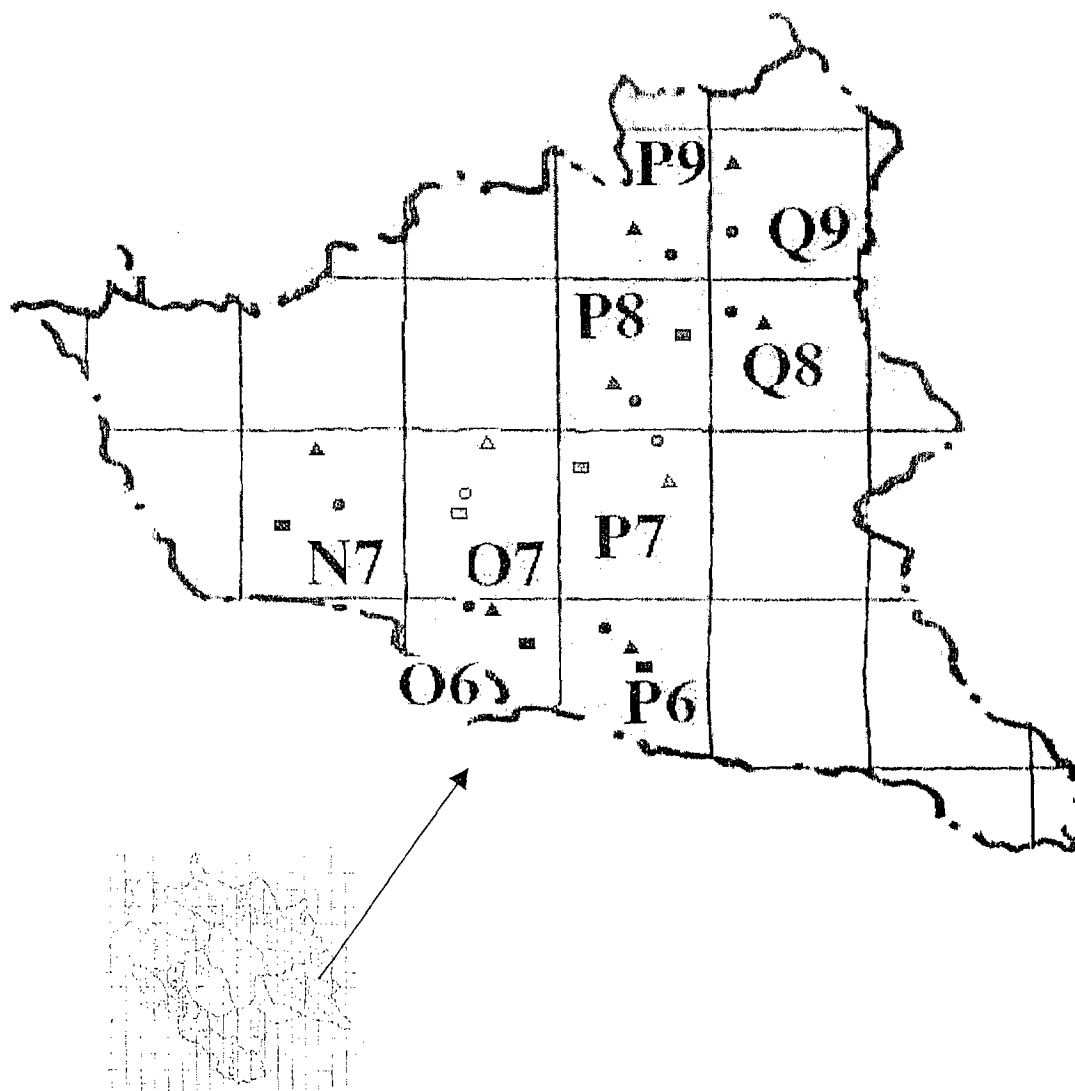
Studies have been carried out in the forests of Kinnaur, a North-eastern frontier district of Himachal Pradesh situated between 31°05'50" and 32°05'15" North latitude and between 77°45' and 79°00'35" East longitudes. It comes under Zone IV of the four Agro-climatic Zones of Himachal Pradesh, chiefly a mountainous tract and represents the dry temperate and cold deserts of the Trans-Himalayas. A detailed account of the sampling units (study sites) has been given in the Table 1, which are further presented on the map(Fig. 1).

3.2 EXPERIMENTAL METHODOLOGY

The area was divided into grids of 20 x 20 km. In one grid transects of 180 m to 480 m were laid depending upon the presence of woody vegetation and accessibility of the area. There were 2-3 transects in one grid. Quadrats were demarcated at an interval of 40 m in every transect. The area of one quadrat for trees was 20 x 20 m whereas for shrubs it was 5 x 5 m. There were three to eight quadrats in one transect and total number of quadrats varied from 6 to 24 in one grid. Sampling was done according to Stratified Random Sampling (Krebs, 1989).

3.2.1 SPECIES DIVERSITY

Diversity, one of the characteristics of community structure, bears to qualitative observations the relationship that variance bears to quantitative measurements. In the same way that statistical variance provides a measure of the variability in attributes, a diversity index measures the variability of species identity. The purpose of measuring a community's diversity is usually to judge its relationship either to other community properties such as productivity and stability or to the environmental conditions that the community is exposed to (Pielou, 1975).



○	= I	} Sampling units
△	= II	
□	= III	

Fig. 1 Map showing grids and sampling units studied in district Kinnaur

Table: 1 Grids studied in Kinnaur district

Grid Code	Sampling Unit Code	Sampling Unit	Altitudinal Range (amsl)	No. of Quadrats
N ₇	N ₇ I	Sungra	2460 – 2740m	8
	N ₇ II	Nichar	2860 – 2940m	8
	N ₇ III	Kafnu	2060 – 2150m	6
O ₆	O ₆ I	Shong	1920 – 2100m	8
	O ₆ II	Barua	1860 – 2060m	8
	O ₆ III	Sangla	2470 – 2570m	8
O ₇	O ₇ I	Kalpa	2720 – 2810m	5
	O ₇ II	Pangi	2740 – 2990m	8
	O ₇ III	Poari	1950 – 2120m	6
P ₆	P ₆ I	Kharogla	2720 – 2940m	8
	P ₆ II	Mastarang	3000 – 3030m	8
	P ₆ III	Chhitkul	3120 – 3310m	8
P ₇	P ₇ I	Jangi	2800 – 3025m	8
	P ₇ II	Moorang	2860 – 2940m	8
	P ₇ III	Ribba	2520 – 2640m	8
P ₈	P ₈ I	Lippa	2760 – 2945m	7
	P ₈ II	Asrang	3190 – 3370m	8
	P ₈ III	Karla	2930 – 3030m	8
P ₉	P ₉ I	Giabung	3270 – 3460m	8
	P ₉ II	Ropa	3120 – 3280m	7
Q ₈	Q ₈ I	Pooh	2940 – 3000m	3
	Q ₈ II	Dubling	3100 – 3180m	6
Q ₉	Q ₉ I	Maling	3120 – 3150m	3
	Q ₉ II	Chango	3160m	3

Species diversity, which is considered a rough proxy for biodiversity has been used by ecologists since several decades for characterizing and comparing communities and ecosystems. Diversity may be measured at a variety of levels from genes to landscape. In this study the focus was on species level and on two components namely species packing or α - diversity and species turnover or β -diversity.

a) α - Diversity

Number of species or any other higher ranks of taxonomic organization in a site is termed as α - diversity (Whittakar, 1972).

i) Species Richness (S)

One measure of the community's diversity is simply the number of species (S) it contains. This, however, is an un-weighted measure but would appear an unambiguous and straightforward index of species richness.

ii) Shannon Index (H')

A weighted measure that takes account of the degree to which proportional abundances are distributed among the species is Shannon-Wiener index (H'), which is defined as:

$$H' = - \sum_{i=1}^S [(p_i) \log (p_i)]$$

Where,

- H' = Shannon Index
- p_i = IV of i^{th} species
- S = number of species
- IV = Importance Value

Importance Value (IV %)

Importance value of a species was calculated as described by Basnet (1992).

$$IV\% = \frac{(RBA + RD)}{2}$$

iii) Simpson's Index of Dominance (C) or Coefficient of Dominance (Cd)

$$C = \sum_{i=1}^S (p_i)^2 \quad (\text{Simpson, 1949})$$

The symbols have the same meaning as in Shannon-Wiener index (H'). This function is the probability that any two individuals picked independently and at random from the community will belong to the same species. It thus measures a property that is opposite to diversity. If a single species dominates a community and community's diversity is low, C is high. Conversely, if there are numerous species all fairly evenly represented, all are uncommon and ' C ' is low.

iv) Evenness or Equitability(J')

The diversity of a community depends on two things: the number of species and the evenness with which the individuals are apportioned among them. A community with a few evenly represented species can have the same diversity index as one with many, unevenly represented species. A method of measuring evenness is therefore required. The measure of equitability as given by Pielou (1975), is as follows:

$$J' = \frac{H'}{\log S}$$

Where,

H' = Shannon Index

S = number of species occurring at each site.

b) Importance Value Index (IVI)

It is a measure of relative importance of a species in a community and is measured as:

$$IVI = RBA + RD + RF$$

$$\text{Relative Basal Area} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

$$\text{Relative Density} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all the species}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

(Phillips, 1959)

$$\% \text{ Frequency} = \frac{\text{Number of sampling units in which species occurred}}{\text{Total number of units studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals}}{\text{Number of quadrats of occurrence}}$$

$$\text{Basal Area} = \pi r^2 \quad (r = \text{radius}) \quad (\text{Curtis \& McIntosh, 1950})$$

c) Spatial Distribution

Spatial distribution of a species in a community was obtained on the basis of abundance to frequency ratio (A/F). Different values of the A/F ratio indicate different distributions:

Regular	(< 0.025)
Random	(0.025 to 0.050)
Contagious	(>0.050)

d) Niche Width (B_i)

It explains the range of distribution of a species across the communities and is given by the following formula:

$$B_i = \frac{\left(\sum_{j=1}^{S_j} N_{ij} \right)^2}{\sum_{j=1}^{S_j} N_{ij}^2} \quad (\text{Levins, 1968})$$

Where,

N_{ij} = density value of a species on site J.

e) β - diversity or Species turnover

The rate of change of species composition across communities in a landscape is called β - diversity (Magurran 1998, Negi & Gadgil 2002). The measures of β - diversity used are as follows:

i) **Sorenson's Index of Similarity (s) between two communities**

$$s = \frac{2C}{A + B} \quad (\text{Sorenson, 1948})$$

Where,

- A = number of species in community A
- B = number of species in community B and
- C = number of species common to both the communities

The value of 's' varies between 0 to 1, when the two communities are having no species common, its value is 0 and when both the communities have same species only then s is 1.

ii) **Jaccard's index of similarity (J)**

$$J = \frac{2C}{A + B - C} \quad (\text{Magurran, 1988})$$

Where,

- J = similarity index between two communities A and B
- C = number of species common to both the communities
- A & B = number of species in community A and B respectively

iii) Chord distance between two communities

Chord distance between the j_{th} and k_{th} sites is given as:

$$D_{jk} = 1 - \left[\frac{\sum_{i=1}^S N_{ij} N_{ik}}{\sqrt{\sum_{i=1}^{S_j} N_{ij}^2 \sum_{i=1}^{S_k} N_{ik}^2}} \right]^{1/2}$$

Where,

N_{ij} and N_{ik} are the number of individuals of species in sites j and k respectively, and S_j and S_k are the number of species in j and k sites, respectively. The dissimilarity (distance) values vary from 0 to 1 for pairs of sites corresponding with having none to completely dissimilar taxonomic composition. This index is more robust to measure β -diversity as it uses abundance information also.

f) Interspecific Association

Association in the statistical sense, is the amount of co-occurrence in excess of that to be expected if two species are independently distributed. Positive association is to be anticipated in the case of two species which exhibit overlapping habitat requirements or which interact in such a way as to favor mutual presence. Negative association in this sense is to be anticipated when habitat requirements or tolerances are distinct or where one species tends to exclude the other (Cole, 1949).

This is measured on the basis of the departure of the distribution of presence or absence from independence. It is assumed that the probability of

occurrence of the species is constant for all samples. The basic feature of this method is the 2x2 contingency table:

Species B	Species A		
	Present	Absent	
Present	a	b	a + b
Absent	c	d	c + d
	a + c	b + d	a + b + c + d = N

Test of association was done through chi-square test of independence.

Chi-square value was calculated as:

$$\chi^2 = \frac{(ad-bc)^2 N}{(a+b)(a+c)(c+d)(b+d)}$$

Yate's correction:

$$\chi^2 = \frac{(ad-bc - \frac{1}{2} N)^2 N}{(a+b)(a+c)(c+d)(b+d)}$$

Coefficient of Association

If χ^2 is significant, coefficient of association (Debauche, 1962) may be used to give an actual quantitative value for comparison with other species. The range is +1 = complete positive association, to -1 = complete negative association and 0 = no association.

$$C_{AB} = \sqrt{\frac{\chi^2}{\chi^2 + N}}$$

Where,

C_{AB} = Coefficient of association between A & B,
 n = Total number of occurrences.

If χ^2 is significant at 5% level then *Null Hypothesis*: that the co-occurrence of two species is independent is discarded and it is concluded that both the species are associated, either positively or negatively.

If 'ad' is greater than 'bc' then the association is positive (affinity); if 'bc' is greater than 'ad' then the association is negative (repulsion). $\chi^2(0.05) = 3.84$, if less than this is obtained, any apparent association could well be due to chance.

3.2.2 Frequency Distribution

It is of utmost importance to have knowledge of the expected behavior of a phenomenon or, the expected frequency distribution. They serve as benchmarks against which to compare observed distributions and provide decision-makers with a logical basis for making decisions and prediction on the basis of limited information. Several probability density functions for statistical distributions have been used to model the distribution of tree diameters. The usual process of developing a diameter distribution type growth and yield model has been to, a) acquire a data set; b) select a family of distributions; c) estimate indexing parameters of the distribution and finally; d) fit the distribution.

Amongst expected or theoretical continuous distributions, the following are the most commonly used:

- | | |
|---------------------------|------------------------------|
| i) Normal distribution | ii) Log-normal distribution |
| iii) Gamma distribution | iv) Exponential distribution |
| v) Weibull distribution | vi) Logistic distribution |
| vii) Pearson distribution | |

These distributions were tried to fit the data of different tree species for the characters height and dbh (diameter at breast height). But only three distributions (normal, log-normal and exponential) were found to fit the data.

Normal Distribution

The single most used distribution in statistical analysis is the *normal distribution*, first discovered by an English Mathematician Abraham De Moivre (1733).

A random variable X is normally distributed if it has probability density function (pdf):

$$f(X; \mu, \sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp \left[-\frac{1}{2} \left\{ \frac{(x - \mu)}{\sigma} \right\}^2 \right];$$

$$-\infty < x < \infty$$

$$-\infty < \mu < \infty$$

$$\sigma > 0$$

Where,

x = Value of the continuous random variable

μ = Mean of the normal random variable

e = Mathematical constant approximated by 2.7183

π = Mathematical constant approximated by 3.1416

Log-normal Distribution

A distribution in which logarithm of the original variate is distributed normally is called *Log-normal*. It was Gibrat (1930, 1931) who found that the distribution can usefully represent the distribution for size for varied kinds of 'natural' economic units. It is given as:

$$f(X) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp \left[-\frac{1}{2\sigma^2} \{\ln(x - \theta) - \mu\}^2 \right]; (x > \theta)$$

Exponential Distribution

A continuous random variable X assuming non-negative values is said to have an exponential distribution if it has a pdf:

$$f(x) = \sigma^{-1} \exp \left[-\frac{(x - \theta)}{\sigma} \right]; x > \theta, \sigma > 0$$

EXPERIMENTAL RESULTS

The current investigation provides qualitative information on species diversity, pattern of frequency distribution and relation of abiotic and biotic factors with the vegetation of Kinnaur district. The findings are elaborated under the following headings:

4.1 GENERAL FEATURES OF THE SAMPIING UNITS

4.2 SPECIES DIVERSITY

a) α -Diversity

- I. Species richness (S)
- II. Shannon index (H')
- III. Simpson's index of dominance (C)
- IV. Evenness or equitability (J')

b) Importance Value Index (IVI)

c) Spatial Distribution

d) Species distribution with respect to biotic and abiotic factors

e) Structural parameters of the dominant tree species with respect to biotic and abiotic factors

f) Niche Width (B_i)

g) β -Diversity

- I. Sorenson's Index of Similarity (s) between two communities
- II. Jaccard's index of similarity (J)
- III. Chord distance between two communities

h) Interspecific Association

4.3 FREQUENCY DISTRIBUTION

4.1 GENERAL FEATURES OF THE SAMPLING UNITS

Name and code of the sampling units along with altitudinal range and number of the quadrats are presented in Table 1. These sites were located on all the four aspects and in the altitudinal range of 1960 m to 3365 m above mean sea level. All the study sites were having a hilly terrain with a maximum slope of 25° (Table 2). Different forms of biotic and abiotic pressures prevalent in the study sites are given in Table 3. A total of 19 tree and 13 shrub species represented the floral diversity of woody plants in district Kinnaur (Table 4).

4.2 SPECIES DIVERSITY

a) α -Diversity

i) Species Richness (S)

For trees, number of species present at a site varied from 1 (N_{7III} , Q_{8I} , Q_{9I}) to 7 (P_6I). P_8II was having 5 species and sites N_{7II} , P_6II , P_6III and Q_{7II} were found to have 4 species each. Eight of the 24 sites studied were having 3 species each and 6 sites had 2 species each (Table 5). In case of shrubs the number of species ranged from zero (P_{7III} , P_{8III} , P_9I and P_9II) to five (N_{7II} and P_6I). O_{7III} was having 4 species. Of the 24 sites, six were found to have 3 species, seven sites had 2 species, whereas, four sites were having one species each. Table 5 presents the detailed account of number of species in case of trees and shrubs under the 24 sampling units studied in 9 different grids.

ii) Shannon Index (H')

A measure of diversity that takes account of the relative quantities of the species present in different sites is given in Table 5. The highest value of species diversity for trees was recorded for site P_6I (1.984) followed by P_6III (1.646) and N_{7II} (1.286). Sites N_{7III} , Q_{8I} and Q_{9I} were having the lowest value of

Table: 2 Characteristics of the sampling units

Sr. No.	Sampling Unit Code	Sampling Unit	Altitude (amsl)	Aspect	Slope (°)	Soil Texture	Soil Color
1	N ₇ I	Sungra	2105m	Northern	10-25	Gravelly-Silt	Grayish black
2	N ₇ II	Nichar	2600m	Northern	10-25	Clay-Loam	Dark brown
3	N ₇ III	Kafnu	2900m	Southern	10-25	Clay-Loam	Dark brown
4	O ₆ I	Shong	2010m	Eastern	10-25	Sandy-Loam	Dark black
5	O ₆ II	Barua	1960m	Eastern	10-25	Gravelly-Silt	Dark-Gray
6	O ₆ III	Sangla	2520m	Northern	0-5	Loam	Dark brown
7	O ₇ I	Kalpa	2765m	Eastern	10-25	Loam	Reddish yellow
8	O ₇ II	Pangi	2865m	Southern	10-25	Sandy-Loam	Light yellow
9	O ₇ III	Paori	2035m	Eastern	10-25	Gravelly-Loam	Light brown
10	P ₆ II	Kharogla	2830m	Southern	5-10	Loam	Dark brown
11	P ₆ I	Mastrang	3015m	Southern	0-5	Silty-Loam	Light yellow
12	P ₆ III	Chitkul	3215m	Northern	10-25	Sandy-Loam	Yellow
13	P ₇ I	Jangi	2915m	Western	10-25	Gravelly-Sand	Light yellow
14	P ₇ II	Moorang	2900m	Eastern	10-25	Gravelly-Sand	Light yellow
15	P ₇ III	Ribba	2560m	Northern	10-25	Sandy-Silt	Yellow
16	P ₈ I	Lippa	2850m	Eastern	5-10	Clay-Silt	Dark gray
17	P ₈ II	Asrang	3280m	Western	10-25	Sandy-Silt	Gray
18	P ₈ III	Karla	2980m	Western	10-25	Sandy-Silt	Light gray
19	P ₉ I	Giabung	3365m	Southern	10-25	Clay-Loam	Black
20	P ₉ II	Ropa	3200m	Southern	10-25	Clay-Loam	Black
21	Q ₈ I	Pooh	2970m	Southern	10-25	Gravelly-Silt	Light brown
22	Q ₈ II	Dubling	3140m	Northern	10-25	Loam	Reddish brown
23	Q ₉ I	Maling	3135m	Western	5-10	Gravelly- Loam	Yellow
24	Q ₉ II	Chango	3160m	Northern	5-10	Sandy-Loam	Grayish black

Table: 3 Biotic and abiotic pressures in the sampling units

Sr. No.	Sampling Unit Code	Sampling Unit	Fire	Trampling	Grazing	Lopping	Landslide	Others
1	N ₇ I	Sungra	Moderate	Low	Low	-	-	
2	N ₇ II	Nichar	Low	Moderate	Moderate	Moderate	-	Logs of deodar present
3	N ₇ III	Kafnu	High	Moderate	Moderate	High	-	-
4	O ₆ I	Shong	Low	Moderate	Moderate	High	Low	-
5	O ₆ II	Barua	Very Low	High	High	Very High	Low	-
6	O ₆ III	Sangla	Very Low	Very High	Very High	Very Low	Very Low	-
7	O ₇ I	Kalpa	Very Low	Moderate	High	High	-	
8	O ₇ II	Pangi	Moderate	High	High	Very High	-	Snow effect on tree top
9	O ₇ III	Paori	-	Moderate	Moderate	Very High	-	Scrapping of trees for torch and fuel wood
10	P ₆ I	Kharogla	-	-	High	Moderate	Moderate	-
11	P ₆ II	Mastrang	-	High	High	Very Low	Very High	-
12	P ₆ III	Chitkul	-	Low	Moderate	Low	Very High	-
13	P ₇ I	Jangi	Moderate	Low	Low	High	-	Scrapping of trees for torch and fuel wood
14	P ₇ II	Moorang	Low	Moderate	Moderate	High	-	- do-
15	P ₇ III	Ribba	Low	Moderate	High	Moderate	-	-
16	P ₈ I	Lippa	Very Low	Moderate	-	High	Low	- do-
17	P ₈ II	Asrang	Very Low	High	High	High	-	-
18	P ₈ III	Karla	Low	Moderate	Moderate	High	-	-
19	P ₉ I	Giabung	High	High	Moderate	Very High	High	-
20	P ₉ II	Ropa	Low	Moderate	Moderate	High	-	-
21	Q ₈ I	Pooch	-	-	-	Mod.	-	-
22	Q ₈ II	Dubling	Very Low	Moderate	Moderate	High	High	-
23	Q ₉ I	Maling	Very Low	Low	Low	High	High	-
24	Q ₉ II	Chango	Very Low	Moderate	Moderate	Mod.	-	-

Table: 4. Presence of Trees & Shrubs in different Grids

[illegible]

H' (0.000) corresponding to species richness, $S=1$. In case of shrubs P_{6I} had the highest value of H' (2.136), closely followed by N_{7III} (2.130), O_{6III} (1.558), N_{7I} (1.518) and O_{7III} (1.458). The lowest value of H' (0.000) was observed for P_{6II} , P_{7II} , P_{8I} and Q_{8I} . All the other sites were having H' value ranging from 0.244 to 1.440. On four sampling sites viz., P_{7III} , P_{8III} , P_{9I} and P_{9II} no shrub species was encountered.

iii) Equitability (J')

It is a measure of evenness of a community. The value of J' for trees was found to be the highest (0.934) for site P_{7I} closely followed by site P_{9II} (0.915) and lowest (0.000) for N_{7I} , Q_{8I} and Q_{9I} . The value of J' for rest of the sites ranged from 0.823 (P_{6III}) to 0.157 (P_{8III}).

In case of shrubs Q_{9II} was having the maximum value of J' (0.991) closely followed by O_{6III} (0.983), O_{7I} (0.969), N_{7I} (0.958) and O_{7II} (0.948). The minimum value of J' (0.000) was observed for sites P_{6II} , P_{7II} , P_{8I} and Q_{8I} while P_{7III} , P_{8III} , P_{9I} and P_{9II} were having no shrubs in the sampling quadrates. Rest of the sites were having intermediate values of J' .

iv) Simpson's Index of Dominance (C_d)

It is inversely proportional to evenness (J') and is a measure of dominance of one or a few species in a community. For trees, the highest value of C_d (1.000) corresponds to lowest value of J' (0.000). Sites N_{7I} , Q_{8I} and Q_{9I} had C_d equal to 1.000 followed by P_{8III} (0.931), O_{7III} (0.804) and P_{7II} (0.799) while lowest values of C_d were observed for P_{6I} (0.365) and P_{6III} (0.374). The value of C_d for shrubs was maximum (1.000) for P_{6II} , P_{7II} , P_{8I} and Q_{8I} which was followed by O_{6I} (0.922) (Table 2). Rest of the sites were having value ranging from 0.243 (N_{7III}) to 0.645 (P_{7I}).

b) Importance Value Index (IVI) and Importance Value (IV%)

A perusal of data in the Table 6 indicates that *Cedrus deodara* showed IVI values of 158.94, 131.11, 181.57, 207.43, 137.72 and 142.12 and IV % values of 65.68, 56.46, 68.56, 85.53, 54.97 and 58.15 for the sites N₇II, N₇III, P₇III, O₆III, O₇I and O₇II, respectively, which were the highest in the respective communities. The IVI and IV% values for *Pinus gerardiana* were the highest in the following communities: P₇I (167.54 and 58.77), P₇II (229.08 and 83.77), P₈I (137.79 and 48.30), P₈III (272.93 and 96.46), P₉I (210.51 and 76.68), P₉II (187.20 and 66.98), O₇III (164.26 and 64.48) and Q₈II (91.40 and 32.54). *P. wallichiana* was observed to have high values of IVI and IV per cent only at four sites viz. P₆I (84.15 and 32.77) P₆II (188.35 and 71.95), P₆III (119.62 and 42.42) and P₈II (97.91 and 33.74). *P. roxburghii* was the dominant species at one site at N₇III with values of IVI and IV(%) as 174.32 and 70.49, respectively. At sites O₆I and O₆II, *Quercus ilex* was found to be the most important species having the IVI and IV% values as 152.62 and 57.26, and 148.33 and 58.78, respectively. Site Q₈I was dominated by *Juniperus macropoda* (IVI = 195.41 and IV(%) = 67.70) whereas site Q₉I was having *Salix fragilis* as the dominant species with IVI and IV(%) value as 172.88 and 69.77, respectively. At the site Q₉II *Rosa webbiana* had the highest values of IVI and IV(%) (IVI = 60.70 and IV(%) = 29.25).

Tables 7a and 7b present the data of IVI and IV present for tree and shrub communities separately at each site. At sites N₇II, N₇III, P₇III, O₆III, O₇I and O₇II the values of IVI and IV per cent for *C. deodara* were 218.84 and 84.42, 180.29 and 72.75, 181.58 and 68.56, 220.83 and 88.19, 117.6 and 67.96 and 177.98 and 67.93, respectively (Table 7a). *P. gerardiana* was having highest IVI and IV(%) in its respective communities at sites P₇I (188.36 and 65.01), P₇II (250.03 and 88.65), P₈I (151.78 and 52.55), P₈III (272.94 and 96.47), P₉I (210.51 and 76.68), P₉II (183.96 and 66.95), O₇III (263.65 and 88.96) and Q₈II (255.05 and 85.85). Four sites, P₆I, P₆II, P₆III and P₈II were dominated by *P. wallichiana* with

Table: 5 Species Richness (S), Shannon's index (H'), Evenness (J') and Coefficient of dominance (Cd) for trees and shrubs in different sites

Sites	Grid Code	Locality	Trees				Shrubs			
			S	H'	J'	Cd	S	H'	J'	Cd
1	N ₇ I	Sungra	1	0.000	0.000	1.000	3	1.518	0.958	0.357
2	N ₇ II	Nichar	3	0.780	0.492	0.725	3	1.364	0.861	0.433
3	N ₇ III	Kafnu	4	1.286	0.643	0.555	5	2.130	0.917	0.243
4	O ₆ I	Shong	3	0.646	0.408	0.777	2	0.244	0.244	0.922
5	O ₆ II	Barua	3	0.797	0.503	0.690	2	0.921	0.921	0.554
6	O ₆ III	Sangla	3	0.640	0.404	0.785	3	1.558	0.983	0.345
7	O ₇ I	Kalpa	3	1.221	0.770	0.545	2	0.969	0.969	0.521
8	O ₇ II	Pangi	4	1.022	0.511	0.553	3	0.503	0.948	0.368
9	O ₇ III	Paori	2	0.501	0.501	0.804	4	1.458	0.729	0.345
10	P ₆ I	Kharogla	7	1.984	0.707	0.365	5	2.136	0.920	0.248
11	P ₆ II	Mastarang	4	0.897	0.448	0.690	1	0.000	0.000	1.000
12	P ₆ III	Chitkul	4	1.646	0.823	0.374	2	0.916	0.916	0.557
13	P ₇ I	Jangi	2	0.934	0.934	0.545	2	0.780	0.780	0.645
14	P ₇ II	Moorang	2	0.511	0.511	0.799	1	0.000	0.000	1.000
15	P ₇ III	Ribba	3	1.157	0.730	0.531	0	-	-	-
16	P ₈ I	Lippa	3	1.154	0.728	0.476	1	0.000	0.000	1.000

Contd....

17	P ₈ II	Asrang	5	1.823	0.785	0.312	3	1.091	0.688	0.564
18	P ₈ III	Karla	3	0.249	0.157	0.931	0	-	-	-
19	P ₉ I	Giabung	2	0.783	0.783	0.642	0	-	-	-
20	P ₉ II	Ropa	2	0.915	0.915	0.557	0	-	-	-
21	Q ₈ I	Pooh	1	0.000	0.000	1.000	1	0.000	0.000	1.000
22	Q ₈ II	Dubling	2	0.588	0.588	0.757	3	1.440	0.908	0.391
23	Q ₉ I	Maling	1	0.000	0.000	1.000	2	0.882	0.882	0.579
24	Q ₉ II	Chango	3	1.226	0.774	0.470	2	0.991	0.991	0.506

Table:6 Relative Density (R.D.), Relative Frequency (R.F.), Relative Basal Area (R.B.A.), Importance Value (IV %) and Importance Value Index (IVI) of different Species in Kinnaur

Locality	Species	R.D.	R.F.	R.B.A.	IV (%)	IVI
Sungra	<i>Pinus roxburghii</i>	65.81	33.33	75.18	70.49	174.32
	<i>Plectranthus rugosus</i>	14.53	26.67	12.61	13.57	53.83
	<i>Berberis lycium</i>	11.96	26.67	6.06	9.01	44.69
	<i>Desmodium tiliaefolium</i>	7.69	13.33	6.15	6.92	27.17
Nihar	<i>Cedrus deodara</i>	45.57	27.58	85.79	65.68	158.94
	<i>P. wallichiana</i>	7.59	17.24	1.67	4.63	26.50
	<i>Abies pindrow</i>	5.06	10.34	7.26	6.16	22.66
	<i>Plectranthus rugosus</i>	29.75	24.14	2.28	16.01	56.17
Kafnu	<i>Rhus semialata</i>	6.96	10.34	2.27	4.61	19.57
	<i>Desmodium tiliaefolium</i>	5.06	10.34	0.73	2.89	16.13
	<i>C. deodara</i>	46.58	18.18	66.35	56.46	131.11
	<i>Pinus wallichiana</i>	8.69	13.64	3.23	5.96	25.56
Shong	<i>A. pindrow</i>	5.59	9.09	9.17	7.38	23.85
	<i>Juglans regia</i>	4.97	11.36	10.01	7.49	26.34
	<i>R. semialata</i>	9.32	11.36	4.14	6.73	24.82
	<i>D. tiliaefolium</i>	7.45	13.64	1.85	4.65	22.94
Barua	<i>Indigofera gerardiana</i>	9.94	13.64	1.38	5.66	24.96
	<i>Berberis aristata</i>	5.59	6.82	3.02	4.30	15.43
	<i>Plectranthus rugosus</i>	1.86	2.27	0.27	1.06	4.40
	<i>Quercus ilex</i>	47.59	38.09	66.94	57.265	152.62
Sangla	<i>F. xanthoxyloides</i>	6.63	14.28	4.25	5.44	25.16
	<i>Pinus gerardiana</i>	1.20	4.76	3.68	2.44	9.64
	<i>Plectranthus rugosus</i>	42.17	38.09	24.46	33.31	104.72
	<i>D. mucronata</i>	2.41	4.76	0.67	1.54	7.84
Kalpa	<i>Q. ilex</i>	49.72	30.77	67.84	58.78	148.33
	<i>F. xanthoxyloides</i>	13.56	23.08	8.70	11.13	45.34
	<i>Pinus gerardiana</i>	1.13	3.85	2.55	1.84	7.53
	<i>Plectranthus rugosus</i>	28.25	26.92	11.16	19.70	66.33
Kalpa	<i>D. mucronata</i>	7.34	15.38	9.75	8.54	32.47
	<i>C. deodara</i>	75.69	36.36	95.38	85.53	207.43
	<i>Pinus wallichiana</i>	7.73	27.27	1.90	4.81	36.90
	<i>Abies pindrow</i>	10.49	18.18	2.33	6.41	31.00
Kalpa	<i>I. gerardiana</i>	1.66	4.54	0.20	0.93	6.40
	<i>Berberis jaeschkeana</i>	2.21	9.09	0.14	1.17	11.44
	<i>Rhus semialata</i>	2.21	4.54	0.05	1.13	6.80
	<i>C. deodara</i>	46.76	27.78	63.18	54.97	137.72
Kalpa	<i>P. gerardiana</i>	31.65	27.78	12.75	22.20	72.18
	<i>P. wallichiana</i>	5.03	11.11	3.15	4.09	19.29
	<i>Plectranthus rugosus</i>	11.51	22.22	10.72	11.11	44.45
	<i>D. mucronata</i>	5.03	11.11	10.20	7.61	26.34

Contd....

Pangi	<i>Pinus gerardiana</i>	29.20	25.81	21.32	25.26	76.33
	<i>C.deodara</i>	46.90	25.81	69.41	58.15	142.12
	<i>P.wallichiana</i>	0.88	3.22	0.01	0.44	4.10
	<i>Robinia pseudoacasia</i>	1.77	6.45	0.22	0.99	8.44
	<i>Cotoneaster microphylla</i>	7.08	12.90	3.09	5.08	23.07
	<i>D. mucronata</i>	2.65	9.68	2.02	2.33	14.35
	<i>I. gerardiana</i>	7.96	16.13	3.93	5.94	28.02
Poari	<i>P.gerardiana</i>	63.51	35.29	65.46	64.48	164.26
	<i>Q.ilex</i>	6.76	5.88	9.31	8.03	21.95
	<i>D. mucronata</i>	17.57	23.53	13.14	15.35	54.24
	<i>Plectranthus rugosus</i>	5.40	5.88	1.38	3.39	12.66
	<i>I. gerardiana</i>	2.70	11.76	0.52	1.61	14.98
	<i>Q.ilex</i>	4.05	17.64	10.19	7.12	31.88
	<i>Populus ciliata</i>	19.51	16.28	27.15	23.33	62.94
Kharogla	<i>Pinus wallichiana</i>	28.05	18.6	37.50	32.77	84.15
	<i>Prunus armeniaca</i>	0.61	2.32	1.21	0.91	4.14
	<i>Salix elegans</i>	9.76	4.65	4.13	6.94	18.54
	<i>Betula utilis</i>	1.83	4.65	0.37	1.10	6.85
	<i>C. deodara</i>	1.22	4.65	2.39	1.80	8.26
	<i>A. pindrow</i>	0.61	2.32	0.45	0.53	3.38
	<i>Berberis jaeschkeana</i>	8.54	11.63	6.74	7.64	26.91
	<i>I. gerardiana</i>	12.19	16.28	8.91	10.55	37.38
	<i>Rosa webbiana</i>	3.05	6.98	2.22	2.63	12.25
	<i>Hippophae rhamnoides</i>	12.80	9.30	5.49	9.14	27.59
	<i>Rhus semialata</i>	1.83	2.32	3.44	2.63	7.59
	<i>Pinus wallichiana</i>	73.05	44.44	70.22	71.95	188.35
	<i>Populus ciliata</i>	7.78	11.11	13.98	10.79	32.69
	<i>S. elegans</i>	2.99	5.55	2.34	2.63	10.81
	<i>Betula utilis</i>	1.79	5.55	2.99	2.37	10.29
	<i>Berberis jaeschkeana</i>	14.37	33.33	10.47	12.25	57.84
Mastrang	<i>Pinus wallichiana</i>	37.50	34.78	47.34	42.42	119.62
	<i>Betula utilis</i>	30.36	21.74	18.56	24.46	70.66
	<i>A. pindrow</i>	7.14	8.69	6.82	6.98	22.65
	<i>Picea smithiana</i>	8.03	8.69	8.36	8.19	25.08
	<i>Cotoneaster microphylla</i>	12.50	17.39	10.43	11.46	40.32
	<i>Rosa webbiana</i>	4.46	8.69	6.94	5.70	20.09
	<i>Pinus gerardiana</i>	66.19	50.00	51.35	58.77	167.54
Chitkul	<i>Cedrus deodara</i>	22.53	35.71	41.33	31.93	99.57
	<i>Daphne mucronata</i>	4.22	7.14	0.64	2.43	12.00
	<i>Rhus semialata</i>	7.04	7.14	6.68	6.86	20.86
	<i>P.gerardiana</i>	80.00	61.54	87.54	83.77	229.08
Moorang	<i>C. deodara</i>	10.00	23.07	11.48	10.74	44.55
	<i>Lonicera quinquelocularis</i>	10.00	15.38	0.98	5.49	26.36
	<i>C. deodara</i>	62.73	44.44	74.4	68.56	181.57
Ribba	<i>P.gerardiana</i>	33.64	33.33	13.01	23.32	79.98
	<i>Alnus nitida</i>	3.64	22.22	12.59	8.11	38.45

Contd....

Lippa	<i>P. gerardiana</i>	52.43	41.18	44.18	48.30	137.79
	<i>C. deodara</i>	38.83	41.18	42.82	40.82	122.83
	<i>A. nitida</i>	2.91	5.88	2.38	2.64	11.17
	<i>Rosa webbiana</i>	5.82	11.76	10.62	8.22	28.20
Asrang	<i>C. deodara</i>	15.91	21.74	24.59	20.25	62.24
	<i>P. gerardiana</i>	1.14	4.35	0.41	0.77	5.90
	<i>Acer oblongum</i>	2.27	4.35	1.43	1.85	8.05
	<i>Cupressus torulosa</i>	15.91	17.39	5.03	10.47	38.33
	<i>P. wallichiana</i>	3.41	30.43	64.07	33.74	97.91
	<i>Rhus semialata</i>	10.23	8.69	4.17	7.20	23.09
	<i>L. quinquelocularis</i>	2.27	4.35	0.14	1.20	6.76
	<i>Rosa webbiana</i>	7.95	8.69	0.16	4.05	16.44
Karla	<i>P. gerardiana</i>	93.10	80.00	99.83	96.46	272.93
	<i>Cedrus deodara</i>	1.72	10.00	0.01	0.86	11.73
	<i>Alnus nitida</i>	5.17	10.00	0.16	2.66	15.33
Giabung	<i>P. gerardiana</i>	82.76	57.14	70.61	76.68	210.51
	<i>C. deodara</i>	17.24	42.86	29.39	23.31	89.49
Ropa	<i>P. gerardiana</i>	76.79	50.00	57.17	66.98	187.20
	<i>C. deodara</i>	23.21	50.00	42.83	33.02	116.04
Pooh	<i>Juniperus macropoda</i>	75.00	60.00	60.41	67.70	195.41
	<i>J. recurva</i>	25.00	40.00	39.59	32.29	104.59
Dubling	<i>P. gerardiana</i>	53.01	26.31	12.08	32.54	91.40
	<i>J. macropoda</i>	4.82	5.26	3.01	3.91	13.09
	<i>R. webbiana</i>	6.02	15.79	11.19	8.60	32.99
	<i>L. quinquelocularis</i>	16.87	26.31	38.19	27.53	81.37
	<i>Fraxinus xanthoxyloides</i>	19.28	26.31	35.53	27.40	81.12
Chango	<i>S. fragilis</i>	22.22	3.29	31.97	27.09	57.48
	<i>Prunus armeniaca</i>	4.44	1.09	0.78	2.61	6.31
	<i>Populus ciliata</i>	17.78	1.09	16.05	16.91	34.92
	<i>H. rhamnoides</i>	33.33	2.19	14.91	24.12	50.43
	<i>Rosa webbiana</i>	22.22	2.19	36.29	29.25	60.70
Maling	<i>S. fragilis</i>	62.86	33.33	76.69	69.77	172.88
	<i>H. rhamnoides</i>	25.71	33.33	16.48	21.09	75.52
	<i>R. webbiana</i>	11.43	33.33	6.84	9.13	51.60

Table: 7a Importance Value Index and Importance Value (%) for trees in different sites

Locality	RD	RF	RBA	IVI	IV
Sungra					
<i>Pinus roxburghii</i>	100.00	100.00	100.00	300.00	100.00
Nichar					
<i>Cedrus deodara</i>	78.27	50.00	90.57	218.84	84.42
<i>Pinus wallichiana</i>	13.04	31.25	1.76	46.05	7.40
<i>Abies pindrow</i>	8.69	18.75	7.67	35.11	8.18
Kafnu					
<i>C. deodara</i>	70.76	34.78	74.75	180.29	72.75
<i>P. wallichiana</i>	13.20	26.10	3.64	42.94	8.42
<i>Juglans regia</i>	7.55	21.73	12.28	41.56	9.91
<i>A. pindrow</i>	8.49	17.39	10.33	36.21	9.41
Kharogla					
<i>P. wallichiana</i>	45.54	34.79	51.23	131.56	48.39
<i>Populus ciliata</i>	31.68	30.45	37.09	99.22	34.38
<i>Salix elegans</i>	15.85	8.70	5.64	30.19	10.74
<i>C. deodara</i>	1.98	8.70	3.27	13.95	2.62
<i>Betula utilis</i>	2.97	8.70	0.51	12.18	1.74
<i>Prunus armeniaca</i>	0.99	4.34	1.65	6.98	1.32
<i>A. pindrow</i>	0.99	4.34	0.61	5.94	0.80
Mastarang					
<i>Pinus wallichiana</i>	85.73	66.67	78.43	230.83	82.08
<i>Populus ciliata</i>	8.84	16.67	15.61	41.12	12.22
<i>S. elegans</i>	3.40	8.33	2.62	14.35	3.01
<i>B. utilis</i>	2.03	8.33	3.34	13.70	2.68
Chitkul					
<i>Pinus wallichiana</i>	45.16	47.06	58.39	150.61	51.77
<i>B. utilis</i>	36.56	29.42	22.89	88.87	29.73
<i>Picea smithiana</i>	9.68	11.76	10.31	31.75	10.00
<i>A. pindrow</i>	8.60	11.76	8.41	28.77	8.50
Jangi					
<i>Pinus gerardiana</i>	74.61	58.34	55.41	188.36	65.01
<i>C. deodara</i>	25.39	41.66	44.59	111.64	34.99
Moorang					
<i>P. gerardiana</i>	88.89	72.73	88.41	250.03	88.65
<i>C. deodara</i>	11.11	27.27	11.59	49.97	11.35
Ribba					
<i>C. deodara</i>	62.73	44.45	74.4	181.58	68.56
<i>P. gerardiana</i>	33.63	33.33	13.01	79.97	23.32
<i>Alnus nitida</i>	3.64	22.22	12.59	38.45	8.11
Lippa					
<i>P. gerardiana</i>	55.68	46.67	49.43	151.78	52.55
<i>C. deodara</i>	41.23	46.67	47.91	135.81	44.57
<i>A. nitida</i>	3.09	6.66	2.66	12.41	2.87

Contd...

Asrang					
<i>P. wallichiana</i>	8.83	38.88	67.07	114.78	37.95
<i>C. deodara</i>	41.17	27.78	25.73	94.68	33.45
<i>Cupressus torulosa</i>	41.18	22.22	5.27	68.67	23.25
<i>Acer oblongum</i>	5.87	5.56	1.50	12.93	3.68
<i>P. gerardiana</i>	2.95	5.56	0.43	8.94	1.69
Karla					
<i>P. gerardiana</i>	93.11	80.00	99.83	272.94	96.47
<i>Alnus nitida</i>	5.17	10.00	0.1612	15.33	2.67
<i>C. deodara</i>	1.72	10.00	0.0063	11.72	0.86
Giabung					
<i>P. gerardiana</i>	82.76	57.14	70.61	210.51	76.68
<i>C. deodara</i>	17.24	42.86	29.39	89.49	23.31
Ropa					
<i>P. gerardiana</i>	76.79	50.00	57.17	183.96	66.95
<i>C. deodara</i>	23.21	50.00	42.83	116.04	33.02
Pooh					
<i>Juniperus macropoda</i>	100.00	100.00	100.00	300.00	1.00
Dubling					
<i>P. gerardiana</i>	91.66	83.34	80.05	255.05	85.85
<i>J. macropoda</i>	8.34	16.66	19.95	44.95	14.14
Maling					
<i>S. fragilis</i>	100.00	100.00	100.00	300.00	1.00
Chango					
<i>S. fragilis</i>	50.00	60.00	65.51	175.51	57.75
<i>Populus ciliata</i>	40.00	20.00	32.89	92.89	36.44
<i>Prunus armeniaca</i>	10.00	20.00	1.60	31.6	5.80
Shong					
<i>Quercus ilex</i>	85.87	66.67	89.41	241.95	87.64
<i>Fraxinus xanthoxyloides</i>	11.96	25.00	5.68	42.64	8.82
<i>P. gerardiana</i>	2.17	8.33	4.91	15.41	3.54
Barua					
<i>Q. ilex</i>	77.19	53.33	85.78	216.3	81.48
<i>F. xanthoxyloides</i>	21.05	40.00	11.00	72.05	16.02
<i>P. gerardiana</i>	1.76	6.67	3.22	11.65	2.49
Sangla					
<i>C. deodara</i>	80.64	44.44	95.75	220.83	88.19
<i>P. wallichiana</i>	8.21	33.33	1.91	43.45	5.06
<i>Abies pindrow</i>	11.15	22.22	2.34	35.71	6.74
Kalpa					
<i>C. deodara</i>	56.04	41.67	79.89	177.6	67.96
<i>P. gerardiana</i>	37.93	41.67	16.13	95.73	27.03
<i>P. wallichiana</i>	6.03	16.66	3.98	26.67	10.01
Pangi					
<i>C. deodara</i>	59.55	42.11	76.32	177.98	67.93
<i>P. gerardiana</i>	37.08	42.11	23.44	102.63	30.26
<i>Robinia pseudoacacia</i>	2.25	10.52	0.24	13.01	1.24
<i>P. wallichiana</i>	1.12	5.25	0.007	6.377	0.56
Poari					
<i>P. gerardiana</i>	90.38	85.72	87.55	263.65	88.96
<i>Q. ilex</i>	9.62	14.28	12.45	36.35	11.03

Table: 7b Importance Value Index and Importance Values (%) for shrubs in different sites

Locality	RD	RF	RBA	IVI	IV
Nichar					
<i>Plectranthus rugosus</i>	71.22	53.86	43.18	168.26	57.20
<i>Rhus semialata</i>	16.66	23.07	43.00	82.73	29.83
<i>Desmodium tiliaefolium</i>	12.12	23.07	13.82	49.01	12.97
Kafnu					
<i>R. semialata</i>	27.28	23.80	38.84	33.06	89.92
<i>D. tiliaefolium</i>	21.81	28.58	17.35	19.58	67.74
<i>Indigofera gerardiana</i>	29.10	28.58	12.95	21.02	70.63
<i>Berberis aristata</i>	16.36	14.29	28.33	22.34	58.98
<i>P. rugosus</i>	5.45	4.75	2.53	3.99	12.73
Sungra					
<i>P. rugosus</i>	42.51	40.00	50.80	133.31	46.65
<i>B. lycium</i>	35.00	40.00	24.42	125.80	29.71
<i>D. tiliaefolium</i>	22.49	20.00	22.78	65.27	22.63
Kharogla					
<i>B. jaeschkeana</i>	22.23	25.00	25.15	72.38	23.69
<i>I. gerardiana</i>	31.74	35.00	33.25	99.99	32.49
<i>Rosa webbiana</i>	7.94	15.00	8.28	31.22	8.11
<i>Hippophae rhamnoides</i>	33.33	20.00	20.48	73.81	26.90
<i>Rhus semialata</i>	4.76	5.00	12.84	22.6	8.80
Mastarang					
<i>B. jaeschkeana</i>	100.00	100.00	100.00	300.00	100.00
Chitkul					
<i>Cotoneaster microphylla</i>	73.70	66.68	60.05	200.43	66.87
<i>Rosa webbiana</i>	26.30	33.32	39.95	99.57	33.13
Jangi					
<i>Daphne mucronata</i>	37.48	50.00	8.74	96.22	23.11
<i>Rhus semialata</i>	62.52	50.00	91.26	203.78	76.89
Moorang					
<i>Lonicera quinquelocularis</i>	100.00	100.00	100.00	300.00	100.00
Lippa					
<i>Rosa webbiana</i>	100.00	100.00	100.00	300.00	100.00
Asrang					
<i>Rhus semialata</i>	50.02	40.00	93.29	183.31	71.65
<i>L. quinquelocularis</i>	11.10	20.00	3.13	34.23	7.11
<i>Rosa webbiana</i>	38.88	40.00	3.58	82.46	21.23
Pooh					
<i>Juniperus recurva</i>	100.00	100.00	100.00	300.00	100.00
Dubling					
<i>R. webbiana</i>	14.28	23.08	13.18	50.54	13.73
<i>L. quinquelocularis</i>	40.00	38.46	45.00	123.46	42.50
<i>Fraxinus xanthoxyloides</i>	45.72	38.46	41.82	126.00	43.77
Maling					
<i>H. rhamnoides</i>	69.22	50.00	70.67	189.89	69.94
<i>R. webbiana</i>	30.78	50.00	29.33	110.11	30.05
Chango					
<i>H. rhamnoides</i>	60.00	50.00	29.12	139.12	44.56
<i>R. webbiana</i>	40.00	50.00	70.88	160.88	55.44

Contd....

Shong					
<i>P. rugosus</i>	94.59	88.89	97.33	280.81	95.96
<i>D. mucronata</i>	5.41	11.11	2.67	19.19	4.04
Barua					
<i>P. rugosus</i>	79.38	63.64	53.37	196.39	66.37
<i>D. mucronata</i>	20.62	36.36	46.63	103.61	33.63
Sangla					
<i>I. gerardiana</i>	27.30	24.98	51.28	103.56	39.29
<i>B. jaeschkeana</i>	36.35	50.02	35.90	122.27	36.12
<i>Rhus semialata</i>	36.35	25.00	12.82	74.17	24.58
Kalpa					
<i>P. rugosus</i>	69.53	66.67	51.24	187.44	60.38
<i>D. mucronata</i>	30.47	33.33	48.76	112.56	39.61
Pangi					
<i>C. microphylla</i>	40.02	33.32	34.18	107.52	37.10
<i>D. mucronata</i>	14.98	25.01	22.35	62.34	18.66
<i>I. gerardiana</i>	45.00	41.67	43.47	130.14	44.23
Poari					
<i>D. mucronata</i>	59.12	40.00	52.08	151.2	55.60
<i>P. rugosus</i>	18.17	10.00	5.47	42.64	11.82
<i>I. gerardiana</i>	9.08	20.00	2.06	31.14	5.57
<i>Quercus ilex</i>	13.63	30.00	40.39	84.02	13.59

highest value of IVI and IV(%) as 131.56 and 48.39, 230.83 and 82.08, 150.61 and 51.77, and 114.78 and 37.95, respectively. Site N₇I was completely dominated by *P. roxburghii* in the tree community giving maximum possible IVI and IV(%), values for a species i.e. 300 and 100, respectively. The IVI and IV(%) value for *Quercus ilex* were 241.95 and 87.64 and 216.30 and 81.48 for sites O₆I and O₆II, respectively. Site Q₈I was completely occupied by *Juniperus macropoda* having IVI equal to 300 and IV(%) 100, while for sites Q₉I and Q₉II *Salix alba* was the dominant tree species with IVI and IV(%) values 300 and 100, and 175.51 and 57.75, respectively.

In the shrub layer (Table 7b), *Plectranthus rugosus* was the dominant species at N₇I, N₇II, O₆I, O₆II and O₇I with IVI and IV per cent values (133.31 and 46.65), (168.26 and 57.20), (280.81 and 95.96), (196.39 and 66.37) and (187.44 and 60.38), respectively. At sites P₆I and O₇II, *Indigofera gerardiana* dominated the shrub community with values of IVI and IV per cent (99.99 and 32.49) and (130.14 and 44.23), respectively. *Rhus semialata* was the principal shrub with high IVI (203.78) and IV per cent (76.89) at site P₇I and with IVI (183.31) and IV per cent (71.65) at site P₈II. P₆II and O₆III were dominated by *Berberis jaeschkeana* with values of IVI and IV per cent as 300.00 and 100.00 and 122.27 and 36.12, respectively. Site P₆III was mostly covered with *Cotoneaster microphylla* (IVI, 200.43 and IV per cent, 66.87). P₇II and Q₈I were completely composed of *Lonicera quinquelocularis* and *Juniperus recurva* with IVI (300.00) and IV per cent (100.00), each. *Rosa webbiana* was the main shrub growing at P₈I and Q₉II having maximum IVI and IV per cent (300.00 and 100.00 and 160.88 and 55.44, respectively). *Fraxinus xanthoxyloides* was growing in abundance at Q₈II with IVI (126.00) and IV per cent (43.77). Q₉I and O₇III were observed to have *Hippophae rhamnoides* and *Daphne mucronata* as the main shrubs with IVI and IV per cent value of 189.89 and 69.94 and 151.20 and 55.60, respectively.

c) Spatial Distribution

Abundance to frequency ratio is used as an indicator of spatial distribution of a species in the community. A close look at the Table 8 depicts that most of the species in most of the communities are distributed contagiously. Out of fourteen sites, *C. deodara* was found randomly distributed at three sites (P_6I , P_7II and P_8II) and distributed regularly at P_9I and P_9II . At all other sites, it was distributed in a contagious fashion. *Pinus gerardiana* tended to be distributed contagiously except at site O_7II (random distribution). Three sites (N_7II , N_7III and O_6III) were observed to have random distribution for *P. wallichiana*. Out of four sites where *Abies pindrow* existed, N_7III was found to have random distribution. The distribution of *Juglans regia* was regular. *Alnus nitida* had regular distribution at site P_7I . *Salix fragilis* was found to be regularly distributed at site Q_9II . Among shrubs only *Rosa webbiana* was found to be regularly distributed (Q_9I). While *Cotoneaster microphylla* (O_7II), *Plectranthus rugosus* (O_7I), *Hippophae rhamnoides* (Q_9I), *Rhus semialata* (N_7III), *Desmodium tiliæefolium* (N_7III), *Indigofera gerardiana* (N_7II , P_6I and O_7II), *Berberis jaeschkeana* (P_6I), *Rosa webbiana* (P_6I and Q_8II), *Juniperus recurva* (Q_8I), *Lonicera quinquelocularis* (Q_8II), *Fraxinus xanthoxyloides* (Q_8II) and *Daphne mucronata* (O_7II and O_7III) were distributed randomly. Distribution pattern for the above mentioned shrub species is contagious at all other sites, while the remaining tree species *Pinus roxburghii*, *P. ciliata*, *Prunus armeniaca*, *Salix elegans*, *Betula utilis*, *Acer oblongum*, *P. smithiana*, *Cupressus torulosa*, *J. macropoda*, *Q. ilex* and *F. xanthoxyloides* and shrub species *Berberis aristata*, *B. lycium* and *Lonicera quinquecloridis* were distributed contagiously at all the sites.

d) Species Distribution with respect to Abiotic and Biotic Factors

The relationship between IV(%) and average altitude of the sampling sites for three dominant tree species (*Cedrus deodara*, *Pinus wallichiana* and *P. gerardiana*) having high niche width is presented in Fig. 2. *Pinus gerardiana*

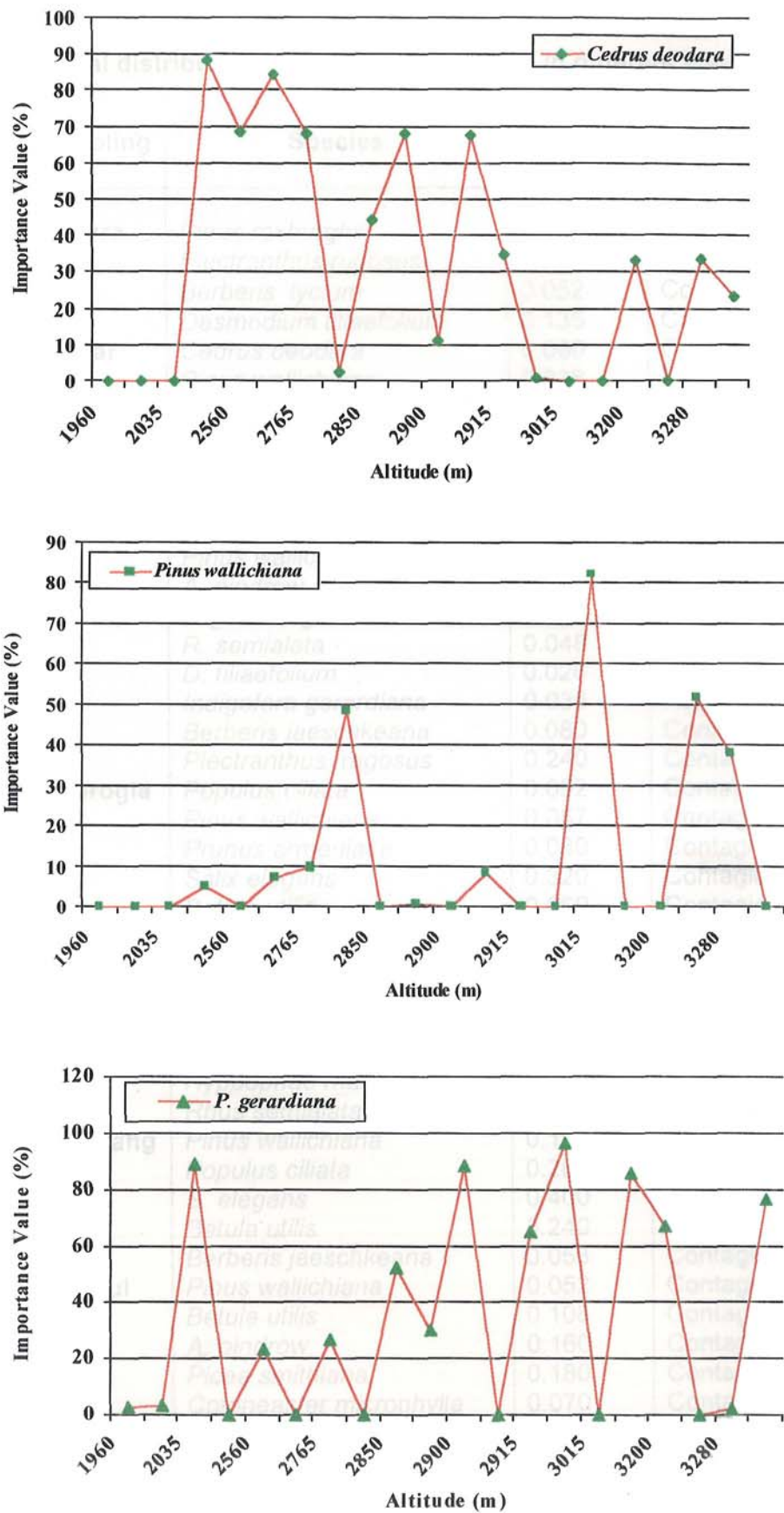


Fig. 2. Relationship of IV (%) and altitude for *Cedrus deodara*, *Pinus wallichiana* and *Pinus gerardiana*

Table: 8 Spatial distribution of the species present in different sampling units

Sampling unit code	Sampling unit	Species	A/F Ratio	Distribution
N ₇ I	Sungra	<i>Pinus roxburghii</i>	0.185	Contagious
		<i>Plectranthus rugosus</i>	0.063	Contagious
		<i>Berberis lycium</i>	0.052	Contagious
		<i>Desmodium tiliaefolium</i>	0.135	Contagious
N ₇ II	Nichar	<i>Cedrus deodara</i>	0.090	Contagious
		<i>Pinus wallichiana</i>	0.038	Random
		<i>Abies pindrow</i>	0.071	Contagious
		<i>Plectranthus rugosus</i>	0.076	Contagious
		<i>Rhus semialata</i>	0.097	Contagious
		<i>D. tiliaefolium</i>	0.071	Contagious
		<i>C. deodara</i>	0.093	Contagious
		<i>Pinus wallichiana</i>	0.031	Random
N ₇ III	Kafnu	<i>A. pindrow</i>	0.045	Random
		<i>Juglans regia</i>	0.025	Regular
		<i>R. semialata</i>	0.048	Random
		<i>D. tiliaefolium</i>	0.026	Random
		<i>Indigofera gerardiana</i>	0.035	Random
		<i>Berberis jaeschkeana</i>	0.080	Contagious
		<i>Plectranthus rugosus</i>	0.240	Contagious
		<i>Populus ciliata</i>	0.052	Contagious
		<i>Pinus wallichiana</i>	0.057	Contagious
		<i>Prunus armeniaca</i>	0.080	Contagious
		<i>Salix elegans</i>	0.320	Contagious
		<i>Betula utilis</i>	0.060	Contagious
		<i>C. deodara</i>	0.040	Random
		<i>A. pindrow</i>	0.080	Contagious
		<i>Berberis jaeschkeana</i>	0.045	Random
		<i>I. gerardiana</i>	0.033	Random
P ₆ I	Kharogla	<i>Rosa webbiana</i>	0.044	Random
		<i>Hyppophae rhamnoides</i>	0.105	Contagious
		<i>Rhus semialata</i>	0.240	Contagious
		<i>Pinus wallichiana</i>	0.157	Contagious
		<i>Populus ciliata</i>	0.260	Contagious
		<i>S. elegans</i>	0.400	Contagious
		<i>Betula utilis</i>	0.240	Contagious
		<i>Berberis jaeschkeana</i>	0.053	Contagious
P ₆ II	Mastrang	<i>Pinus wallichiana</i>	0.052	Contagious
		<i>Betula utilis</i>	0.108	Contagious
		<i>A. pindrow</i>	0.160	Contagious
		<i>Picea smithiana</i>	0.180	Contagious
P ₆ III	Chitkul	<i>Cotoneaster microphylla</i>	0.070	Contagious

Contd...

P ₇ I	Jangi	<i>Rosa webbiana</i>	0.100	Contagious
		<i>Pinus gerardiana</i>	0.067	Contagious
		<i>Cedrus deodara</i>	0.045	Random
		<i>Daphne mucronata</i>	0.210	Contagious
P ₇ II	Moorang	<i>R. semialata</i>	0.350	Contagious
		<i>P. gerardiana</i>	0.080	Contagious
		<i>C. deodara</i>	0.071	Contagious
		<i>Lonicera quinquelocularis</i>	0.16	Contagious
P ₇ III	Ribba	<i>C. deodara</i>	0.086	Contagious
		<i>P. gerardiana</i>	0.823	Contagious
P ₈ I	Lippa	<i>Alnus nitida</i>	0.020	Regular
		<i>P. gerardiana</i>	0.088	Contagious
		<i>C. deodara</i>	0.065	Contagious
		<i>Alnus nitida</i>	0.240	Contagious
P ₈ II	Asrang	<i>Rosa webbiana</i>	0.120	Contagious
		<i>C. deodara</i>	0.044	Random
		<i>P. gerardiana</i>	0.080	Contagious
		<i>Acer oblongum</i>	0.160	Contagious
		<i>Cupressus torulosa</i>	0.070	Contagious
		<i>P. wallichiana</i>	0.064	Contagious
		<i>Rhus semialata</i>	0.180	Contagious
		<i>L. quinquelocularis</i>	0.160	Contagious
P ₈ III	Karla	<i>Rosa webbiana</i>	0.140	Contagious
		<i>P. gerardiana</i>	0.067	Contagious
		<i>Cedrus deodara</i>	0.080	Contagious
		<i>Alnus nitida</i>	0.240	Contagious
P ₉ I	Giabung	<i>P. gerardiana</i>	0.060	Contagious
P ₉ II	Ropa	<i>C. deodara</i>	0.022	Regular
		<i>P. gerardiana</i>	0.062	Contagious
Q ₈ I	Pooh	<i>C. deodara</i>	0.018	Regular
		<i>Juniperus macropoda</i>	0.060	Contagious
Q ₈ II	Dubling	<i>J. recurva</i>	0.045	Random
		<i>P. gerardiana</i>	0.123	Contagious
		<i>J. macropoda</i>	0.280	Contagious
		<i>R. webbiana</i>	0.039	Random
		<i>L. quinquelocularis</i>	0.039	Random
		<i>Fraxinus xanthoxyloides</i>	0.044	Random
Q ₉ I	Maling	<i>S. fragilis</i>	0.073	Contagious
		<i>H. rhamnoides</i>	0.030	Random
		<i>R. webbiana</i>	0.013	Regular
Q ₉ II	Chango	<i>S. fragilis</i>	0.033	Random
		<i>Prunus armeniaca</i>	0.060	Contagious
		<i>Populus ciliata</i>	0.240	Contagious
		<i>H. rhamnoides</i>	0.110	Contagious
		<i>Rosa webbiana</i>	0.075	Contagious
O ₆ I	Shong	<i>Quercus ilex</i>	0.090	Contagious
		<i>F. xanthoxyloides</i>	0.090	Contagious
		<i>Pinus gerardiana</i>	0.160	Contagious
		<i>Plectranthus rugosus</i>	0.087	Contagious
		<i>D. mucronata</i>	0.320	Contagious

Contd...

O ₆ II	Barua	<i>Q. ilex</i>	0.110	Contagious
		<i>F. xanthoxyloides</i>	0.053	Contagious
		<i>Pinus gerardiana</i>	0.160	Contagious
		<i>Plectranthus rugosus</i>	0.082	Contagious
O ₆ III	Sangla	<i>D. mucronata</i>	0.065	Contagious
		<i>C. deodara</i>	0.171	Contagious
		<i>Pinus wallichiana</i>	0.031	Random
		<i>Abies pindrow</i>	0.095	Contagious
		<i>I. gerardiana</i>	0.240	Contagious
		<i>Berberis jaeschkeana</i>	0.080	Contagious
		<i>Rhus semialata</i>	0.320	Contagious
O ₇ I	Kalpa	<i>C. deodara</i>	0.116	Contagious
		<i>P. gerardiana</i>	0.088	Contagious
		<i>P. wallichiana</i>	0.087	Contagious
		<i>Plectranthus rugosus</i>	0.047	Random
O ₇ II	Pangi	<i>D. mucronata</i>	0.087	Contagious
		<i>Pinus gerardiana</i>	0.041	Random
		<i>C. deodara</i>	0.066	Contagious
		<i>P. wallichiana</i>	0.080	Contagious
		<i>Robinia pseudoacacia</i>	0.120	contagious
		<i>Cotoneaster microphylla</i>	0.040	Random
		<i>D. mucronata</i>	0.026	Random
O ₇ III	Poari	<i>I. gerardiana</i>	0.028	Random
		<i>P. gerardiana</i>	0.078	contagious
		<i>Quercus ilex</i>	0.290	contagious
		<i>D. mucronata</i>	0.049	Random
		<i>Plectranthus rugosus</i>	0.240	Contagious
		<i>I. gerardiana</i>	0.120	Contagious

had the widest range of distribution in terms of altitudinal band (1960 m to 3365 m). However, from an average altitude of 2900 m upwards, it dominated the community in terms of IV(%). *Cedrus deodara* was present within an altitudinal range of 2520 m to 3365 m. Its IV(%) declined sharply from 2900 m upwards. In case of *P. wallichiana* the average altitudinal range was from 2520 m into 3280 m. Its dominance however was having no clear cut trend with altitudinal variation.

It has been noticed that *C. deodara* was found to be growing on all the four aspects i.e. northern (N₇II, O₆III, P₇III); southern (N₇III, O₇II, P₆I, P₉I, P₉II); eastern (O₇I, P₇II, P₈I) and western (P₇I, P₈II, P₈III). The gradient of these sampling units varied from about flat ground (0-5°, O₆III) to a steep hill slope of 15°-25° at O₇II (Table 2). While *P. wallichiana* was present at the following sampling units: N₇II, O₆III, P₆III (north wards); N₇III, O₇II, P₆I, P₆II (south wards); O₇I, P₇II, P₈I (east wards) and P₇I, P₈II, P₈III (west wards). This species occupied the ground, mostly flat ground (0-5°, P₆II) and ascended to a steep slope of 15°-25° at O₇II. *P. gerardiana*, on the other hand, was distributed on different aspects i.e. northern at P₇III and Q₈II, southern at O₇II, P₉I and P₉II, eastern at O₆I, O₆II, O₇I, O₇III, P₇II and P₈I and western at P₇I, P₈II and P₈III. It was mostly found on the hillside with a gradient ranging from gentle slope (5-10°, P₈I) to a steep slope (15°-25° at Q₈II). *Pinus roxburghii* was present only at one site N₇I, which is located on northern aspect. *Quercus ilex* was found in the sampling units O₆I, O₆II and O₇III, all of which were situated on eastern aspect.

Abies pindrow was found to grow in three sampling units (N₇II, P₆III, O₆III) on northern aspect and in two sampling units (N₇III, P₆I) on southern aspect. *Betula utilis* occurred on south facing slopes at P₆I and P₆II while on north facing slopes at P₆III. *Populus ciliata*, on the other hand, was present in two sampling units P₆I and P₆II on the southern aspect.

The disturbances in the form of threats (biotic/abiotic pressures) most commonly present in the sampling units under study were fire, trampling, grazing, lopping, landslide and others. The degree of intensity, however, varied from one sampling unit to the other. Fire was a common factor at low elevations (1960 m to 2900 m) in varying degrees of intensity from very low to high (Table 3). Trampling, grazing and lopping were most common features in the forests located near the human settlements. Lopping/cutting of the cones bearing branches of *P. gerardiana* was high to very high in the sampling units of O_{7I}, O_{7II}, O_{7III}, P_{9I}, P_{9II}, P_{8I}, P_{8II}, P_{7I}, P_{7II}. Lopping of *Quercus ilex* was high to very high at O_{6I}, O_{6II} and O_{7III}. Landslide was commonly found in or along the sampling units P_{6III}, P_{9I}, P_{6I}, P_{6II} and Q_{8II} (Table 3).

Heavy snow, heavy winds and scrapping of tree bark or wood for fuel/torch wood by the villagers are the threats to the growth and development of a tree are included in the category of 'others' (Table 3). Effect of snow/heavy winds was seen at only one sampling unit (O_{7II}), while scrapping of trees near the base could be seen at four sites i.e. O_{7III}, P_{7I}, P_{7II}, P_{8I}, P₉ and P_{9II}.

e) Structural Parameters of the Dominant Tree Species with respect to Abiotic and Biotic Factors

Among the various sites where *Cedrus deodara* was growing in abundance, the mean basal area (cm²) of O_{7II} was maximum (5016.22±538.79), closely followed by 4219.78±821.63 and 4105.23±811.55 for sites P_{9I} and P_{9II} (Table 9). On the contrary, mean diameter (DBH) was found to be the maximum for site P_{9I} (72.38±5.88 cm) followed by P_{9II} and O_{7II} (67.91±4.64 cm and 53.18±3.03 cm, respectively). Site N_{7II} had the tallest trees with mean height (m) of 30.51±2.32, N_{7III} and P_{6I} were also found to have tall trees but with a little less height of 25.08±1.85 and 23.00±0.71, respectively. Trees of P_{8I} were in a comparatively young stage of growth having the minimum mean height (9.91±1.17 m), DBH (19.83±3.24 cm) and basal area (1174.52±386.45 cm²). In case of *Pinus gerardiana*, maximum mean basal area (cm²) of 3045.34± 289.62

Table: 9 **Mean height, mean diameter (dbh) and mean basal area of dominant tree species in Kinnaur**

Species	Sampling unit code	Sampling unit	mean. ht. (m)	mean dbh (cm)	mean basal area (Sq. cm)
<i>Cedrus deodara</i>	N ₇ II	Nichar	30.51±2.32	50.96±2.53	2706.12±250.40
	N ₇ III	Kafnu	25.08±1.85	32.23±2.39	1654.65±198.82
	P ₆ I	Kharogla	23.00±0.71	44.10±2.05	1956.18±440.41
	P ₇ I	Jangi	15.44±1.07	48.05±3.88	3810.09±248.14
	P ₇ II	Moorang	19.63±1.47	51.03±3.08	2724.37±393.24
	P ₇ III	Ribba	19.72±1.18	32.54±2.66	3269.27±905.48
	P ₈ I	Lippa	9.91±1.17	19.83±3.24	1174.52±386.45
	P ₈ II	Asrang	20.89±3.34	48.29±7.77	3735.06±1377.07
	P ₉ I	Giabung	18.95±1.55	72.38±5.88	4219.78±821.63
	P ₉ II	Ropa	18.77±1.16	67.91±4.64	4105.23±811.55
	O ₆ III	Sangla	18.20±1.21	29.96±2.33	2873.54±415.95
	O ₇ I	Kalpa	10.37±0.86	23.94±3.09	2515.36±560.25
	O ₇ II	Pangi	18.72±0.76	53.18±3.03	5016.22±538.79
	N ₇ I	Sungra	24.16±0.65	17.49±0.53	360.64±17.75
	N ₇ II	Nichar	9.75±2.22	15.53±3.46	434.95±266.43
<i>Pinus roxburghii</i> <i>P. wallichiana</i>	O ₇ I	Kalpa	3.00±1.44	9.20±2.11	178.06±50.97
	O ₆ III	Sangla	9.46±2.99	9.23±3.65	328.54±183.48
	P ₆ I	Kharogla	15.62±1.58	28.55±3.43	1397.88±211.47
	P ₆ II	Masatarang	10.67±0.59	13.61±0.78	307.09±34.09
	P ₆ III	Chitkul	6.43±0.74	12.26±1.13	430.65±101.98
	P ₈ II	Asrang	27.00±1.51	44.06±4.15	2811.12±494.26

Contd...

<i>P. gerardiana</i>	P ₇ I	Jangi	12.638±0.63	35.964±2.58	1628.73±215.03
	P ₇ II	Moorang	10.953±0.29	46.147±1.96	2495.45±158.05
	P ₇ III	Ribba	9.246±1.40	23.729±2.45	514.74±138.86
	P ₈ I	Lippa	9.940±1.07	29.995±3.49	1093.53±241.94
	P ₈ II	Asrang	9.50±0.00	30.4±0.00	73.58±0.00
	P ₈ III	Karla	12.046±0.37	47.257±2.30	3045.34±289.62
	P ₉ I	Giabung	11.219±0.56	41.823±3.28	2207.35±280.68
	P ₉ II	Ropa	11.114±0.50	39.823±3.19	2157.15±263.54
	O ₆ I	Shong	9.25±2.29	23.2±4.24	2098.31±706.81
	O ₆ II	Barua	10.75±2.29	38.7±4.59	1423.22±349.09
	O ₇ I	Kalpa	4.996±0.44	9.507±1.37	518.73±159.69
	O ₇ II	Pangi	7.434±0.85	14.955±2.12	493.42±119.21
	O ₇ III	Poari	12.281±0.95	34.315±3.57	2333.53±476.99
	Q ₈ II	Dubling	3.734±0.25	7.903±0.73	94.99±13.89
<i>Quercus ilex</i>	O ₆ I	Shong	9.481±0.38	22.806±1.33	744.77±82.64
	O ₆ II	Barua	8.528±0.33	26.291±1.43	836.70±87.05
	O ₇ III	Poari	3.33±0.23	2.85±0.28	50.58±8.55
<i>Populus ciliata</i>	P ₆ I	Kharogla	13.227±2.02	28.772±4.09	1474.18±251.94
	P ₆ II	Masatarang	14.923±2.09	37.546±6.67	2294.79±602.73
<i>Betula utilis</i>	P ₆ I	Kharogla	7.0±0.00	28.2±0.00	645.21±0.00
	P ₆ II	Mastarang	13.33±2.03	34.133±3.53	1718.87±218.05
	P ₆ III	Chitkul	6.71±0.38	8.91±0.55	146.41±10.98

was found for P₈III followed by P₇II (2495.45±158.05), O₇III (2333.53±476.99) and P₉I (2207.35±280.68). P₈III had maximum mean DBH (cm) of 47.257±2.30 closely followed by 46.147±1.96 (P₇II) and 41.823±3.28 (P₉I). On the other hand mean height (m) was found to be maximum for P₇I (12.638±0.63) with little less values for O₇III and P₈III (12.281±0.95 and 12.046±0.37, respectively). In terms of overall growth of trees, Q₈II had minimum mean height, mean DBH and mean basal area i.e. 3.734±0.25 m, 7.903±0.73 cm and 94.99±13.89 cm², respectively. *Pinus roxburghii* was found only at N₇I with mean height (m) 24.16±0.65, DBH (cm) 17.49±0.53 and mean basal area (cm²) 360.64±17.75. Among the various sites, *P. wallichiana* had excellent growth at P₈II with maximum mean height, (27.00±1.51m), mean DBH, (44.06±4.15cm) and mean basal area 2811.12±494.26 cm². O₇I was observed to have comparatively small trees having mean height 3.00±1.44 m, mean DBH 9.20±2.11 cm and mean basal area 178.06±50.97 cm² (Table 9). At site O₆II, *Quercus ilex* had maximum mean DBH and mean basal 26.291±1.43 cm and 836.70±87.05 cm², respectively, but mean height (m) of O₆I was a little more (9.48±0.38) as compared to O₆II (8.528±0.33). Trees of O₇III were very small as compared to the above two sites with minimum mean height 3.33±0.23 m, mean DBH 2.85±0.28 cm and mean basal area 50.58±8.55 cm².

Populus ciliata had maximum mean basal area at P₆II (2294.79±602.73 cm²), mean DBH 37.546±6.67 cm and mean height 14.923±2.09 m as compared to P₆I, where trees of mean height 13.227±2.92 m, mean DBH 28.772±4.09 cm and mean basal area 1474.18±251.94 cm² were found to be growing.

Among the three sampling sites, P₆II had trees of *Betula utilis* with maximum growth dimensions i.e. mean height 13.33±2.03 m, mean DBH 34.133±3.53 cm and mean basal area 1718.87±218.05 cm² (Table 9) in comparison to P₆I and P₆III. Trees growing at P₆III and P₆I were almost of same mean height (6.71±0.38 m and 7.0±0.00 m, respectively), but at P₆I trees had greater value of mean DBH, 28.2±0.00 cm than that at P₆III (8.91±0.55 cm).

Average density of the stems of component tree species in the sampling sites was calculated on per hectare basis in different diameter classes. In the grids under study, *Cedrus deodara* was found to be growing in six grids (N₇, O₆, O₇, P₇, P₈ and P₉). Average density (ha⁻¹) was the maximum (67.96) in the diameter class >20.0 cm (Table 10). In 3.0-10.0 cm diameter class, the density was 16.226 which was followed by 11.285 under the seedling class. The lowest average density (2.513) was observed in the diameter class (>3.0 cm). Among different grids, maximum density (109.1) was found for the diameter class >20.0 cm and minimum (2.10) in 10.0-20.0 cm. At P₉, there was no individual in all the diameter classes except in >20.0 cm where the density was 38.33 ha⁻¹. Various grids (O₆, O₇, P₇, P₈, P₉ and Q₈) where *P. gerardiana* was present, the maximum average density was 59.67 ha⁻¹ observed in the diameter class >20.0 cm and the minimum was 1.353 ha⁻¹ in >3.0 cm. Among the above mentioned grids, P₉ had the highest density (130.0, >20.0 cm), while the lowest density (1.04, 10.0-20.0 cm) was found for O₆ for which overall density was the least (4.17, Table 10). In case of *P. roxburghii*, maximum density (200.00) was observed for the diameter class 10.0-20.0 cm followed by 116.67 (>20.0 cm) and the minimum (20.83) for 3.0-10.0 cm, while there was no individual under seedling and <3.0 cm classes.

Average number of individuals (ha⁻¹) for *P. wallichiana* was maximum in the diameter class >20.0 cm (17.698), closely followed by 16.51 (10.0-20.0 cm), 16.364 (3.0-10.0 cm) and the minimum was under seedling and <3.0 cm i.e. 4.934 and 4.118, respectively. Among the grids where *P. wallichiana* was present (N₇, O₆, O₇, P₆ and P₈), P₆ was having high average density in 3 diameter classes i.e. 3.0-10.0 cm and 10.0–20.0 cm (67.71 each), and >20.0 cm (44.79). O₇ was having minimum overall average density (10.53). In two grids (O₆ and O₇), *Quercus ilex* was observed to have the highest average density 47.67 in <20.0 cm, second highest 33.475 in 10.0-20.0 cm and the least (0.52) in <3.0 cm diameter classes. Total density (ha⁻¹) in all the diameter classes was the highest (171.29) in O₆ and the lowest (9.22) in O₇. *Betula utilis* was found to

Table:10 Average Density (Stems ha⁻¹) of different species in different diameter classes (dbh) in Kinnaur

Species	Grid Code	Seedling	Diameter Classes				Total
			< 3.0cm	3.0 – 10.0 cm	10.0 – 20.0 cm	>20.0 cm	
<i>Cedrus deodara</i>	N ₇	22.73	11.36	13.64	10.23	109.1	167.06
	O ₆	40.63	0.00	15.63	2.10	78.13	136.49
	O ₇	0.00	2.63	31.58	19.74	80.26	134.21
	P ₇	0.00	0.00	10.42	11.46	80.21	102.09
	P ₈	4.35	1.09	26.09	14.13	21.74	67.40
	P ₉	0.00	0.00	0.00	0.00	38.33	38.33
	Average	11.285	2.513	16.226	9.61	67.96	107.59
<i>Pinus gerardiana</i>	O ₆	0.00	0.00	0.00	1.04	3.13	4.17
	O ₇	3.95	3.95	72.37	18.42	57.89	156.58
	P ₇	13.54	4.17	14.58	41.66	80.21	154.25
	P ₈	9.78	0.00	10.87	7.61	82.61	110.87
	P ₉	0.00	0.00	0.00	21.67	130.0	151.67
	Q ₈	33.33	0.00	120.83	29.17	4.17	187.50
	Average	10.10	1.353	36.44	19.93	59.67	127.49
<i>P. roxburghii</i>	N ₇	0.00	0.00	20.83	200.00	116.67	337.50
<i>P. wallichiana</i>	N ₇	7.95	5.68	4.55	3.41	6.82	28.41
	O ₆	0.00	8.33	1.04	3.13	2.1	14.60
	O ₇	0.00	1.32	5.26	3.95	0.00	10.53
	P ₆	15.63	4.17	67.71	67.71	44.79	200.01
	P ₈	1.09	1.09	3.26	4.35	34.78	44.59
	Average	4.934	4.118	16.364	16.51	17.698	59.628
<i>Quercus ilex</i>	O ₆	0.00	1.04	14.58	65.63	92.71	171.29
	O ₇	0.00	0.00	5.27	1.32	2.63	9.22
	Average	0.00	0.52	9.925	33.475	47.67	91.59
<i>Betula utilis</i>	P ₆	0.00	0.00	21.87	10.42	3.13	35.42
<i>Abies pindrow</i>	N ₇	0.00	0.00	0.00	3.41	6.82	10.23
	O ₆	10.42	0.00	3.13	1.04	3.13	17.72
	P ₆	1.04	0.00	4.17	3.13	0.00	8.34
	Average	3.82	0.00	2.433	2.527	3.317	12.10
<i>Fraxinus xanthoxyloides</i>	O ₆	0.00	0.00	3.13	15.63	11.46	30.22
<i>Alnus nitida</i>	P ₇	0.00	0.00	1.04	6.25	7.29	14.58
	P ₈	1.09	0.00	3.26	2.17	0.00	6.52
	Average	0.36	0.00	2.476	4.21	3.645	10.55
<i>Populus ciliata</i>	P ₆	10.42	1.04	3.13	2.10	26.04	42.73

be present in only one grid (P_6) and the total density was 35.42, with average density in the diameter class 3.0-10.0 cm as 21.87, 10.0-20.0 cm as 10.42 and >20.0cm as 3.13, while there was no individual under seedling and <3.0 cm classes. There were three grids (N_7 , O_6 and P_6) where *Abies pindrow* was present. Average density in all the grids varied from 2.433 to 3.82 in 3.0-10.0 cm and seedling classes, respectively. Overall density in all the classes was the highest (17.72) in O_6 with maximum number of individuals (10.42) under seedlings and the lowest density was observed for P_6 (8.34). O_6 was the only grid, where *Fraxinus xanthoxyloides* was present. Total density was 30.22 in all the diameter classes with maximum (15.63) in 10.0-20.0 cm and minimum (3.13) in 3.0-10.0 cm and there was no individual in the first two classes. *Alnus nitida* represented two grids P_7 and P_8 , the lowest average density (ha^{-1}) was 0.36 for seedlings and the highest was 8.02 for 10.0-20.0 cm diameter class. Overall density in all the classes was 14.58 in P_7 and 6.52 in P_8 and there was no individual under <3.0 cm (P_7 and P_8) and seedlings class in P_7 .

Populus ciliata was found to be growing naturally only in one grid (P_6) and was not encountered in the other grids under study. The total density (ha^{-1}) was 42.73 with a maximum of 26.04 in >20.0 cm and a minimum of 1.04 in <3.0 cm diameter class.

f) Niche Width (B_i)

Niche width was calculated for those tree species, which were found to be dominant at one or more than one sampling sites depending upon their IVI values (Table 11). Highest niche width (10.877) was recorded for *Pinus gerardiana* followed closely by *Cedrus deodara* (7.909) and the lowest value for *P. roxburghii*. *P. wallichiana* and *Abies pindrow* were having an intermediate range of niche width (4.250 and 3.546, respectively); whereas, *Alnus nitida*, *Fraxinus xanthoxyloides*, *Quercus ilex*, *Populus ciliata*, *Juniperus macropoda* and

Betula utilis had a lower range of niche width (2.941, 2.127, 2.112, 1.566, 1.423 and 1.423, respectively).

Pinus gerardiana had the broadest range of distribution in terms of altitude (Table 11) from 1860 m to 3460 m above mean sea level. *Qercus ilex* and *Fraxinus xanthoxyloides* were abundant in lower altitudinal range (1860 m to 2100 m). *Cedrus deodara*, *Pinus wallichiana*, *Juniperus macropoda*, *Abies pindrow*, *Populus ciliata* and *Alnus nitida* were distributed at a comparatively higher altitude.

g) β -Diversity

i) Sorenson's Index of Similarity

The value of Sorenson's index lies between 0 to 1. For trees, eleven combinations [(7,8); (9, 10); (9, 12); (10, 12); (7, 13); (8, 13); (7, 14); (8, 14); (13, 14), (15, 16) and (1, 17)] of sampling units showed Sorenson's index as unity, while 0.86 was observed for three pairs of communities [(1, 2); (2, 17) and (18, 19)] and seventeen community combinations [(9, 7); (9, 8); (10, 7); (10, 8); (12, 7); (12, 8); (12, 11); (13, 9); (13, 10); (12, 13); (14, 9); (14, 10); (14, 12); (18, 7); (18, 8); (18, 13) and (18, 14)] had the value as 0.80 (Table 12a). For the shrubs (Table 12b) the maximum value 1 of similarity was found for three pairs [(15, 16); (15, 18) and (16, 18)] of communities. The next highest values of Sorenson's index of similarity 0.80 and 0.75 were observed for three [(15, 20); (16, 20) and (18, 20)] and four community pairs [(1, 2); (2, 3); (2, 17) and (4, 17)], respectively.

ii) Jaccard's Index of Similarity

A similar trend, as observed in Sorenson's index of similarity between different sites was also observed for Jaccard's index for trees. The absolute values, however, differed in these two cases. The maximum value 1 was closely followed by 0.75 and 0.67 for trees (Table 13a). The highest value in case of

Table: 11 Niche width (B_i) and altitude range of different tree species present at the sampling sites.

Sr. No.	Species	Altitude Range (amsl)	Niche Width
1	<i>Cedrus deodara</i>	2460m – 3460m	7.909
2	<i>Pinus gerardiana</i>	1860m – 3460m	10.877
3	<i>P. wallichiana</i>	2460m – 3370m	4.250
4	<i>P. roxburghii</i>	2060m – 2150m	1.000
5	<i>Abies pindrow</i>	2460m – 3310m	3.546
6	<i>Juniperus macropoda</i>	2940m – 3180m	1.423
7	<i>Quercus ilex</i>	1950m – 2100m	2.112
8	<i>Betula utilis</i>	2720m – 3310m	1.423
9	<i>Alnus nitida</i>	2520m – 3030m	2.941
10	<i>Fraxinus xanthoxyloides</i>	1860m – 2100m	2.127
11	<i>Populus ciliata</i>	2720m – 3030m	1.566

Table: 12a Sorenson's index of similarity between different sites for trees

Sites	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.86	0.00	0.60	0.29	0.57	0.40	0.40	0.33	0.33	0.50	0.33	0.40	0.40	0.00	0.00	1.00	0.67	0.57	0.00	0.00	0.00	0.00	0.00
2		0.00	0.54	0.25	0.50	0.33	0.33	0.29	0.29	0.44	0.29	0.33	0.33	0.00	0.00	0.86	0.57	0.50	0.00	0.00	0.00	0.00	0.00
3			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4				0.73	0.54	0.22	0.22	0.20	0.20	0.30	0.20	0.22	0.22	0.00	0.00	0.60	0.40	0.36	0.00	0.00	0.00	0.00	0.00
5					0.50	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.25	0.00	0.00	0.00	0.00	0.00
6						0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.29	0.25	0.00	0.00	0.00	0.00	0.00
7							1.00	0.80	0.80	0.57	0.80	1.00	1.00	0.40	0.40	0.40	0.80	0.67	0.50	0.50	0.50	0.50	0.00
8								0.80	0.80	0.57	0.80	1.00	1.00	0.40	0.40	0.40	0.80	0.67	0.50	0.50	0.50	0.50	0.00
9									1.00	0.50	1.00	0.80	0.80	0.33	0.33	0.33	0.67	0.57	0.40	0.00	0.40	0.40	0.00
10										0.50	0.80	0.57	0.57	0.25	0.25	0.33	0.75	0.57	0.29	0.00	0.29	0.40	0.00
11											0.80	0.80	0.80	0.33	0.33	0.50	0.67	0.57	0.40	0.00	0.40	0.00	0.00
12												0.80	0.80	0.33	0.33	0.33	0.67	0.57	0.40	0.00	0.40	0.00	0.00
13													1.00	0.40	0.40	0.40	0.80	0.67	0.50	0.00	0.50	0.00	0.00
14														0.40	0.40	0.40	0.80	0.67	0.50	0.00	0.50	0.00	0.00
15															1.00	0.00	0.33	0.29	0.40	0.00	0.40	0.00	0.00
16																	0.67	0.57	0.00	0.00	0.40	0.00	0.00
17																		0.86	0.33	0.00	0.33	0.00	0.00
18																			0.00	0.00	0.00	0.00	0.00
19																			0.00	0.00	0.00	0.00	0.00
20																			0.00	0.00	0.00	0.00	0.00
21																			0.00	0.00	0.00	0.00	0.00
22																			0.00	0.00	0.00	0.00	0.00
23																			0.00	0.00	0.00	0.00	0.00

- | | | | |
|--------------|-------------|-------------|-------------|
| 1. Niehar | 2. Kafnu | 3. Sungra | 4. Kharogla |
| 5. Mastarang | 6. Chitkul | 7. Jangl | 8. Moorang |
| 9. Ribba | 10. Lippa | 11. Astrang | 12. Karla |
| 13. Giabung | 14. Ropa | 15. Shong | 16. Barua |
| 17. Sangla | 18. Kalpa | 19. Pangl | 20. Poari |
| 21. Pooh | 22. Dubling | 23. Maling | 24. Chango |

Table: 12b Sorenson's index of similarity between different sites for shrubs

Sites	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.75	0.67	0.25	0.00	0.00	0.40	0.00	-	0.00	0.33	-	-	-	0.40	0.40	0.33	0.40	0.00	0.33	0.00	0.00	0.00	0.00
2		0.75	0.20	0.33	0.00	0.29	0.00	-	0.00	0.25	-	-	-	0.29	0.29	0.75	0.29	0.25	0.50	0.00	0.00	0.00	0.00
3			0.25	0.50	0.00	0.00	0.00	-	0.00	0.00	-	-	-	0.40	0.40	0.33	0.40	0.00	0.33	0.00	0.00	0.00	0.00
4				0.33	0.29	0.29	0.00	-	0.00	0.50	-	-	-	0.00	0.00	0.75	0.00	0.25	0.25	0.00	0.25	0.29	0.29
5					0.00	0.00	0.00	-	0.00	0.00	-	-	-	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6						0.00	0.00	-	0.00	0.66	-	-	-	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40	0.50	0.50
7							0.00	-	0.00	0.40	-	-	-	0.50	0.50	0.40	0.50	0.40	0.40	0.00	0.00	0.00	0.00
8								-	0.00	0.50	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	-	0.50	0.00	-
9									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10										0.50	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.67	0.67
11										-	-	-	-	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.67	0.40	0.40
12											-	-	-	-	-	-	-	-	-	-	-	-	-
13												-	-	-	-	-	-	-	-	-	-	-	-
14													-	-	-	-	-	-	-	-	-	-	-
15														-	-	-	-	-	-	-	-	-	-
16															1.00	0.00	1.00	0.40	0.80	0.00	0.00	0.00	0.00
17																0.00	1.00	0.40	0.80	0.00	0.00	0.00	0.00
18																	0.00	0.33	0.33	0.00	0.00	0.00	0.00
19																		0.40	0.80	0.00	0.00	0.00	0.00
20																			0.67	0.00	0.00	0.00	0.00
21																					0.00	0.00	0.00
22																						0.00	0.40
23																							0.00

- | | | | | | | | |
|-----|-----------|-----|---------|-----|---------|-----|----------|
| 1. | Nichar | 2. | Kafnu | 3. | Sungra | 4. | Kharogla |
| 5. | Masterang | 6. | Chitkul | 7. | Jangi | 8. | Moorang |
| 9. | Ribba | 10. | Lippa | 11. | Astrang | 12. | Karla |
| 13. | Giabung | 14. | Ropa | 15. | Shong | 16. | Barua |
| 17. | Sangla | 18. | Kalpa | 19. | Pangi | 20. | Poari |
| 21. | Pooh | 22. | Dubling | 23. | Maling | 24. | Chango |

Table: 13b Jaccard's index of similarity between different sites for shrubs

Sites	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.60	0.50	0.14	0.00	0.00	0.25	0.00	-	0.00	0.20	-	-	-	0.25	0.25	0.20	0.25	0.00	0.20	0.00	0.00	0.00	0.00
2		0.60	0.11	0.20	0.00	0.17	0.00	-	0.00	0.14	-	-	-	0.17	0.17	0.60	0.17	0.14	0.33	0.00	0.00	0.00	0.00
3			0.14	0.33	0.00	0.00	0.00	-	0.00	0.00	-	-	-	0.25	0.25	0.20	0.25	0.00	0.20	0.00	0.00	0.00	0.00
4				0.20	0.17	0.17	0.00	-	0.00	0.33	-	-	-	0.00	0.00	0.60	0.00	0.14	0.14	0.00	0.14	0.17	0.17
5					0.00	0.00	0.00	-	0.00	0.00	-	-	-	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6						0.00	0.00	-	0.00	0.50	-	-	-	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.33	
7							0.00	-	0.00	0.25	-	-	-	0.33	0.33	0.25	0.33	0.25	0.25	0.00	0.00	0.00	0.00
8								-	0.00	0.33	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
9									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10										0.33	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.50
11											-	-	-	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.50	0.25	0.25
12												-	-	-	-	-	-	-	-	-	-	-	-
13													-	-	-	-	-	-	-	-	-	-	-
14																							
15																							
16															1.00	0.00	1.00	0.25	0.67	0.00	0.00	0.00	0.00
17																0.00	1.00	0.25	0.67	0.00	0.00	0.00	0.00
18																	0.00	0.20	0.20	0.00	0.00	0.00	0.00
19																		0.25	0.67	0.00	0.00	0.00	0.00
20																			0.50	0.00	0.00	0.00	0.00
21																				0.00	0.00	0.00	0.00
22																					0.00	0.00	0.00
23																						0.25	0.25
																							0.00
1. Nichar																							
5. Mastarang																							
9. Ribba																							
13. Giabung																							
17. Sangla																							
21. Pooh																							

- | | | | |
|--------------|-------------|-------------|-------------|
| 1. Niehar | 2. Kafnu | 3. Sungra | 4. Kharogla |
| 5. Mastarang | 6. Chitkul | 7. Jangi | 8. Moorang |
| 9. Ribba | 10. Lippa | 11. Astrang | 12. Karla |
| 13. Giabung | 14. Ropa | 15. Shong | 16. Barua |
| 17. Sangla | 18. Kalpa | 19. Pangl | 20. Poari |
| 21. Pooh | 22. Dubling | 23. Maling | 24. Chango |

Table: 14a Chord distance for trees between different sites

Sites	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.075	1.000	0.914	0.915	0.927	0.827	0.937	0.370	0.641	0.735	0.991	0.894	0.842	1.000	1.000	0.049	0.414	0.411	1.000	1.000	1.000	1.000	1.000
2		1.000	0.907	0.905	0.920	0.830	0.938	0.381	0.645	0.472	0.991	0.895	0.843	1.000	1.000	0.094	0.421	0.420	1.000	1.000	1.000	1.000	1.000
3			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4				0.386	0.607	0.994	0.998	0.985	0.990	0.536	0.999	0.996	0.994	1.000	1.000	0.940	0.943	0.979	1.000	1.000	1.000	1.000	1.000
5					0.480	1.000	1.000	1.000	1.000	0.339	1.000	1.000	1.000	1.000	1.000	0.949	0.947	0.992	1.000	1.000	1.000	1.000	1.000
6						1.000	1.000	1.000	1.000	0.520	1.000	1.000	1.000	1.000	1.000	0.951	0.960	0.994	1.000	1.000	1.000	1.000	1.000
7							0.144	1.000	1.000	0.936	0.221	0.087	0.018	0.988	0.990	0.826	0.459	0.479	0.235	1.000	1.000	1.000	1.000
8								0.519	0.225	0.968	0.084	0.057	0.125	0.987	0.989	0.937	0.591	0.611	0.099	1.000	1.000	1.000	1.000
9								0.662	0.365	0.841	0.714	0.599	0.536	0.994	0.995	0.364	0.106	0.090	0.727	1.000	1.000	1.000	1.000
10									0.304	0.889	0.436	0.310	0.243	0.990	0.991	0.638	0.249	0.269	0.451	1.000	1.000	1.000	1.000
11											0.986	0.955	0.940	0.987	0.997	0.772	0.794	0.839	0.988	1.000	1.000	1.000	1.000
12												0.138	0.203	0.988	0.989	0.991	0.659	0.678	0.061	1.000	1.000	1.000	1.000
13													0.068	0.988	0.989	0.894	0.540	0.559	0.152	1.000	1.000	1.000	1.000
14														0.988	0.989	0.841	0.477	0.496	0.217	1.000	1.000	1.000	1.000
15															0.090	1.000	0.993	0.993	0.987	1.000	1.000	1.000	1.000
16																	0.994	0.994	0.989	1.000	1.000	1.000	1.000
17																1.000	0.994	0.407	0.670	1.000	1.000	1.000	1.000
18																	0.417	0.094	0.689	1.000	1.000	1.000	1.000
19																							
20																							
21																					0.953	1.000	1.000
22																							
23																							0.478

1.	Nichar	2.	Kafu	3.	Sungra	4.	Kharogla
5.	Mastarang	6.	Chitkul	7.	Jangi	8.	Moorang
9.	Ribba	10.	Lippa	11.	Astrang	12.	Karla
13.	Giabung	14.	Ropa	15.	Shong	16.	Barua
17.	Sangla	18.	Kalpa	19.	Pangi	20.	Poari
21.	Pooh	22.	Dubling	23.	Maling	24.	Chango

Table: 14b Chord distance for shrubs between different sites

Sites	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.832																						
2		0.502																					
3		0.792	0.990																				
4			0.663	1.000	1.000	0.898	1.000	-	1.000	0.908	-	-	-	0.202	0.265	0.927	0.346	1.000	0.836	1.0000	1.000	1.000	1.000
5			0.865	.814	1.000	0.720	1.000	-	1.000	0.751	-	-	-	0.942	0.944	0.399	0.947	0.752	0.819	1.000	1.000	1.000	1.000
6				.643	1.000	1.000	1.000	-	1.000	1.000	-	-	-	0.536	0.556	0.796	0.588	1.000	0.893	1.000	1.000	1.000	1.000
7				.756	0.974	0.960	1.000	-	1.000	0.964	-	-	-	1.000	1.000	0.624	1.000	0.746	0.972	1.000	1.000	0.986	0.970
8					1.000	1.000	1.000	-	1.000	1.000	-	-	-	1.000	1.000	0.613	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9							1.000	-	0.815	0.892	-	-	-	0.985	0.933	1.000	0.891	0.936	0.716	1.000	1.000	0.962	0.930
10								-	1.000	0.577	-	-	-	1.000	1.000	0.681	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11									0.629	-	-	-	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.883	0.776	0.670
12											-	-	-	1.000	1.000	0.717	1.000	1.000	1.000	1.000	0.870	0.871	0.871
13												-	-										
14													-										
15															0.139								
16																1.000	0.250	0.993	0.796	1.000	1.000	1.000	1.000
17																1.000	0.112	0.969	0.678	1.000	1.000	1.000	1.000
18																	1.000	0.813	0.968	1.000	1.000	1.000	1.000
19																		0.950	0.580	1.000	1.000	1.000	1.000
20																			0.822	1.000	1.000	1.000	1.000
21																				1.000	1.000	1.000	1.000
22																					1.000	1.000	0.955
23																							0.123

- | | | | |
|--------------|-------------|-------------|-------------|
| 1. Niehar | 2. Kafnu | 3. Sungra | 4. Kharogla |
| 5. Mastarang | 6. Chitkul | 7. Jangi | 8. Moorang |
| 9. Ribba | 10. Lippa | 11. Astrang | 12. Karla |
| 13. Giabung | 14. Ropa | 15. Shong | 16. Barua |
| 17. Sangla | 18. Kalpa | 19. Pangl | 20. Poari |
| 21. Pooh | 22. Dubling | 23. Maling | 24. Chango |

[illegible][illegible]

shrubs was 1 whereas second and third highest values were 0.67 and 0.60 (Table 13b).

iii) Chord Distance

It is the measure of dissimilarity between two communities in contrast to the above two indices, which measure similarities. The value of Chord distance ranges from 0 to 1. For tree communities, the minimum value (0.018) of Chord distance was observed between sites 7 and 14. The next highest values 0.049 and 0.057 were recorded for community pairs (1,7) and (8,13); however, 123 combinations (Table 14a) of communities had maximum Chord distance of 1. The tabulated form of chord distance between different community pairs is summarized in the form of a dendrogram (Fig.3).

While for the shrubs (Table 14b), the minimum values of Chord distance 0.112, 0.123 and 0.139 were recorded for community pairs (16, 18), (23, 24) and (15, 16), respectively. While, for 113 community pairs the value of Chord distance was unity. Sampling units 9, 12, 13 and 14 were observed to have no shrub species.

h) Inter-specific Association

Chi-square test of independence was done for determining inter-specific association between pairs of tree species, and tree and shrub species. While going through data in Table 15a, it is clear that a positive association was there for two pairs of tree species and a negative association was observed for seven pairs of tree species. In case of positive association, the highest value (7.427) of chi-square was recorded for *Pinus wallichiana* and *Abies pindrow* pair. This is highly significant at 0.01 level. The corresponding value for coefficient of association was 0.486. Chi-square value for *Populus ciliata* and *Betula utilis* was 4.408, which is significant at 0.05 level. The corresponding value of coefficient of association was 0.394. In case of negative association chi-square value was maximum (5.490) for five pairs of tree species (*Fraxinus*

xanthodyloides and *Picea smithiana*, *F. xanthoxyloides* and *Pinus roxburghii*, *F. xanthoxyloides* and *Juniperus macropoda*, *Picea smithiana* and *Pinus roxburghii*, and *Pinus roxburghii* and *Juniperus macropoda*. Coefficient of association for these pairs was 0.431. Chi-square values 4.039 and 4.963 were recorded for the pairs *Pinus gerardiana* and *P. wallichiana*, and *P. gerardiana* and *Abies pindrow*, respectively with corresponding values of coefficient of association as 0.380 and 0.414.

For interspecific association between trees and shrubs (Table 15b), positive association was observed for eight pairs of tree and shrub species and the highest value of chi-square (7.792) was found for three pairs viz., *Populus ciliata* and *Berberis jaeschkeana*, *Betula utilis* and *Berberis jaeschkeana*, and *Betula utilis* and *Rosa webbiana* with the same values (0.495) of coefficient of association. Lowest chi-square (+ve association) was for *Abies pindrow* and *R. webbiana* (3.881) with coefficient of association being 0.373. Negative association was found for three combinations of tree and shrub species with same value of chi-square and coefficient of association (5.490 and 0.431, respectively), chi-square value being significant at 0.05.

4.2 FREQUENCY DISTRIBUTION

A close look at the Table 16 reveals that out of the seven distributions tried to the data of *Cedrus deodara* for the characters tree height and dbh, normal distribution could fit well to the data of group A for tree height and dbh (Fig. 4 and 5). The chi-square values between observed and expected frequencies for these two characters were found to be 10.972 and 7.024 respectively. These values of chi-square came out to be statistically non-significant at 0.05 level of significance indicating a good fit of the distribution. Similarly in case of individuals of group C, normal distribution fits the data (Fig. 6); the value of chi-square (8.429) being non-significant at 0.05 level. In all other cases none of the theoretical distributions tried could fit the data as the chi-square values were highly significant.

Table: 15a Interspecific association between tree species

Species Pair	Association Type	Chi-square	Coefficient of Association
<i>Pinus gerardiana</i> <i>P. wallichiana</i>	—	4.039*	0.380
<i>P. gerardiana</i> <i>Abies pindrow</i>	—	4.963*	0.414
<i>P. wallichiana</i> <i>A. pindrow</i>	+	7.427**	0.486
<i>Fraxinus xanthoxyloides</i> <i>Picea smithiana</i>	—	5.490*	0.431
<i>F. xanthoxyloides</i> <i>Pinus roxburghii</i>	—	5.490*	0.431
<i>F. xanthoxyloides</i> <i>Juniperus macropoda</i>	—	5.490*	0.431
<i>Populus ciliata</i> <i>Betula utilis</i>	+	4.408*	0.394
<i>Picea smithiana</i> <i>Pinus roxburghii</i>	—	5.490*	0.431
<i>P. roxburghii</i> <i>J. macropoda</i>	—	5.490*	0.431

‘*’ non-significant at 0.05 leve

‘***’ non-significant at 0.01 level

Table: 15b Interspecific association between tree and shrub species

Species Pair	Association Type	Chi-square	Coefficient of Association
<i>Quercus ilex</i> <i>Plectranthus rugosus</i>	+	4.869*	0.411
<i>Fraxinus xanthoxyloides</i> <i>Rosa webbiana</i>	—	5.490*	0.431
<i>Abies pindrow</i> <i>Indigofera gerardiana</i>	+	5.053*	0.471
<i>A. pindrow</i> <i>Rhus semialata</i>	+	5.053*	0.471
<i>A. pindrow</i> <i>Rosa webbiana</i>	+	3.881*	0.373
<i>Populus ciliata</i> <i>Berberis jaeschkeana</i>	+	7.792**	0.495
<i>P. ciliata</i> <i>Hippophae rhamnoides</i>	+	4.408*	0.394
<i>Betula utilis</i> <i>Berberis jaeschkeana</i>	+	7.792**	0.495
<i>Betula utilis</i> <i>R. webbiana</i>	+	7.792**	0.495
<i>Picea smithiana</i> <i>R. webbiana</i>	—	5.490*	0.431
<i>Juniperus macropoda</i> <i>R. webbiana</i>	—	5.490*	0.431

‘*’ non-significant at 0.05 level

‘**’ non-significant at 0.01 level

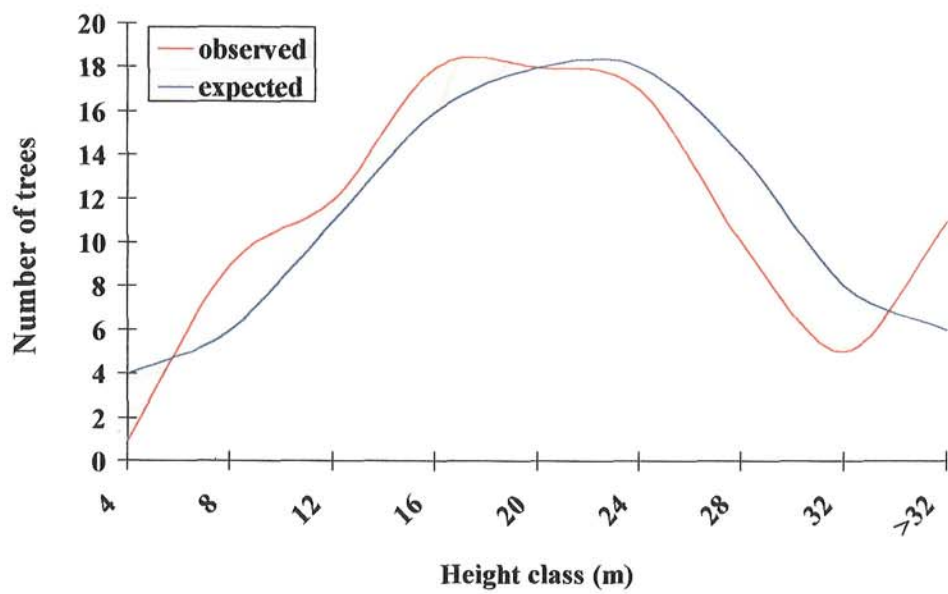


Fig. 4. Normal frequency distribution of *Cedrus deodara* for height (Group A)

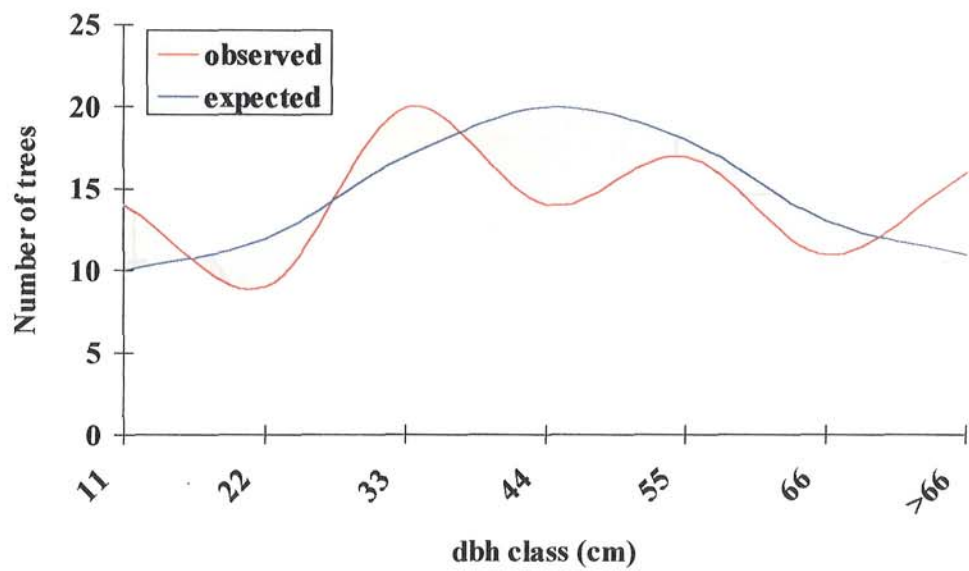


Fig. 5. Normal frequency distribution of *Cedrus deodara* for dbh (Group A)

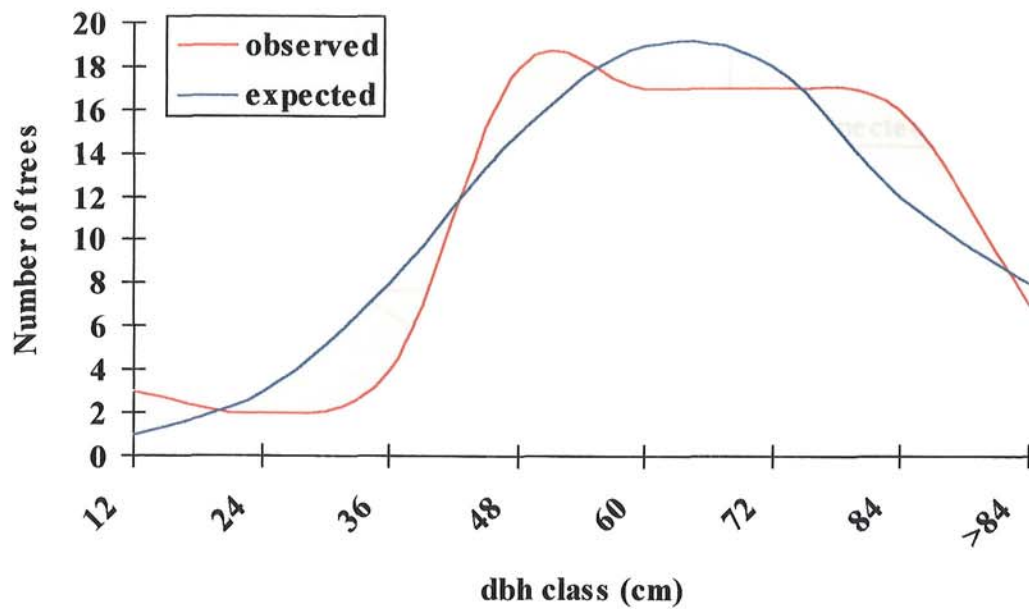


Fig. 6. Normal frequency distribution of *Cedrus deodara* for dbh (Group C)

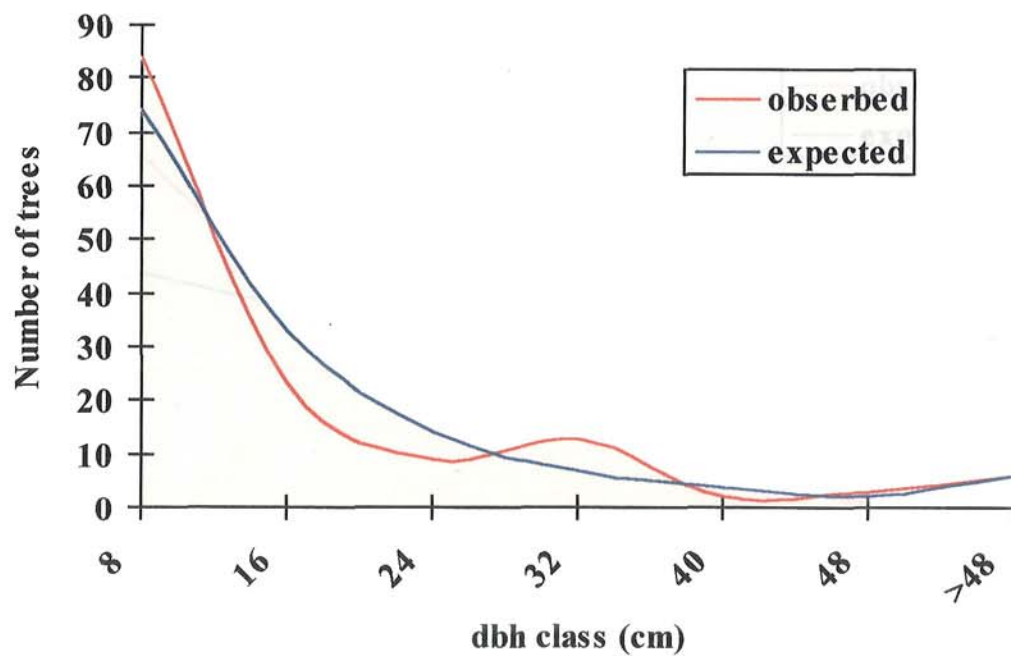


Fig. 7. Log-normal frequency distribution of *Pinus gerardiana* for dbh (Group A)

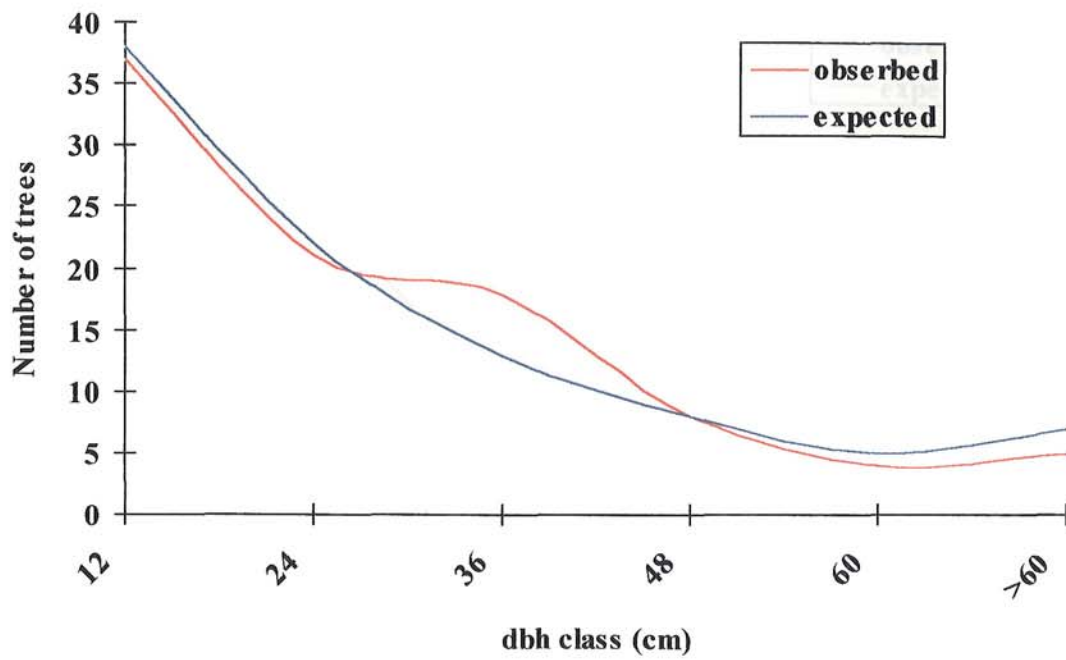


Fig. 8. Exponential frequency distribution of *Pinus gerardiana* for dbh (Group C)

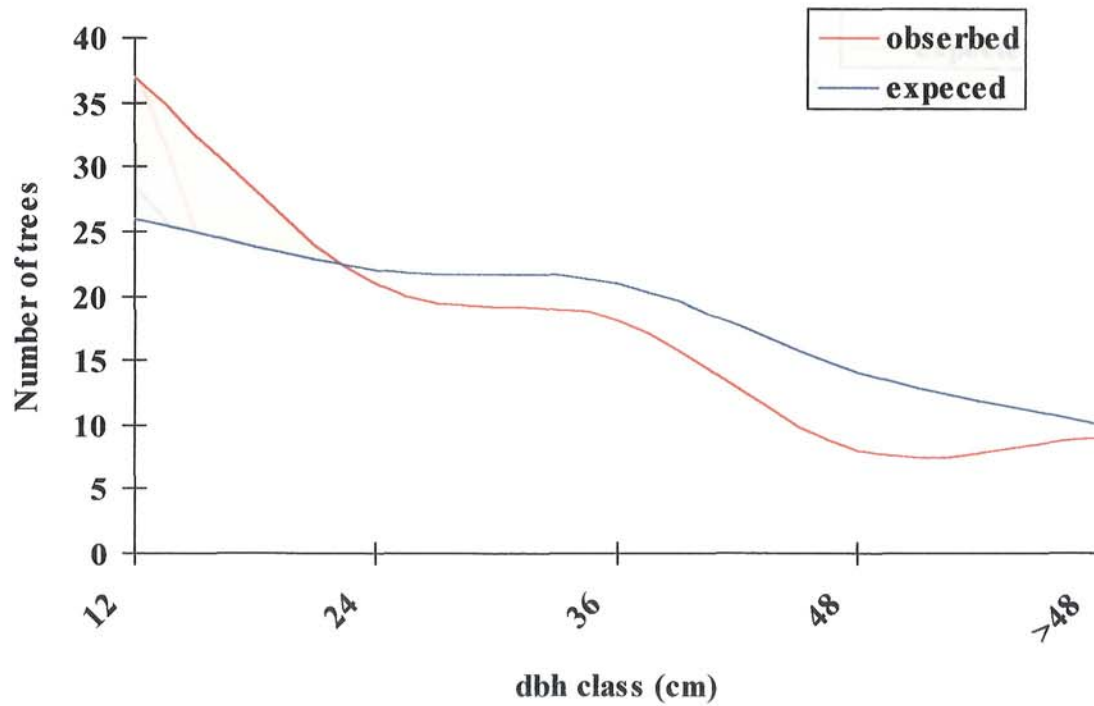


Fig. 9. Normal frequency distribution of *Pinus gerardiana* for dbh (Group C)

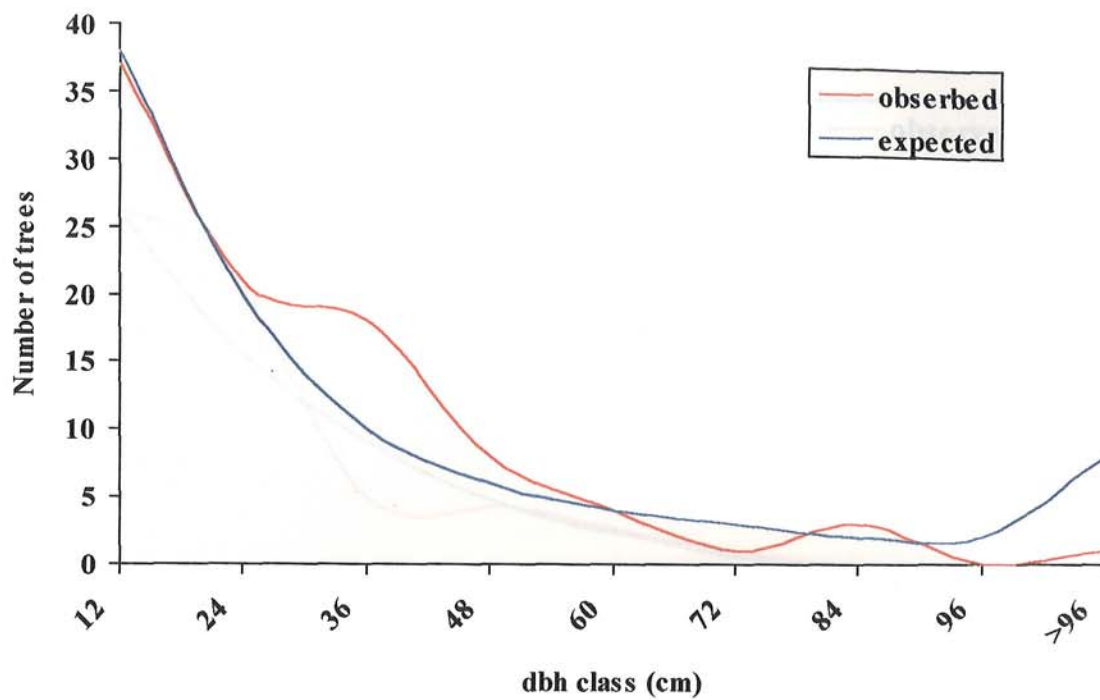


Fig. 10. Log-normal frequency distribution of *Pinus gerardiana* for dbh (Group C)

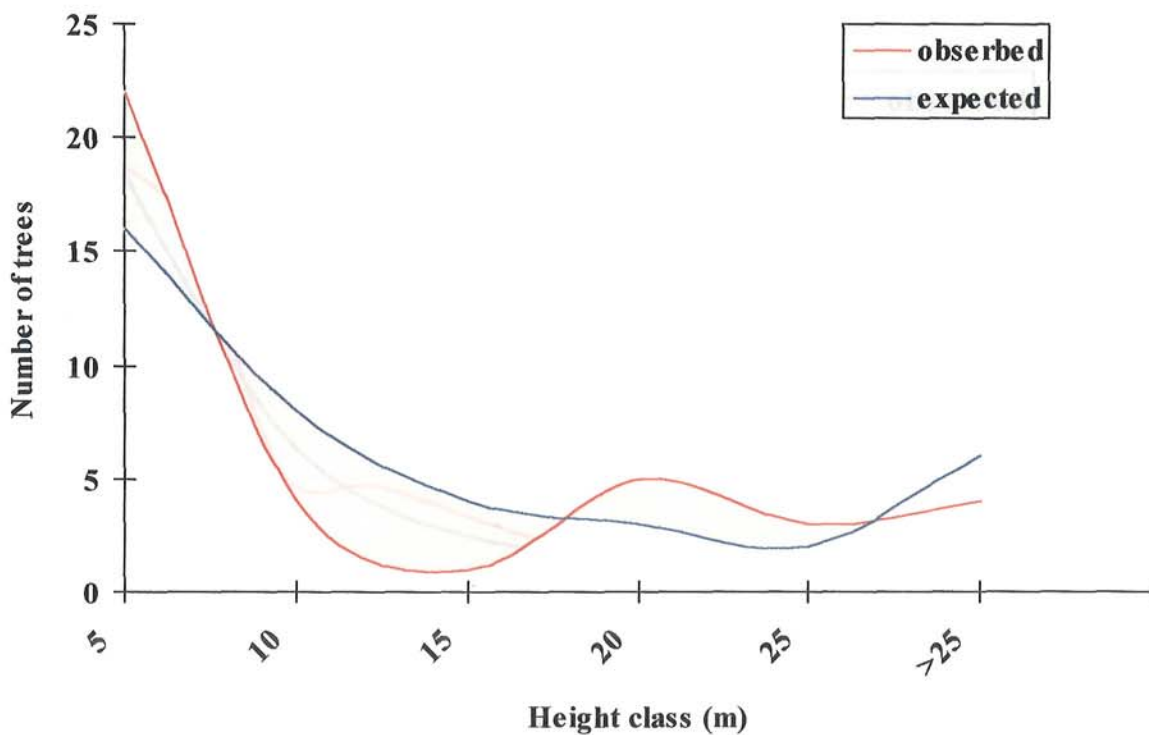


Fig. 11. Log-normal frequency distribution of *Pinus wallichiana* for height (Group A)

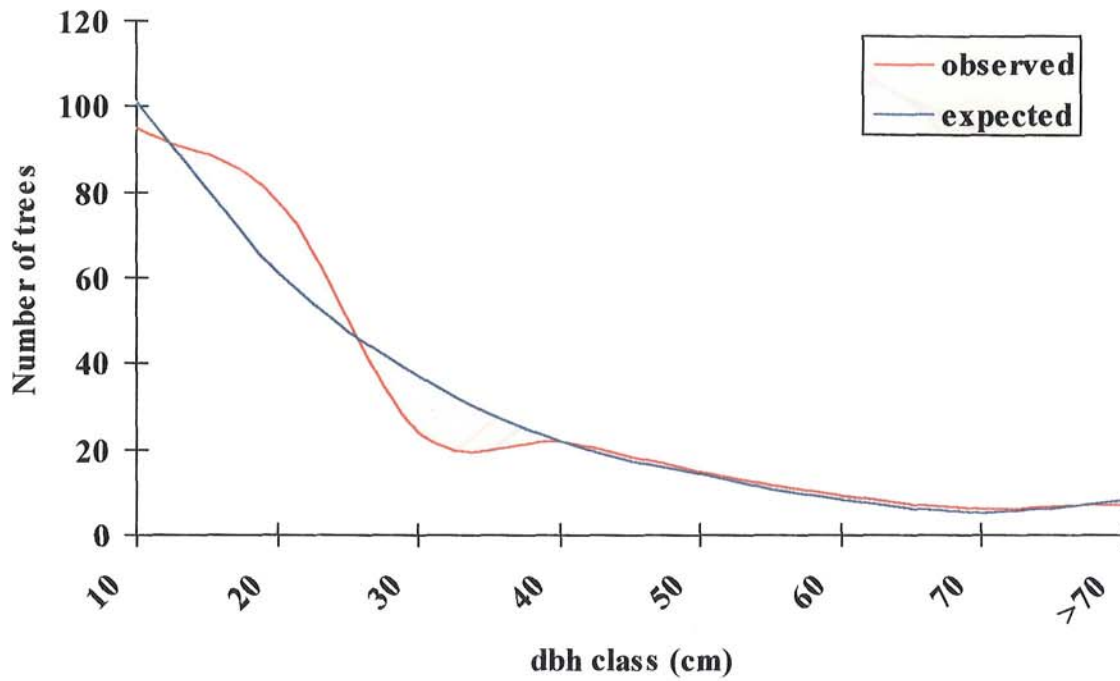


Fig.12. Exponential frequency distribution of *Pinus wallichiana* for dbh (combined)

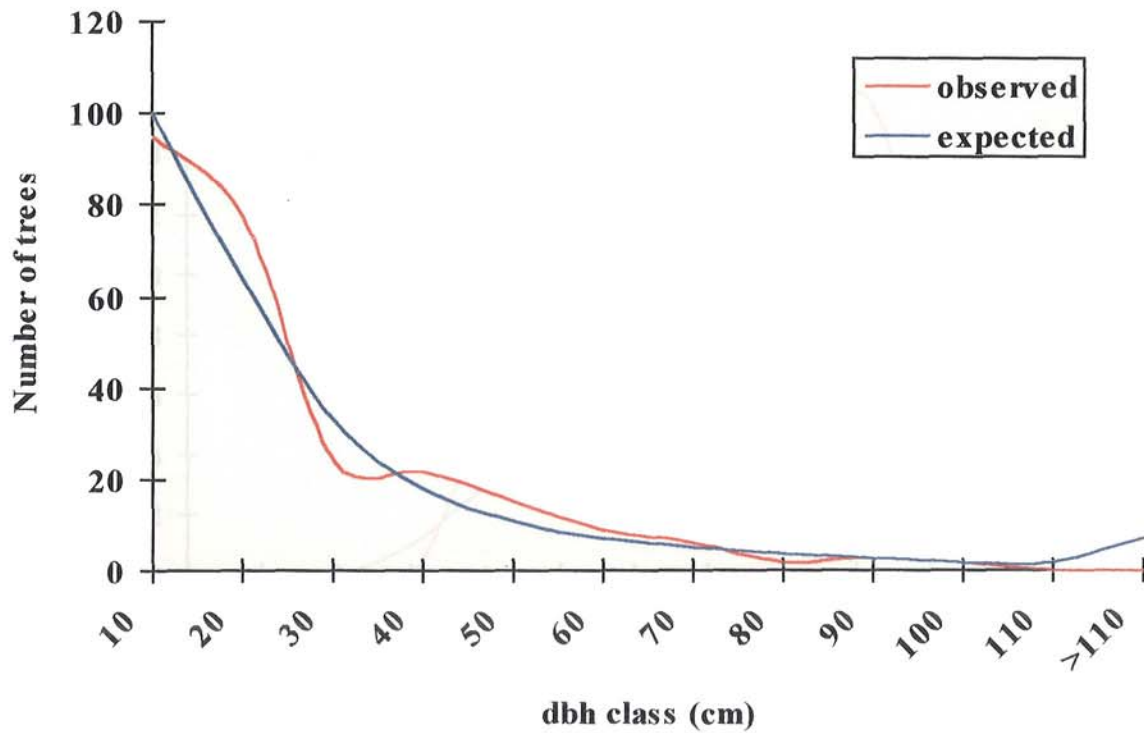


Fig. 13. Log-normal frequency distribution of *Pinus wallichiana* for dbh (combined)

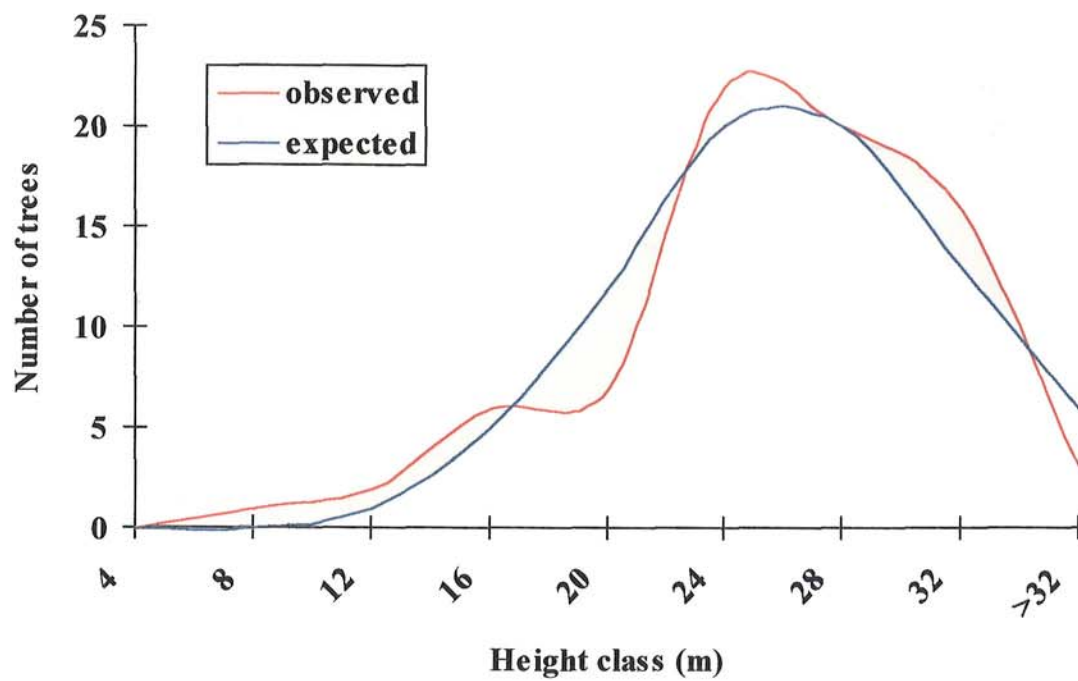


Fig.14. Normal frequency distribution of *Pinus roxburghii* for height

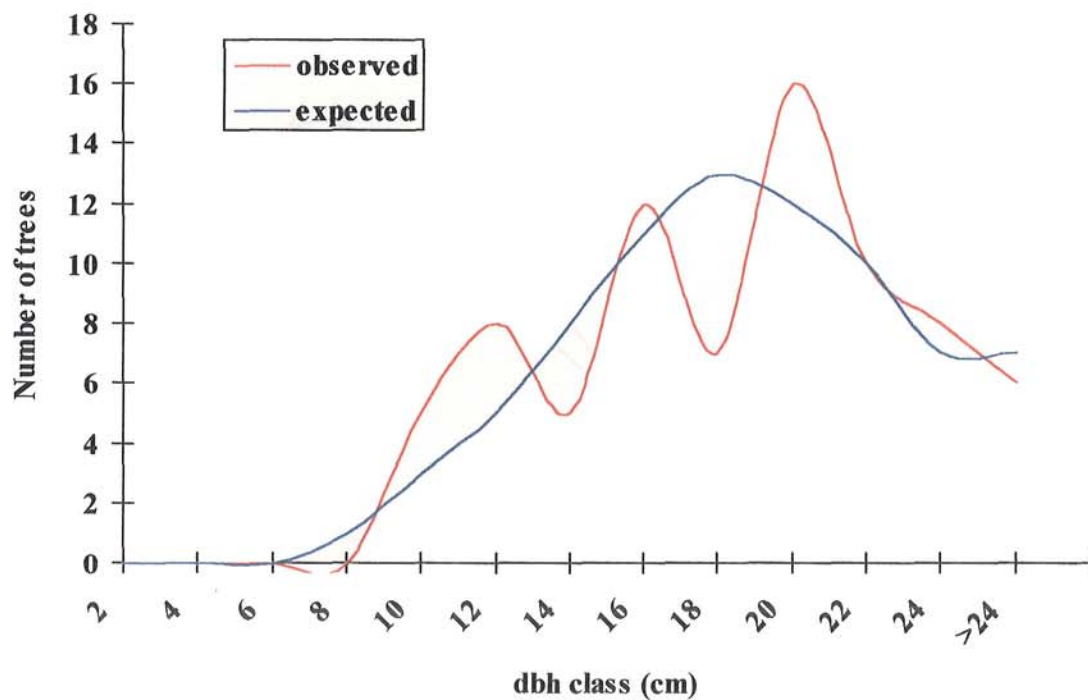


Fig. 15. Normal frequency distribution of *Pinus roxburghii* for dbh

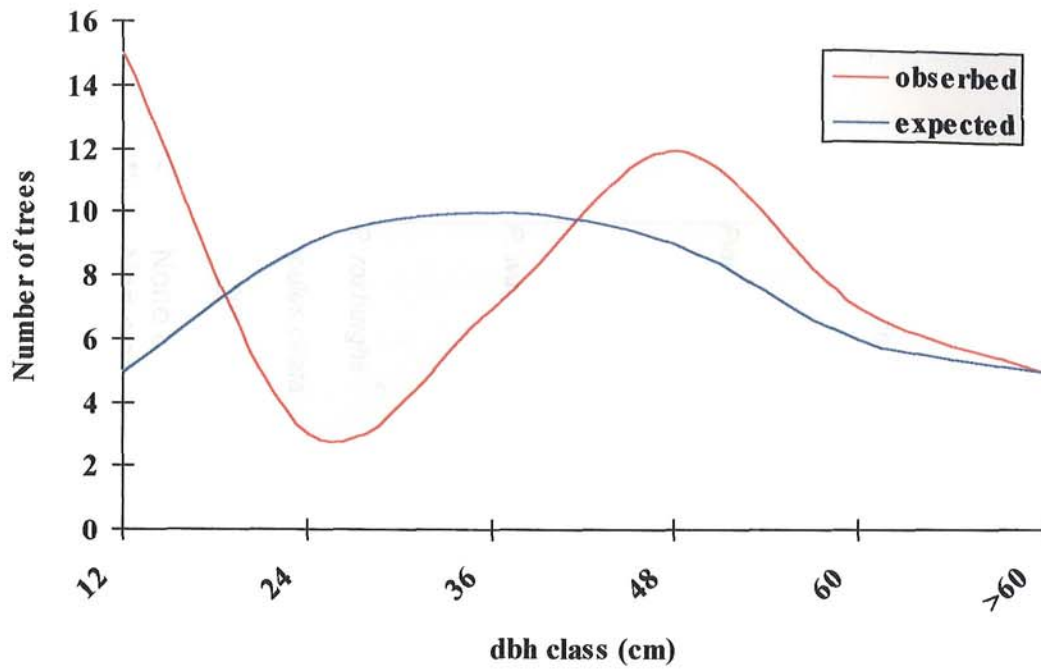


Fig. 16. Normal frequency distribution of *Populus ciliata* for dbh

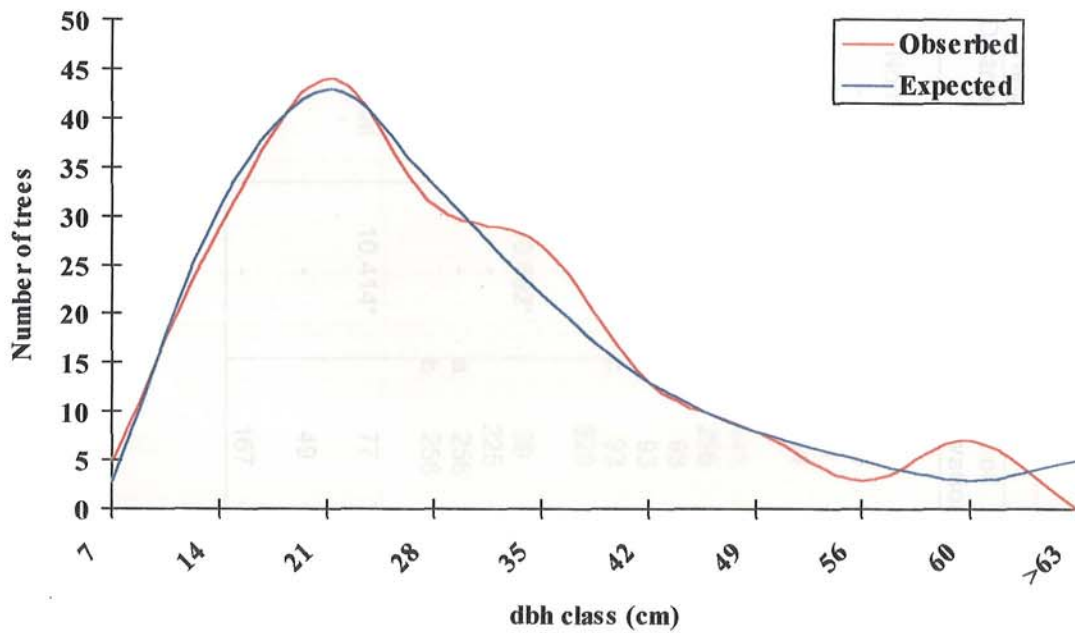


Fig. 17. Log-normal frequency distribution of *Quercus ilex* for dbh

Table: 16 **Types of frequency distribution for tree height and dbh in different groups**

Sr. No.	Species	Group	Sampling units	Height			Dbh		
				No. of observation	Distribution	χ^2	No. of observation	Distribution	χ^2
1.	<i>Cedrus deodara</i>	A B C A+B+C	P _{7I} , P _{7II} , P _{8II} N _{7I} , N _{7II} , O _{6III} , O _{7I} , P _{8I} O _{7II} , P _{7II} , P _{9I} , P _{9II} Combined	101 329 84 514	Normal - - -	10.972*	101 329 84 514	Normal - Normal -	7.024* - 8.429* -
2.	<i>Pinus gerardiana</i>	A B C	O _{7I} , O _{7III} , P _{6III} , Q _{8II} P _{7I} , P _{7II} , P _{8III} , P _{9I} , P _{9II} O _{7II} , P _{7III} , P _{8I}	148 256 93	- - -	- - -	141 256 93 93	Log-normal - Exponential Normal Log-normal	12.419* - 2.417** 7.434* 15.378*
3.	<i>P. wallichiana</i>	A+B+C	Combined	520	-	-	520	-	-
4.	<i>P. roxburghii</i>	A	N _{7I}	39 225 256	Log-normal - -	10.692*	39 225 256	- s- Exponential Log-normal	- - 10.011* 17.261*
5.	<i>Populus ciliata</i>	A	P _{6I} , P _{6II} , Q _{9II}	49	-	-	49	Normal	8.659*
6.	<i>Quercus ilex</i>	A	O _{6I} , O _{6II}	167	-	-	167	Log-normal	13.000*

* None of the distribution tried fitted to the data
 ** Non-significant at 0.05 level
 *** Non-significant at 0.01 level

In a similar fashion the three distributions viz. normal, log-normal and exponential were tried to fit the data pertaining to dbh of *Pinus gerardiana* of group C. The results indicated that the expected frequencies from the distribution functions were very close to that of the observed frequencies which implies that all the three functions provided good fit to the data. The values of chi-square between observed and expected frequency came out to be statistically non-significant. By comparing the three chi-square values, however, it may be concluded that the exponential distribution shows comparatively better fit having the least chi-square value (2.417) which was highly non-significant (at 0.01 level). The next two better fits are normal and log-normal having chi-squares as 7.434 and 15.378, respectively. In group A only log-normal distribution fits the data of dbh. The graph showing the observed and expected frequencies is given in Fig. 7. The chi-square value in this case was found to be 12.419 (Table 16). No distribution could fit in any of the remaining cases.

In case of *Pinus wallichiana* log-normal distribution was observed to fit the data of group A for the character tree height (Fig. 11). The chi-square value (10.692) between observed and expected frequencies came out to be non-significant at 5 per cent level of significance (Table 16). When the two groups were combined and chi-square test of goodness of fit was done, it was found that exponential and log-normal distribution fitted well to the data (Fig. 12 and 13). Comparison of the chi-square values indicated that exponential distribution was better fit ($\chi^2 = 10.011$) than the log-normal ($\chi^2 = 17.261$).

In *Pinus roxburghii* normal distribution was found to fit well to the data of both the characters, tree height and dbh (Fig. 14 and 15); the chi-square values being 10.414 and 11.172 respectively. Normal distribution was also found to fit the dbh data of the trees of *Populus ciliata* (Fig. 16). The chi-square value (8.659) was non-significant at 0.05 level (Table 16). Of the three statistical distributions fitted to the dbh data of *Quercus ilex* (Fig. 17), the chi-square value being 13.000 non-significant at 0.05 level (Table 16).

DISCUSSION

5.1 SPECIES DIVERSITY

a) α -Diversity: Species richness(S), Shannon Index (H'), Equitability (J') and Simpson's Index of Dominance(Cd)

Results obtained from the investigation revealed (Table 5) that 96 per cent of the sites constituted 2 to 5 tree species, although species number ranged from 1 to 7. While in case of shrubs, 2 to 4 species occupied 92 per cent of the sites, but the number of species ranged from none to five. In a similar study of the temperate forests, Marquez *et al.* (1999) found 3 to 5 species in 68 per cent of the plots while the total number of species varied from 1 to 9. In the tropical forests, on the other hand, species richness, in general, is higher. It is evident from the studies of Rawat *et al.* (1999) where species richness was reported to be 39 in Shola-van. These studies provide a support to the earlier investigations that species richness increases along a gradient from pole to equator, and from high elevations to low elevations (Raghubanshi *et al.*, 1991). Trends in species richness correspond to the values of Shannon Index, being highest for the site containing the maximum number of tree as well as shrub species (Table 5). Concentration of dominance [Simpson's Index, Cd] has inverse relation to equitability (J'), highest value of Cd corresponds to the lowest value of J' (Table 5), which is true in case of trees and shrubs as well. Temperate forests are characterized by lower species diversity and greater dominance by one or a few species of trees (Marquez *et al.*, 1999) indicating an uneven sharing of available resources by different species. The range of Shannon Index for temperate forests lies between 1.16 to 3.40 (Pande, 2001). The highest values of Shannon Index for trees and shrubs are 1.984 and 2.136, respectively, which are well accommodated by the above mentioned range. Results of the studies by Marquez *et al.* (1999); Zhang MuMing *et al.* (1999); Pandey and Joshi (1998) also fall within the range explained by Pande (2001). Tropical and sub-tropical

forests, on the other hand, are rich in species diversity (Dumetz, 1999; Xu *et al.*, 2001). The higher values of Shannon Index ($H' = 5.40$ and $H' = 4.89$) were found by Knight, 1975 and Singh *et al.* 1981 while lower estimates of concentration of dominance ($C = 0.06-0.14$) by Singh *et al.*, 1981; Chandrashekara and Ramakrishnan, 1994 and Seetharam *et al.*, 2000. The value of Simpson's Index was reported as high as 1.00 and Shannon Index as low as 0.00 (Table 5) indicating a complete dominance of the stand by only one species (Pande, 2001; Ralhan *et al.*, 1982). Lower diversity in the temperate vegetation could be attributed to a lower rate of evolution and diversification (Simpson, 1949; Fisher, 1960) and severity in environment (Connell and Oris, 1964). Species richness and diversity were generally lower in communities, experiencing environmental extremes, evenness was the greatest at higher altitudes where severe climate limited the ability of single or a group of species to dominate (Brockway, 1998).

(b) Importance Value Index (IVI) and Importance Value (IV%)

IVI of a species represents the relative dominance of the species in a community, which further indicates how important the species is with respect to its associates in terms of resource utilization. Importance value per cent, on the other hand, gives quantitative account of the species in its respective community and it becomes easier to interpret the species' performance relative to the other coexisting species. *Cedrus deodara* was the dominant species in six sampling units, which fall in its natural range (2000 m to 3250 m). O₆III was having the highest relative density (75.69) and relative dominance (95.38) which contributed to its maximum IVI (Table 6). Importance value (%) 85.53, being highest among all the sites, indicates that 85.53 per cent of area of O₆III was occupied by *C. deodara* alone. In other words it utilized a major share of the local resources available and what was left was distributed among the individuals of associated tree as well as shrub species. Out of eight sampling units, where *Pinus gerardiana* was the most important species (IVI being the highest), P₈III was having maximum IVI (272.93) and IV per cent (96.46) which suggest that 96.46

per cent of the area was covered with this species alone. Maximum IVI values indicate that O₆III site is best suited for the growth and development of *C. deodara* and P₈III for *P. gerardiana*. None of the biotic pressures (fire, trampling, grazing and lopping) could do any harm to the crop in general. Even the harvesting of Neoza seed (of high economic worth) by the villagers does not have adverse effect on the growth of *P. gerardiana* trees as indicated by maximum mean diameter and mean basal area of the Neoza pine trees at site P₈III.

Pinus wallichiana, on the other hand, was having the highest IVI and IV (%) at P₆II, of the four sites where it was the dominant species. Relative density (73.05) and relative dominance (70.22) contributed comparatively more to give higher IVI as compared to relative frequency (44.44) as is evident from Table 6. In this particular site, trees of *P. wallichiana* occupied 71.95 per cent of the area indicating that this habitat is most suitable for this species. It is situated very close to the right bank of Baspa river, mostly leveled ground with gravelly-silt type of soil, dark gray in color, though on warm southern aspect, but with no dearth of moisture. Biotic pressures in the form of trampling and grazing were high; lopping could be seen, but to a very low level. There were signs of heavy landslide all along the site, even then it supported a good crop, comparatively of young trees (mean height 10.67 ± 0.59 m, mean diameter 13.61 ± 0.78 cm and mean basal area 307.09 ± 34.09 cm²) in comparison to other sampling units where *P. wallichiana* was present. N₇I was completely dominated by single tree species (*P. roxburghii*) IVI and IV (%) being 174.32 and 70.49, respectively. The character of dominant tree species with respect to its aggressiveness becomes some times the most important determinant of species richness. Monospecific nature of *P. roxburghii* stand has also been reported by Ralhan *et al.* (1982). Relative density (65.81) and relative basal area (75.18) were comparatively more than the relative frequency (33.33). This sampling unit is situated on the northern aspect (2105 m), which is considered to be the preferred aspect at low elevation, whereas it may ascend up to 2300 m on southern aspect.

Qercus ilex was the dominant species at two sites (O_6I and O_6II). IVI was maximum at O_6I , but the proportion of ground covered by the trees was more at O_6II (58.78%), which is slightly more than O_6I (57.26%), for the minute variation in relative density and relative basal area of the species in two sites. These sites were fairly rich in humus due to presence of black clay-loam type of soil (Puri, 1960). It is typically xerophytic species, growing on drier areas (stony/rocky ground) and hot slopes (Troup, 1921). Average height of the trees was generally low as there was high lopping pressure (Table 3) on the branches, even the top was cut, which does not allow the tree to attain a good height. Other pressures were low to moderate in intensity, which do not have any adverse effect on the mature trees, but severely affect the root suckers or seedlings. *Juniperus macropoda* was the only tree species growing at Q_8I ($H'=0.000$ and $Cd = 1.000$). It generally occurs in the inner most arid zone of western Himalaya (2500 m to 4330 m). The site Q_8I was located at an average altitude of 2970 m south wards (20° slope). Trees were of stunted growth with branches being lopped for fuel wood. At Q_9I , *Salix fragilis* was the dominant species, there was no other tree species growing naturally in this locality and *S. fragilis* stand was also a plantation. At Q_9II though *Salix fragilis* and *Populus ciliata* were having better growth and development, the dominant species was *Rosa webbiana* having the highest IVI (60.70). The next important species was *S. fragilis* (IVI, 57.48). Both the sites were located above 3100 m, which is the most arid region in the sub-alpine zone (2900 m-3500 m).

On the basis of IVI the tree communities present in the 24 sites were classified into 13 tree community types. These are i) *Pinus gerardiana* dominated stand (P_7II , P_8III , Q_8II and O_7III), ii) *Pinus gerardiana-Cedrus deodara* stand (P_7I , P_8I , P_9I and P_9II), iii) *Cedrus deodara-Pinus gerardiana* stand (P_7III , O_7I and O_7II), iv) *Cedrus deodara* dominated stand (N_7II , N_7III and O_6III), v) *Pinus wallichiana-Cedrus deodara* mixed stand (P_8II), vi) *Pinus wallichiana* dominated stand (P_6II), vii) *Pinus wallichiana-Populus ciliata* mixed stand (P_6I), viii) *Pinus*

wallichiana-*Betula utilis* mixed stand (P₆III), ix) *Pinus roxburghii* pure stand (N₇I), x) *Quercus ilex* dominated stand (O₆I and O₆II), xi) *Juniperus macropoda* pure scrub (Q₈I), xii) *Salix fragilis* pure plantation (Q₉I) and xiii) *Salix fragilis*-*Populus ciliata* stand (Q₉II). Many ecologists (Rahhan *et al.*, 1982; Singh *et al.*, 1991; Pandey and Joshi, 1998) have used the similar methodology to divide their study areas in to different community types.

In order to study overstorey and understorey communities (tree layer and shrub layer), IVI and IV per cent were calculated separately for each site. For overstorey, IVI and IV per cent presented a similar trend to what was observed in the study of trees and shrubs as a single community (Table 7a), the only difference being in the values. For instance, when trees and shrubs were studied as a single community, IVI and IV per cent for *P. roxburghii* were 174.32 and 70.49, respectively, and when they were studied as separate communities, the values of IVI and IV per cent become 300 and 100, respectively. When understorey was studied in terms of IVI and IV per cent, the objective was to know the importance of shrubs in the shrub community. Results (Table 7b) show that *Plectranthus rugosus* was the dominant shrub at low elevations (1960 m-2765 m) most frequently occurring under the top canopy of *Cedrus deodara*, *Pinus gerardiana*, *P. roxburghii* and *Quercus ilex* etc. *Indigofera gerardiana* was the principal shrub at two sites P₆I and O₇II (2830 m and 2865 m). *Berberis jaeschkeana* and *Cotoneaster microphylla* were the second important species at P₆I and O₇II, respectively. Of the two sites (P₇I and P₈II), where *Rhus semialata* was the dominant shrub, IVI in P₇I was the highest (203.78) and it occupied 76.89 per cent of the area whereas, *Daphne mucronata* accounted for 23.11 per cent. *Berberis jaeschkeana* dominated O₆III and P₆II (2520 m to 3015m); it was the only shrub in P₆II while in O₆III, it was associated with *Indigofera gerardiana* and *R. semialata*. Its upperstorey was occupied by *Pinus wallichiana*, *C. deodara*, *Betula utilis*, *Populus ciliata* and *Salix elegans*. Two-third of the ground cover was composed of *Cotoneaster microphylla* in P₆III, while approximately one third being covered by *Rosa webbiana*. The top canopy

was mostly dominated by *Pinus wallichiana*, *Betula utilis*, *Picea smithiana* and *Abies pindrow* in descending order of IVI and IV(%). *Lonicera quinquelocularis* and *Juniperus recurva* completely dominated their respective sites (P₇II and Q₈I) presenting the highest values of IVI (300.00) and IV per cent (100.00). At P₇II, *Pinus gerardiana* and *Cedrus deodara* formed the overstorey while *J. macropoda* was the dominant tree species in Q₈I. *Rosa webbiana* was the principal shrub in the understorey where the top canopy was composed of *P. gerardiana* and *C. deodara* (P₈I). At Q₉II, it was growing on the dry and exposed places in association with *Hippophae rhamnoides*. *Fraxinus xanthoxyloides* was the most abundant shrub species in Q₈II. It is a tree, which attains height of about 7 to 8 m at low elevations (1900 m), but appears as a bush at high altitudes (3100 m). Other associated shrubs were *R. webbiana* and *L. quinquelocularis*. *Hippophae rhamnoides* was the dominant undergrowth in Q₉I coexisting with *R. webbiana* while *Daphne mucronata* was the main shrub in O₇III with maximum IVI (151.2) and IV per cent (55.60), *Plectranthus rugosus* and *I. gerardiana* were the associated shrubs at this site. *Pinus gerardiana* and *Quercus ilex* were present in the top canopy in O₇III, *D. mucronata* was the dominant shrub of low altitudes (1960 m to 2865 m).

(c) Spatial Distribution

The structures that are identified in the populations of plants result from the action of biotic and abiotic forces to which their members have been exposed in the past. The spatial distribution of plants in a population is the legacy of the spatial arrangement of parent plants and of the interactions that have taken place between plants in the past. As discussed earlier, A/F ratio indicates the spatial patterns i.e. regular, contagious and random. The terms 'regular' and 'contagious' or 'aggregated' describe spatial patterns that are respectively more uniform and more clumped than random distributions. With reference to the results (Table 8), most of the species were spatially contagious in most of the communities while very few were having random or regular distribution. In many species flowers are spatially aggregated and thus both seed dispersal and

germination are also often-aggregated (Rabinowitz and Rapp, 1980). The spatial distribution of mature plants reflects the spatial pattern of recruitment and the modification of this pattern by mortality factors, which differ in intensity from place to place. Where density-dependent mortality is strong, the distribution of surviving adult plants is less aggregated than that of seedlings. Young trees tend to be more aggregated than old trees within the same stands (Well and Getis, 1999). In contrast, inverse density-dependent mortality (when abiotic mortality factors are important, especially at the edge of the population distribution) would produce greater aggregation in the adult population than in the seedlings. Germination, may be positively density-dependent, and suitable safe-sites for germination may be clumped due to the activities of digging animals, soil micro-topographic features, etc. On a large scale, a heterogeneous habitat might represent a mosaic of suitable and unsuitable patches for the growth of particular species. Contagious distribution in natural vegetation has also been reported by several workers (Greig Smith, 1957; Kershaw, 1973, and Singh and Yadava, 1974; Ralhan *et al.*, 1982; Singh *et al.*, 1991; Nautiyal *et al.*, 1998 and Condit *et al.*, 2000). Contagious pattern depends on the (i) local habitat differences (ii) daily and seasonal weather changes and (iii) reproductive processes. In general, contagious distribution is common in nature, random distribution is found in very uniform environment only and regular distribution occurs where severe competition exists between the individuals (Odum, 1971). The aggregated distribution of oaks (*Quercus robur*) depends on the seed-dispersing animals to a greater extent than microhabitat conditions (Frost and Rydin, 2000). Similarly Brewer and Webb (2002) experienced that species were aggregated in North Central America because of high proportion of vertebrate-dispersed fruits. Environment was the main reason of aggregate distribution in low tree classes as observed by Guang Qui *et al.* (2002) in Chinese fir (*Cunninghamia lanceolata*).

Strictly random spatial patterns are rare in plant populations and regular distributions are also uncommon. Whenever, plants are irregularly spaced, differential demands are made on the resources supplied by the habitat. Where

local demand for resources causes competition, competition-induced mortality is likely to be high, which would decrease the local densities and aggregated or random distribution would become more regular through time as shown by Kenkel (1988) in *Pinus banksiana*. As a consequence of intense intraspecific competition, a regular pattern was noticed in the trees of *Fagus sylvatica*, while random spatial pattern could be a consequence of either self-thinning processes or exogeneous factors (Rozas and Fernandez-Prieto, 2000). In this particular study, *Cedrus deodara* was noticed to follow contagious distribution at 9 sites, random at 3 and regular at P_{9I} and P_{9II} (Table 8). Regular distributions of plants have often been reported in desert perennial communities. It has been suggested (Woodell *et al.*, 1969) that competition for water has converted initially aggregated or random spatial patterns into more regular pattern through spatially-density-dependent mortality. Chapin *et al.* (1989) also suggested that regular spacing is found in resource-poor habitats such as deserts and tundra because of strong competition for some limited resource and because the communities contain only one or a few dominant species, individuals of which compete for their resource at a given rooting depth or canopy height. Regular distribution in *Helicteres isora* and *Treminalia paniculata* was governed by topographic and biotic factors (Manjunatha *et al.*, 2001).

Not all desert perennial communities exhibit regular spacing (Gulmon *et al.*, 1979). For example, populations of most of the shrubs were either randomly distributed or had contagious distribution (Table 8). Finally, random distribution is a feature observed in dioecious species, which should optimize dispersal of pollen to female plants and minimize seed predation by promoting more even dispersal, sexes are segregated in many dioecious species (almost exclusively wind pollinated). The sex ratio of adult *Populus tremuloides* is altitude dependent with females predominating at lower elevations and males at higher (Grant and Mitton, 1979). Several dioecious species exhibit segregation of sexes along moisture gradients (Shea *et al.*, 1993).

(d) Species distribution with respect to abiotic and biotic factors

Abiotic factors are most crucial with respect to species composition and scatteredness of the individuals of component species in the given locality or whole landscape. According to Hwan *et al.* (1999) in a mountain forest ecosystem, altitude and the site factors were the major variables which explained the differences in the species diversity in the whole forest. Species diversity increases with the change in forest types from coniferous forest to coniferous and broad-leaved mixed forest (Zheng Sheng *et al.*, 1998).

While studying the distribution of three dominant tree species i.e. *Cedrus deodara*, *Pinus wallichiana* and *P. gerardiana* (based on the highest IVI and widest niche breadth) across the altitudinal range (Fig. 2), it was observed that the importance value (%) of *Cedrus deodara* decreased with the increasing altitude. Kapplle *et al.* (1995) has mentioned that species richness, canopy height and stem diameter decreased with increasing altitude. A change in the between - species abundance with increasing altitude has also been reported by (Leppaniemi *et al.*, 1998). Dominance of *P. wallichiana* was not having any correspondence with the increasing altitude in the present study. It was the principal component of the community (48.39 IV %) at an average altitude of 2830 m (P_6I) while it was the second important species (IV % = 8.42, N_7II) at 2900 m and again a dominant species (IV % = 37.95, P_8II) at an average altitude of 3280 m. From these results, it is clear that altitude is not the major variable determining the importance and abundance of *P. wallichiana* and there may be other factors which exercise control in making this species more important in its respective community.

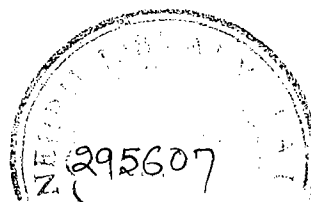
In case of *Pinus gerardiana*, the range of distribution across the altitudinal band was the widest (Fig. 2). It was the most dominant species (maximum IVI and IV %) in the community as the altitude increased from 2900 m upwards. It has been reported that the distribution of this species is from 2000 m to 3350 m

and it occupies primarily a waterless tract. It is hardy, being able to withstand a considerable degree of cold in winters and excessive drought. The robustness of this species tends it to scatter in a greater part of dry valleys of Western Himalayas (Troup, 1921).

Observations of the present study revealed that *Cedrus deodara* was distributed from east to west and north to south facing slopes. In general, deodar is found on all the aspects though grows best and reaches largest dimensions on northern aspect and in cool situations. Its growth is usually poor on hot southern aspect. Best growth is attained on deep, fairly porous, fertile soil in cool situations, for instance along the sides of moist ravines as has been noticed at O₆III, which is situated on the left bank of Baspa river and close to which runs a water source (Nallah).

Pinus wallichiana was present on all the aspects between 2470 m and 3370 m, though occupies warmer slopes and spurs at higher elevation and cooler aspects, and moist depression at low elevations. It accompanies deodar throughout the whole range of its distribution comparatively at low altitudes while its common associates at higher and cooler aspects are *Abies pindrow*, *Picea smithiana* and some of the broad-leaved species such as *Populus ciliata*, *Salix elegans*, *Betula utilis* and sometimes *Juglans regia* too (N₇III).

Pinus gerardiana had the widest distribution as it was found to be present from 1860 m to 3460 m on all the aspects. However, the best growth was seen on eastern (O₇III and P₇III) and western (P₈III) aspects where it was growing in the association of *Cedrus deodara*, *Quercus ilex* and *Alnus nitida*. Other associated species were *Fraxinus xanthoxyloides* and sometimes *Pinus wallichiana* too. *Q. ilex* was found growing on the cool eastern aspects at three sampling units, one of which (O₆I) was located on the left bank of Baspa river, in a depression, at a gradient ranging from 5-20° and 2010 m (average) above mean sea level in association with *P. gerardiana* and *Fraxinus xanthoxyloides*.



In the dry region (O₇III) it was associated with *P. gerardiana* only where it grew on the exposed areas amidst big boulders, the soil of which was sandy-loam in texture and light gray in color. It is a xerophytic species growing between 1600 m to 2400 m in the arid valley of Satluj (Champion and Seth, 1935).

Abies pindrow was always found in association with *Pinus wallichiana*, *Picea smithiana*, *C. deodara* and *Betula utilis* (P₆I, P₆II and P₆III). This is in conformity with the findings of Troup (1921). *Betula utilis* occurred at higher elevations, on open exposed tracts, which are under snow throughout the greater part of winter (P₆II and P₆III). There were two sampling units (P₆I and P₆II) where *Populus ciliata* was accompanied by *Pinus wallichiana*, *Salix elegans* and *Betula utilis*.

These findings indicate that *Cedrus deodara* was the principal species on the northern aspect, where *P. wallichiana*, *Abies pindrow*, *P. gerardiana* and *Alnus nitida* were the associated species. On the south facing slopes, it was the most important species at two sites (N₇III and O₇II), second important species at P₉I and P₉II and was one of the associates in *P. wallichiana* dominated community (P₆I). On the eastern aspect, it was the dominant species at O₇I and was the second important species in *P. gerardiana* dominated stands (P₇II and P₈I). On west facing slopes, it was the codominant in the stands dominated by *P. gerardiana* (P₇I) and by *P. wallichiana* (P₈II). At P₈III, it was the least important species in the stand where *P. gerardiana* was the most important species. *P. wallichiana*, on the other hand was the most dominant species on southern aspect (P₆I, P₆II), northern (P₆III), and western aspect (P₈II), while it was at the third rank on east facing slopes (O₇I). On eastern, western and northern aspects, *P. gerardiana* dominated its respective communities. The importance of aspect on species richness, diversity and composition of communities has also been emphasized by Baduni and Sharma (1996); Metz (1997) and Pandey and Joshi (1998).

All of the sampling units, where the present investigations have been conducted, were under the influence of one or the other form of biotic pressure (Table 3). These were mainly fire, trampling, grazing, lopping, landslide and others which include the scrapping of the tree bark for fuel or torch wood by the villager or travelers. The observations of these biotic pressures could, however, be subjective, but they render a great deal of help in interpreting the species distribution/composition as biotic disturbances along with the abiotic factors determine the structure of a forest to a greater extent (Wells and Getis, 1999; Chandraprakash and Uniyal, 1999; Rawat *et al.*, 1999; InHyeop, 1999; Sano and Ohtsuka, 1998; Jiang Guo *et al.*, 1998).

Climate dictates the overall pattern of vegetation. Within the framework set by climate, other factors exercise their influence, and a more detailed study of vegetation of a given area is, the more intimately it will have to inquire into the factors active in that area. The mountain system of the Himalayas provides a particularly exciting case in point. Throughout the Himalayas landuse is the mainstay of the population, which means that, wherever there are human settlements, vegetation displays the results (Schweinfurth, 1983).

Several external pressures such as the disturbance by humans and livestock grazing were active in varying degrees of intensity almost in every sampling unit. Traces of fire were only present in the sites located at lower altitude. Fire has outstanding influence on the vegetation, applied to control last years grass cover or weeds, destroys simultaneously the regenerative growth of trees and many other forest plants and leads to a subsequent accelerated erosion. Lopping/cutting of the branches of trees or shrubs either to be used as fodder/fuelwood or to harvest the seeds from cones especially in case of neoza pine (*Pinus gerardiana*) was most common throughout the forest/stands of neoza pine. This is due to the high economic value of the seeds, which are sold in the market at a price of Rs. 300-400 per Kg. Lopping of the branches either for fodder or fuel wood was very high in case of *Quercus illex* forests (O_{6I} and O_{6II}).

This higher intensity may be attributed to the fact that the two sampling units, where *Q. ilex* was found, were close to the villages and the young leaves of *Quercus* being palatable are fed to the cattle and the leftover is used as fuelwood. It could be a possible reason that the mean height of the trees did not exceed 9.48 ± 0.38 m, the trees otherwise generally attain a height of 14 m to 15 m (Troup, 1921) in the absence of any human interference. Among the abiotic pressures, landslide was quite apparent in the sampling units with steep to very steep hill slope (15° - 25°), it was also seen on the gentle slope (5° - 10°), where the landslide might have occurred in previous years and which have led the site to have an appearance of gentle slope. Other factors which could have considerable influence on the growth and development of trees include breaking of the tree top either by heavy snow or strong winds as a result of which the vertical growth of the tree is hampered and it gives a stunted look to the tree. Consequently a patch/stand of trees will emerge having trees of poor quality which not only reduces the commercial importance of the trees, but also affect its regeneration capabilities. This phenomenon was quite evident in the site O₇II where *Cedrus deodara* trees were damaged by heavy snow. Another factor which influences the quality of individual tree and stand as a whole is a common practice by the villagers or the travelers, in which they remove bark of the tree along with some wood to be used as torch for night journeys or for fuel wood. It was very frequently noticed in six sites (O₇III, P₇I, P₇II, P₈I, P₉I and P₉II) in the trees of neoza pine (*P. gerardiana*) and deodar (*C. deodara*) which have resin content in the wood and are very easy to be burnt. This though, useful for the village people, deteriorates the quality of wood and makes the tree vulnerable to be attacked by insects or fungal diseases. The trees can be easily broken by the heavy winds at a point where considerable amount of wood has been removed from the standing tree. Consequently the tree becomes very weak and can not stand the pressure of strong winds. The disturbance from livestock in the form of grazing and trampling was noticed almost everywhere. The effect of grazing on the composition of the vegetation that is conspicuous in the Himalayas is the promotion of species that are not or scarcely browsed (the so called "pasture

weeds”, because they are hard, spiny, poisonous or unpalatable). Species of this type increase in density while the density of species that are browsed decreases. Thus, a vegetation type poor in species results, which is dominated by one or two species e.g. *Plectranthus rugosus*, *Berberis* spp. and *Rosa* spp. etc. Trampling, on the other hand, damages the tiny seedlings which results in a forest of uneven-aged distribution (Schweinfurth, 1983).

(e) Structural parameters of the dominant tree species with respect to abiotic and biotic factors

Growth variables such as height, diameter (DBH) and basal area were measured for every single individual present in the quadrates of sampling unit. The data in Table 9 are presented for the main tree species in the study sites. Results show that *Cedrus deodara* (deodar) at O₇II was having the maximum basal area which in turn indicates that the individuals of this species accommodated a major chunk of the ground cover. It was the most important species at this site and the second important species was *Pinus gerardiana* which had less basal area (Table 9) in comparison to *C. deodara*. A close perusal of the results would reveal that the overall growth performance (mean height, diameter and basal area) of *C. deodara* was the best at P₉I. It may be that the macrosite of this particular locality has provided the most congenial conditions for the growth and development of deodar trees. However, the density of the stems (ha^{-1}) was low (Table 10) as compared to other sampling units. All the trees found, belonged to upper diameter class (>20.0 cm). There was no individual in the lower diameter classes, which indicates the absence of regeneration of deodar at P₉.

For the optimum growth, deodar prefers well-drained sandy-loam soils and warm southern aspects (Working Plan, Kinnaur). Both the sampling units of P₉ are situated on the warm southern aspect. Absence of seedlings and saplings were may be due to moderate to high biotic pressures (Table 3). Moreover, newly emerged seedlings require shelter from the direct sunlight and lower

density means the trees are far apart from each other and could not provide shade to the newly regenerated seedlings. Highest density was noticed in N₇ and O₆, which are located on the cool, north facing slopes. The presence of seedlings shows good regeneration of *C. deodara* at both the sites. It has been reported that this species occurs at higher altitudes on hot southerly aspects while on cool northerly aspects at lower altitudes (Troup, 1921). In the present study also deodar is present on southern aspect at the higher altitudes (P₉) and on northern aspect at the lower elevation (N₇ and O₆).

Pinus roxburghii (Chir pine) was the dominant tree species at N₇I, having trees with mean height of 24.16 ± 0.65 m, mean diameter of 17.49 ± 0.53 cm and mean basal area of 360.64 ± 17.75 cm². Total density observed was 337.50 (stem ha⁻¹) which was mostly contributed by the higher diameter classes i.e. 10.0-20.0 cm and >20.0 cm. There was no individual in the lower classes, which means complete lack of regeneration. Being a pioneer species it requires exposed soil and a complete overhead light for its regeneration. The stand however is dense (337.50 stems ha⁻¹) consisting mainly of trees with well developed crown and hence the absence of regeneration. This site is situated at an altitude of 2600 m amsl on the northern aspect with a nearly steep slope and forms a pure stand of this species. It has been reported that chir pine forms poor quality crops on the hot southern aspects and shallow soils, but on the northern aspect there are a few good pure patches of this species (Working Plan, Kinnaur). At this site the value of H' was zero, which indicates a complete domination of the site by one species (*Pinus roxburghii*). Zero diversity (H'=0) in *Pinus roxburghii* forests has also been reported by Ralhan *et al.* (1982) in Western Himalayas.

Among the seven sampling units, where *Pinus wallichiana* (Kail) was found to be growing abundantly, it was P₈II, where best trees in terms of highest mean height, diameter and basal area were present. This site is characterized by 3280 m of elevation, western aspect, slope of 10°-25° and silty-loam type of

soil. The high level dry blue pine forests (13.C.4) occur from 3000 m to 3600 m. Maximum total density, however, was observed for P₆, where trees in all the diameter classes were found to grow. This is an indication that the site is suitable for the regeneration of this species. It generally prefers snow beds of the colder aspects for its moisture supply. Other sampling units where kail was growing have northern aspects (N_{7II}, O_{6III}, P_{6III}), eastern O_{7I}, and southern P_{6I} and P_{6II}. The low-level blue pine forests prefer warm well drained ridges.

Pinus gerardiana had excellent growth of trees at P_{8III} presenting the highest basal area, diameter and height (mean), which was followed by P_{7II} and O_{7III}. Q_{8II}, on the contrary, was having trees with poorest growth. Sites O_{7III} and P_{7II} are having eastern aspect while P_{8III} has western aspect, which comes under dry zone. Total density was noticed to be the highest for Q₈ in which maximum number of stems were found in the diameter class of 3.0-10.0 cm. When all the grids were compared, number of individuals under seedling class was maximum which indicates a good regeneration of the species in Q₈. Trees of higher diameter class (>20.0 cm) on the other hand, were found to be maximum at P₉, and there was complete absence of individuals in the lower classes; clearly showing that no regeneration is taking place. From the perusal of data in Table 9, it's very much clear that the growth pattern of the trees at the two sites are showing reverse trends. Trees in P₉ were of large dimensions than that of Q₈. Moreover, the biotic disturbances in the form of trampling and lopping were respectively high to very high at P₉. Trees of Q₈ were too small to be affected by lopping as they have not yet reached the seed bearing stage. Lopping of seed bearing branches, which hampers the process of regeneration is a threat to the continuity of a tree species at a given site (P₉ and O₆). The overall picture of regeneration status of *P. gerardiana* in the different grids is grim. Even at the sites where new recruits are present, the trees in < 3.0 cm dbh class were still less (P₇, P₈, Q₈). This implies that either no germination has taken place in the last few years or if it had taken place at all, the seedlings were unable to establish themselves. A fairly good number of seedlings in Q₈ is the result of

fencing of the area and supplementation of natural regeneration by artificial regeneration.

At sites O₆I and O₆II, *Quercus ilex* was present in the form of a small patch, almost uniform in composition and had trees of higher growth parameters than those of trees at O₇III (Table 9). Overall density was the highest at O₆, where trees in the higher diameter classes were more as compared to the lower classes. There was complete lack of regeneration in both the grids O₆ and O₇. Poor regeneration is the result of high biotic pressure in the form of lopping of young shoots for fodder, which leads to removal of the acorn also. All the three sites are situated at the same altitude, having same aspect (eastern), same degree of gradient (10°-25°) and same soil texture. *Q. ilex* comes in the association with other xerophytic species such as *C. deodara*, *P. gerardiana*, *Fraxinus xanthoxyloides* and *Olea cuspidata* (Champion and Seth, 1968) on sheltered sites and cool aspects.

Average growth of the trees of *Populus ciliata* was better at P₆II than P₆I. Total density was 42.73 stems (ha⁻¹), out of which maximum number of individuals were found in the highest and lowest classes (>20.0 cm and seedlings). A comparatively higher proportion of individuals in seedling class is the result of natural regeneration by root suckers. The sites in the grid P₆ are highly disturbed by landslide which seems to have occurred in the recent past. Landslide results in exposure of soil and severing the roots of older trees, which promote regeneration by root suckers. Both of the sites have southern aspect, P₆I was having gentle slope while P₆II was comparatively flat. Soils of the former was sandy-loam while it was gravelly-silt loam in the later case. This species is capable of growing on dry hill-sides, trees of large size are often found in the ravines running through blue pine forests, as has been observed at P₆II and is often associated with deodar and silver fir (P₆I).

Maximum growth dimensions were exhibited by the trees of *Betula utilis* (birch) growing at P₆II as compared to P₆I, and P₆III, while trees of P₆III were

comparatively in the young stages of development as reflected by the growth parameters (Table 9). In grid P₆ number of stems (ha⁻¹) was concentrated in the class 3.0-10.0 cm, there were very few (3.13) large sized trees (>20.0 cm). There was no individual in the seedling and the <3.0 cm classes. Preponderance of young trees (3.0-10.0 cm dbh class) results in lack of viable seed production and hence absence of regeneration. P₆I, P₆II have southern aspect while P₆III faces northwards. Birch was found mixed with kail at P₆II and with *Abies pindrow* and *Picea smithiana* at P₆III, which was situated at comparatively higher elevation than P₆II. Similar findings have been reported by Troup (1921) and also in the working plan of district Kinnaur.

(f) Niche width (B_i)

Niche of a taxon has been defined depending on its resource needs, habitat requirements, environmental tolerance and interactions with both biotic as well as abiotic parameters (Grinnell, 1917; Elton, 1927; Gause, 1934; Hutchinson, 1957; MacArthur, 1968; Pianka, 1974; Pielou, 1972 and Hurlbert, 1978). Niche breadth (width) is the range of values along an axis at which the species can persist. In other words, it is a measure of the width of resource utilization by a species. Table 11 presents the results of niche width measurements. While majority of the species have very narrow niche-width, the species of *Pinus wallichiana* and *Abies pindrow* had an intermediate range. *Pinus gerardiana*, on the other hand, exhibited the broadest niche-width closely followed by *Cedrus deodara*. Broad-niched (generalist) species can grow almost anywhere along the axis (e.g. altitude in the present studies), while narrow-niched (specialist) species are restricted to a narrow band of values (Crawley, 1997, Plotnick and Gardner, 2002). From the results, it can be interpreted that *P. gerardiana* has adaptation to a wide range of altitude (1860 m-3460 m). It, however, was the most important species at an average elevation of 2980 m (P₈III), exhibiting maximum IVI (272.94) and IV per cent (96.47). *Cedrus deodara* had the distribution ranging from 2460-3460 m suggesting that it can utilize a

broad range of resources and it thrives well against all odds of the environmental conditions. There is a slight difference in the niche width of *P. wallichiana* and *A. pindrow*. Though they have a similar lower limit of elevation (2460 m) they vary in the upper limits of occurrence, which are respectively 3370 m and 3310 m. *A. pindrow* can, however, go up to 3400 m especially on northern aspects and sheltered sites (Champion and Seth, 1968). Species with narrow niche width are *Pinus roxburghii*, *Juniperus macropoda*, *Quercus ilex*, *Betula utilis*, *Alnus nitida*, *Populus ciliata* and *Fraxinus xanthoxyloides* (Table 11), which shows that these species are restricted to a narrow range of resources and are very specific to the microhabitat requirements. For instance, *Juniperus macropoda* is localized in the innermost arid zone of Western Himalayas from 2500 m-4330 m of elevation. In this study the species was found at an elevation of 2970 m (Q₈l). *B. utilis* occurs in the sub-alpine zone from 2900->3500 m. These species may be narrow-niched in relation to altitude, but may be broad-niched with respect to others (e.g. germination temperature, soil pH, soil texture and light requirements (Crawley, 1997).

g) β -Diversity: Sorenson's Index of Similarity, Jaccard's Index of Similarity and Chord Distance

Similarity coefficients vary from a minimum of 0 (when two sampling units in a pair are completely different) to a maximum of 1 (when the sampling units are identical). Two indices of similarity i.e. Sorenson and Jaccard have been used to study β -diversity, which is the rate of change of species-composition across sites (Whittaker, 1972). A similar trend in the rate of change of species-composition as reflected in the Tables 12 and 13 has been revealed by the two indices. Sorenson's Index, however, gives a little higher values for a pair of sampling units as compared to Jaccard's Index. Maximum value in case of Sorenson index is 0.86, while it is 0.75 in case of Jaccard's Index for the same pair of sampling units. For both the indices, 40.33 per cent of the site pairs were quite dissimilar, while 3.67 per cent had more or less identical species composition for trees. Species composition for shrubs, on the other hand, was

similar in 1.35 per cent of the cases and dissimilar in 50.90 per cent of the site combinations.

Chord distance, on the other hand, measures differences in the species composition of two communities. It puts greater importance on the relative proportions of species in the sampling units and correspondingly less importance on their absolute quantities. Results obtained from the data (Table 14a & 14b) show that 40.33 per cent and 37.67 per cent of the community pairs for trees and shrubs, respectively were completely dissimilar with respect to species composition. No two sites were identical with respect to species composition as well as number of individuals in a species, (Chord distance = 0). This shows high species turnover rate across the sites. The change of tree species composition across the sites/sampling units is depicted in the form of a dendrogram Fig. 2. The sites from the similar macro-habitat types tend to cluster depending upon the species composition. The tree species assemblages therefore, appear to reflect the characteristics of the macro-habitats in which they occur (Negi, 1999). It is a well known fact that environment alters from place to place, correspondingly, the vegetation alters in both species composition and in the frequency of the component species. At a comparatively low elevation, there was no significant difference in the species composition across the stands (Bhandari *et al.*, 1998), while Vazquez and Givnish (1998) noticed that community composition varied roughly 4 times rapidly with altitude. Similarity indices at species level varied from 26-44 per cent (Ferreira and Prance, 1998), while in present study the range is from 3.67-40.33 per cent for trees and for shrubs it is 1.35-50.90 per cent. InHyeop *et al.* (1999), however, mentioned the range of similarity index between 42.0-71.8 per cent. They found that with increasing altitude, number of species, species diversity and evenness increased, suggesting interference by man was relatively severe at lower elevations. Bell *et al.* (2000) opined that differences in the ecological conditions between various microsites cause differences in species composition. Species turnover rates were higher near the environmental extremes, as observed by

Brockway (1998), and were attributed to highly variable topography and local microclimates, which resulted in substantial geographical isolation and species specialization among sites. Temperature and moisture appeared to have greater influence on species richness and sequential turnover rates at high altitudes where available water is limited by low temperatures. Invariably, all the sites showed remarkable degree of dissimilarity in their composition and structure. This may be a reflection of the difference in the altitudes and aspects (Pande, 2001).

h) Interspecific association

Species interactions are of prime importance in the ecology of a species. Within any given community, there are a number of biotic and abiotic factors that influence the distribution, the abundance, and subsequently, the interactions of species. Depending on whether or not two species select or avoid the same habitat, have some mutual attraction or repulsion or have no interaction, a certain pattern of inter-specific association results. The measurements of which are based on presence or absence data (Hurlbert, 1971), when it is desired to measure the extent to which two species' requirements are similar. This association may be positive, negative or absent. In general, an association between two species exists because:

- both species select or avoid the same habitat.
- they have the same general abiotic and biotic environmental requirements or
- one or both of the species have an affinity for the other, either attraction or repulsion (Hubalek, 1982).

Presently, it is clear from the results of the chi-square test that association between most of the species combinations was non-significant and there were only nine pairs of tree species which showed positive or negative association, but the degree of association varied as revealed by the coefficient of association (Table 15a). Only one species pair (*Pinus wallichiana* and *Abies pindrow*) with

positive association was highly significant (at 0.01 level). *A. pindrow* was found to grow in association with *P. wallichiana* at five sites (N₇II, N₇III, P₆I, P₆III and O₆III). It has been reported in the literature that in the natural habitat of *P. wallichiana* (2000 m-2850 m), *A. pindrow* comes as an associated species on the cold aspects and moist depressions at low elevations and on warmer slopes and spurs at higher elevations (12C.1.d, Champion and Seth, 1968). Silviculturally, *P. wallichiana* (Kail) is a strong light demander and *A. pindrow*, on the other hand, is a shade demander, which requires protection from the direct overhead sun in its early stages of growth (Troup, 1921). Another positive association was between *Populus ciliata* and *Betula utilis*. Both of the species appeared together at two sites (P₆I and P₆II) and were absent together at 20 sites. At the two sites P₆I and P₆II *Populus ciliata* was the second important species in the kail dominated forest and *Betula utilis* was one of the associated species. These two are light demanders in their silvicultural requirements and found in habitats with open exposed tracts and often present in ravines running through blue pine forests (Troup, 1921). Further, *Populus ciliata* and *B. utilis* occupy an altitudinal range of 2720 m-3030 m and 2720 m-3310 m, showing more or less same niche-width (Table 11), which in turn indicates that the broad ecological requirement of the two species is more or less similar. Microhabitat suitability, however, for the two species may vary. It is the patchiness of the environment (Levins, 1974) or spatial heterogeneity (Tilman and Pacala, 1993) that allows coexistence of the species to occur. Among the negatively associated species, *Pinus gerardiana* and *P. wallichiana* had the lowest value of coefficient of association. This indicates that habitat requirements of these species are different. *Pinus wallichiana* prefers colder northern aspects where sufficient moisture is available, *P. gerardiana*, on the other hand, has a general tendency to grow in the exposed dry areas (Troup, 1921). Though the two species occurred together at the three sites viz., P₈II, O₇I and O₇II, they were present separately and not together at 17 other sites. It is this later factor which is reflected in the negative association between the two species. Presence of only one species and absence of the other at a site is an indicator of different

resource requirement of the two species. To coexist, each species must be specialized to a different role of niche: that is to say, different species coexist only if they depend on different resources or live in different places (Leigh, 1999).

As the two species are negatively associated they can not share the same resources at the same time and place, and presence of one would mean absence of another. Even at the three sites where they were present together their abundance were quite low and thus can not be an indicator of positive association. Six other species pairs also showed negative association therefore it indicates that their resource requirements are quite dissimilar. A highly significant positive association was observed for *Populus ciliata* and *Berberis jaeschkeana*; *Betula utilis* and *Berberis jaeschkeana*; and *B. utilis* and *Rosa webbiana*, indicating that these species coexist more frequently (Table 6). There were five more pairs of tree and shrub species, which showed positive association. Some of the tree and shrub species could not account for any kind of association, though they were found together more often (Table 6), while some species, on the other hand, gave positive association regardless of the fact that only a few individuals were present. This type of behaviour, however, seems to be difficult to explain. Macan (1954) explained such type of phenomenon by stating that when measurement of interspecific association is applied to habitats whose uniformity is doubtful, these methods may give results of uncertain value. In such a situation some samples may be from habitats that are outside the environmental ranges of the species; this will have the effect of inflating the value for 'd' and lead to too many positive associations. Moreover, the Western Himalaya presents a more diverse type of macro and micro-habitats. Climatic, topographic and edaphic factors altogether may have an important role for such type of phenomenon to take place. Using presence or absence data to measure inter-specific association, however, gives dubious results i.e. either results in positive/negative association or show no association at all (even if two species are found at one site). Even then, several studies opined that chi-square test together with the association coefficient is an effective method for measuring

species association and the results could provide a theoretical basis for choosing tree species for mixed silviculture (Zhang and Zhang, 1999; Zhang and Zhang, 2001; Singh *et al.*, 1988; Sun *et al.*, 1996).

5.2 FREQUENCY DISTRIBUTION

Fitting statistical distribution to the experimental data is useful in that it gives a summary of the data which is easier to manipulate than the raw data themselves (Aitchison and Brown, 1975). Prediction of the stand yields in term of volume is an important aspect of forest management. The volume is heavily dependent on the distributions of the tree diameter and height (Schreuder and Hafley, 1977). Once the statistical distribution is fitted one can estimate the number of trees in a particular class of diameter or number of trees within a specified diameter range. This information is important because it affects the type and timing of management strategies and treatments applied. Quantification of diameter distribution and its relationship to site, stand composition, age and density is often valuable for both economics and biological purposes (Bailey and Dell, 1973). By studying the diameter class distribution in a natural forest, Shimano (2000) was able to estimate not only the number of juveniles in each dominant tree species populations but also the size dependent mortality operating there.

From the Table 16 it is clear that no theoretical distribution could fit the data of tree height and dbh of the trees of *Cedrus deodara* in group B. The reason could be a tremendous variation in the character under study viz. height and dbh. Further division of these classes to smaller groups could have given a near fit to the data but because of the lengthy procedure it was beyond the scope of present study. The same reason applies to group B of *Pinus gerardiana* and *P. wallichiana* also. The sites included in these groups are generally under high biotic pressures especially lopping and grazing (Table 3). Vicinity of these sites to the villages and place of habitation might have resulted in high biotic pressures,

which could ultimately have caused too much variation in height and dbh. Height distribution in most of the groups in most of the species did not follow any theoretical distribution functions. This shows that growth in height is less consistent than that in dbh and is highly affected by biotic and abiotic disturbances. That is why most of the class distribution studies are concentrated to the diameter class distribution (Kangas and Maltamo, 2002; Zhang *et al.*, 2001; Shimano, 2000; Tewari, 2000; Gove and Patil, 1998; Bailey and Dell, 1973).

In case of *Cedrus deodara*, height and diameter distribution of trees in group A and dbh in group C followed the normal distribution pattern (Fig. 4, 5 and 6). However, the normal curve in case of diameter distribution in group C trees, was skewed to the right (Fig. 6). This is an indication of preponderance of mature and over-mature trees and deficient regeneration of *C. deodara* in this group. Such type of stand structure shows an imbalance of diameter distribution and hence needs management interventions like opening of the canopy or prevention of grazing and trampling etc. to ensure proper regeneration of the stand.

Diameter of the trees of *Pinus gerardiana* in group A was log-normally distributed (Fig. 7). The graph shows the occupation of large proportion of the area by lower diameter class trees. Stand structure dynamics presents three possibilities: i) the tree will grow enough so that it becomes a member of the next growing class, ii) it will not grow and remain in the same growing class or iii) it will die down and create space for the regeneration to take place. Large number of trees in lower diameter classes means that the trees had either died or cut and space was created for the regeneration. In group C all the three frequency distribution function could fit to the dbh data. However the best fit was found to be the exponential distribution having the least value of chi-square, implying that the observed frequencies were close to the expected ones (Fig. 8). A good fit to the diameter measurements of *Acacia tortilis* tree stand was found in more than

one distribution functions by Tewari (2000) also. Exponential curve is a decay curve where dbh growth per period decreases. Fig. 9 shows normal distribution which is highly skewed to the left and is more or less L-shaped. This shows a good regeneration of *P. gerardiana* in group C. Fig. 11 shows a higher proportion of trees in 0-5 m height class and very less number of trees in the higher height classes. Lower height class trees are flourishing at the cost of bigger sized trees. When the two groups were combined together and the dbh data of the total 256 trees of the species were analyzed it was found that two distributions viz. exponential and log-normal fits the data well. The graphical representations are given in figures 12 and 13 respectively. The former fits the data better than the later having chi-square values smaller in the former. Both the curves showed an inverse J-shaped having large number of trees in lower diameter classes and a gradual decrease with increase in diameter size. *P. roxburghii* stand at site N₇l followed normal distribution in both the characters measured, (Fig. 14 and 15). However, the curve was skewed to the right with complete absence of trees of lower diameter classes (seedlings and saplings). This stand reflects a picture of the old stand having deficient regeneration probable due to excessive biotic pressure and preponderance of mature and over-mature trees. *Populus ciliata* trees followed normal distribution and *Quercus ilex* trees followed log-normal distribution with respect to diameter classes, however the seedling class (0-7 cm dbh) showed a deficient distribution.

SUMMARY AND CONCLUSIONS

The investigation on "Floral Dynamics and Distribution Pattern of Dominant Woody Plants in Kinnaur" can be summarized and concluded as:

6.1 SPECIES DIVERSITY

a) α -diversity

For all the sampling units under study, species richness (S) for trees varied greatly from one to seven which corresponds to the values of Shannon Index (H') 0.000 (N_{7III} , Q_{8I} , P_{9I}) and 1.984 (P_{6I}). While in case of shrubs, there were four sampling units where no shrub was encountered and maximum species richness observed was 5 (N_{7II} and P_{6I}) with corresponding value of H' being 2.130 and 2.136, respectively for N_{7II} and P_{6I} . There were four sampling units having one species each with value of H' as 0.000.

The equitability (J') varied from 0.000 (N_{7III} , Q_{8I} , Q_{9I}) to 0.934 (P_{7I}) in case of trees, while for shrubs it ranged from 0.000 (P_{6II} , P_{7II} , P_{8I} and Q_{8I}) to 0.991 (Q_{9II}). The highest value of Cd (1.000) corresponds to the lowest value of J' (0.000). There were three sites (N_{7III} , Q_{8I} , Q_{9I}) with values of Cd (in case of trees) being the highest (1.000) and two sites P_{6I} and P_{6III} with lowest values i.e. 0.365 and 0.374, respectively; Cd for shrubs was maximum (1.000) for four sites i.e. P_{6II} , P_{7II} , P_{8I} , Q_{8I} and minimum (0.243) for one site i.e. N_{7II} .

b) Importance Value Index(IVI) and Importance Value (IV%)

When trees and shrubs were considered as constituents of a single community, *C. deodara* dominated [maximum IVI and IV (%)], six sampling units, while *P. gerardiana* was the most important species in eight sites. *P. wallichiana*,

on the other hand, was the dominant species in four sites, *P. roxburghii* completely occupied the site where it was present as there was no other tree species except some shrubs. *Q. ilex* dominated two sites and *J. macropoda* was the only tree species growing at Q₈I. *Salix fragilis* was the principal species growing at Q₉I, while *Rosa webbiana*, which was growing in association of *S. fragilis* and *Populus ciliata*, dominated Q₉II.

On the basis of IVI the tree communities present in the 24 sites were classified in to 13 tree community types. These are i) *Pinus gerardiana* dominated stand (P₇II, P₈III, Q₈II and O₇III), ii) *Pinus gerardiana-Cedrus deodara* stand (P₇I, P₈I, P₉I and P₉II), iii) *Cedrus deodara-Pinus gerardiana* stand (P₇III, O₇I and O₇II), iv) *Cedrus deodara* dominated stand (N₇II, N₇III and O₆III), v) *Pinus wallichiana-Cedrus deodara* mixed stand (P₈II), vi) *Pinus wallichiana* dominated stand (P₆II), vii) *Pinus wallichiana-Populus ciliata* mixed stand (P₆I), viii) *Pinus wallichiana-Betula utilis* mixed stand (P₆III), ix) *Pinus roxburghii* pure stand (N₇I), x) *Quercus ilex* dominated stand (O₆I and O₆II), xi) *Juniperus macropoda* pure scrub (Q₈I), xii) *Salix fragilis* pure plantation (Q₉I) and xiii) *Salix fragilis-Populus ciliata* stand (Q₉II).

When shrubs were studied as a separate community, it was found that *Plectranthus rugosus* dominated the shrub community at five sites (N₇I, N₇III, O₆I, O₆II and O₇I), *Indigofera gerardiana*, *Rhus semiaeata* and *Berberis jaeschkeana* at two sites (P₆I and O₇II, P₇I and P₈II and P₆II and O₆III, respectively). *Cotoneaster microphylla* was the main shrub at P₆III while *Lonicera quinquelocularis* and *Juniperus recurva* dominated its respective shrub communities (P₇II and Q₈I, respectively). *Rosa webbiana* was the principal shrub at P₈I and Q₉II. *Fraxinus xanthoxyloides* was most abundant at Q₈II while *Hippophae rhamnoides* was the dominant undergrowth at Q₉I and *Daphne mucronata* was the main shrub at O₇III.

c) Spatial distribution

Most of the species followed contagious pattern of distribution. Of the fourteen sites, where *Cedrus deodara* was found to be present, it followed random distribution at three sites, regular at two and at all the other sites it was distributed in a contagious fashion. Except for one site, where *Pinus gerardiana* had a random pattern, it tended to be distributed contagiously. *Pinus wallichiana* was distributed randomly at three sites, *Abies pindrow* at one site, while regular pattern was observed for *Juglans regia*, *Alnus nitida* and *Salix fragilis*. Among the shrubs, regular distribution was noticed only in case of *Rosa webbiana* (Q₉I), while the other shrubs were either found to have random or contagious distribution.

d) Species distribution with respect to abiotic and biotic factors

Cedrus deodara was present with in an average altitudinal range of 2520 m to 3365 m, but its IV (%) declined sharply from 2900 m upwards. *P. wallichiana* did not show either ascending or descending trend in its dominance with altitudinal variation. *P. gerardiana*, on the other hand, had the widest range of distribution (1960 m to 3365 m), it, however, dominated the community from 2900 m upwards.

C. deodara was distributed generally on warmer aspects at comparatively higher elevations and on cooler aspects at lower elevation. A similar trend was observed for *P. wallichiana*. However, in case of *P. gerardiana*, *Betula utilis*, *Populus ciliata* and *Abies pindrow* had no effect of aspect on distribution. *Pinus roxburghii* and *Quercus ilex* were found to be distributed on cooler aspects at lower altitudes only.

Lopping/cutting of the branches was intensive in *Pinus gerardiana* to harvest seed bearing cones and in *Qercus ilex* to be used as fodder and fuel wood as well. Landslide was observed only in or along five sampling units. 'Others' include damaging effect to the tree top either by heavy snow or heavy winds, only seen at one site (O₇II) and scrapping of the bark/wood to be used for fuel or torch wood, it was prevalent in six sites (O₇III, P₇I, P₇II, P₈I, P₉I and P₉II).

e) Structural parameters of the dominant tree species with respect to abiotic and biotic factors

Overall growth (mean height, diameter and basal area) of *C. deodara* was the best at site P₉I, The density of stem was the lowest in P₉ and highest in N₇. A good regeneration was found only in grids N₇ and O₆, which were eventually the cooler aspects. *P. roxburghii* was encountered only at one sampling unit N₇I, where the total density observed was 337.50 (ha⁻¹), mostly contributed by the stems in the higher diameter classes. No individual in the lower classes indicated a lack of regeneration. In case of *P. wallichiana*, best trees in terms of highest mean height, diameter and basal area were present at P₈II. The maximum total density was observed in P₆, where trees of all the diameter classes were found to be growing. *P. gerardiana* had an excellent growth of trees at P₈III. Total density, was the highest at Q₈, where a large number of stems were found in the diameter class of 3.0-10.00 cm. The presence of seedlings indicated a good regeneration in this grid. There was complete lack of regeneration in *Q. ilex*. The density was highest in the grid O₆ where mature and over mature trees were predominant. Average growth of *Populus ciliata* was better at P₆II than P₆I. Maximum numbers of stems were found in the largest diameter class. In case of *Betula utilis*, maximum growth dimensions were exhibited by the trees at P₆II, while density (ha⁻¹) was concentrated in the diameter class 3.0-10.0 cm. There was complete lack of emergence of new seedlings as no individual was present in the lower classes.

f) Niche Width (B_i)

Among the most dominant tree species, *P. gerardiana* had the widest niche width (10.877) followed by *C. deodara* (7.909), while intermediate range of niche width was found for *P. wallichiana* and *A. pindrow*. Rest of the tree species were having niche width of narrow ranges (1.423 to 2.941). Niche width for *P. roxburghii* was observed to be the minimum (1.000).

g) β -diversity

Two indices, Sorenson's Index and Jaccard's Index, as a measure of similarity between two sampling units, while chord distance as a measure of dissimilarity, were used to study β -diversity among different sites. The two similarity indices followed a similar trend with only small, but negligible difference in the values. In both the cases, 40.33 per cent of the site pairs were quite dissimilar (0.00), while 3.67 per cent were similar in species composition for trees. For shrubs, on the other hand, 1.35 per cent of the site pairs were similar and 50.90 per cent were dissimilar in species composition. According to Chord distance, 40.33 and 37.67 per cent of the site pairs were completely dissimilar (Chord distance = 1) in case of trees and shrubs, respectively and no two sites were found identical (Chord distance = 0).

h) Interspecific association

Among the tree species positive association was observed only for *P. wallichiana* and *A. pindrow* (significant at 0.01), *Populus ciliata* and *Betula utilis* (significant at 0.05) and rest of the combinations showed negative or no association at all. For interspecific association between tree and shrub species, eight pairs showed positive association while three pairs were noticed to have negative association. Other combinations had no significant association.

6.2 FREQUENCY DISTRIBUTION

In case of *Cedrus deodara*, height and diameter of trees in group A and dbh in group C followed normal distribution pattern. Diameter of the trees of *Pinus gerardiana* in group A showed log-normal distribution. While in group C all the three distribution functions were found to fit the dbh data. In *Pinus wallichiana*, tree height of group A followed log-normal distribution and the combination of group A and B followed exponential and log-normal distribution.

Normal distribution could fit well to the data of tree height and dbh of *Pinus roxburghii*. Group a of *Populus ciliata* and *Quercus ilex* respectively followed normal and log-normal distribution for dbh.

CONCLUSIONS

- For trees, species richness (S) and Shannon Index (H') were the highest for P₆I and minimum for N₇I. Whereas, for shrubs, N₇III and P₆I showed maximum S, H' and P₇III, P₈III, P₉I and P₉II had no shrubs at all.
- For trees J' was minimum and Cd was maximum in N₇I and J' was maximum and Cd was minimum in P₈II. In case of shrubs, Cd was maximum at P₆II, P₇II, P₈I and Q₈I with corresponding minimum value for J', and Cd was minimum at N₇III with higher value of J'.
- Both Sorenson's and Jaccard's indices of similarity showed that in case of trees, 3.67 per cent of the site combinations were similar whereas, 40.33 per cent were dissimilar with respect to species composition. For shrubs 1.35 per cent site pairs were similar and 50.90 per cent were dissimilar. Chord distance was the maximum (1.000) for 40.33 per cent of the site pairs in case of trees while it was 36.67 per cent in case of shrubs. Site pair (7, 14) was found to have minimum chord distance (0.018) for trees, while for shrubs it was 0.112 (17, 18).
- Most of the tree species were characterized by contagious distribution while random and regular patterns were noticed for a few species at one or two sampling units. Among shrubs, regular distribution was found only in case of *Rosa webbiana*, while others were following either random (occasionally) or contagious patterns (oftenly).
- While studying community diversity (both tree and shrub layers) species dominance was ascertained on the basis of maximum in IVI and IV(%). *Cedrus deodara* was found to be a dominant species at six sites, *P. gerardiana* at seven sites and *P. wallichiana* at four sites, *P. roxburghii* and

Juniperus macropoda were the principal tree species at one and *Quercus ilex* at two sites. When tree and shrub layers were studied as two distinct communities, the trend of dominance by different tree species remained the same and in the shrub layer, different shrub communities had different dominants. *Plectranthus rugosus* was the main shrub at five sites, *Indigofera gerardiana* at three, *Rhus semialata* and *Rosa webbiana* at two sites while *Hippophae rhamnoides*, *Daphne mucronata*, *Berberis jaeschkeana*, *Lonicera quinquelocularis*, *Cotoneaster microphylla*, *Juniperus recurva* and *Fraxinus xanthoxyloides* were the principal shrubs at a single site only.

- On the basis of IVI the 24 study sites were categorized into 13 tree community types.
- *Cedrus deodara* showed a decline in the Importance Value (%) with change in altitude i.e. from 2900 m upwards, and *P. gerardiana*, on the contrary, dominated the community from 2900 m upwards, while *P. wallichiana* did not show any trend in its dominance with altitudinal variation. Other factors such as aspect and slope had little impact on the species distribution.
- Though different biotic pressures did not affect distribution of species, they were effective enough to influence the growth and development of tree species.
- Niche width of *Pinus gerardiana* was the largest, while *P. roxburghii* was found to have a narrow niche width; rest of the species were having niche width of intermediate range.
- Among tree species, positive association was observed only in two pairs of species, while other combinations showed negative association. For tree and shrub species, there were eight pairs with positive association and three with negative association.

Normal, log-normal and exponential frequency distribution functions were found to fit the data for the characters tree height and dbh of *Cedrus deodara*, *Pinus gerardiana*, *P. wallichiana*, *P. roxburghii*, *Populus ciliata* and *Quercus ilex*.

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